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EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards

Acknowledgments

The *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* is a product of a three year interagency effort involving the Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, Washington Department of Ecology, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Nez Perce Tribe, Columbia River Inter-Tribal Fish Commission (representing its four governing tribes: the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakima Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon), and EPA Region 10.

John Palmer of EPA Region 10's Office of Water chaired an interagency policy workgroup and was the principal author of the guidance with assistance from the following workgroup members: Randy Smith and Dru Keenan of EPA Region 10's Office of Water; Dave Mabe and Don Essig of the Idaho Department of Environmental Quality; Mark Charles and Debra Sturdevant of the Oregon Department of Environmental Quality; Dave Peeler and Mark Hicks of the Washington Department of Ecology; Russ Strach, Jeff Lockwood, and Robert Anderson of the National Marine Fisheries Service; Stephen Zylstra, Elizabeth Materna, and Shelley Spalding of the U.S. Fish and Wildlife Service; Barbara Inyan of the Nez Perce Tribe, and Patti Howard and Dale McCullough of the Columbia River Inter-Tribal Fish Commission.

The scientific and technical foundation for the guidance, as reflected in six scientific papers, was developed by an interagency technical workgroup led by Dru Keenan and Geoff Poole of the EPA Region 10. Other members of the technical workgroup were: Chris Mebane and Don Essig of the Idaho Department of Environmental Quality; Debra Sturdevant of the Oregon Department of Environmental Quality; Mark Hicks of the Washington Department of Ecology; Jeff Lockwood of the National Marine Fisheries Service; Elizabeth Materna and Shelley Spalding of the U.S. Fish and Wildlife Services; Dale McCullough of the Columbia River Inter-Tribal Fish Commission; John McMillan of the Hoh Tribe; Jason Dunham of the U.S. Forest Service, and John Risley and Sally Sauter of the U. S. Geological Service. Marianne Deppman of EPA Region 10 provided organizational and facilitation support for the technical workgroup.

Two independent scientific peer review panels were convened to provide comment on various aspects of the guidance and the scientific issue papers. The peer review scientists are identified in the peer review reports, which are referenced in Section X of the guidance.

EPA issued two public review drafts, the first in October, 2001 and the second in October, 2002, and received valuable comments from the public that helped shape the guidance.

An EPA review team consisting of the following individuals also provided valuable input into the development of the guidance: Carol Ann Siciliano of EPA's Office of General Counsel; Cara Lalley, Lars Wilcut, and Jim Keating of EPA's Office of Water; Adrianne Allen, Keith Cohon, and Rich McAllister of EPA Region 10's Office of Regional Counsel; Paula Vanhaagen, Marcia Lagerloef, Kerianne Gardner, Robert Robichaud, Kristine Koch, Kathy Collins, Patty McGrath, Mike Lidgard, Christine Psyk, Jannine Jennings, Rick Parkin, and Jayne Carlin of EPA Region 10's Office of Water; Ben Cope and Peter Leinenbach of EPA Region 10's Office of Environmental Assessment; and Derek Poon and Steve Ralph of EPA Region 10's Office of Ecosystems and Communities.

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www.epa.gov/r10earth/temperature.htm

Forward

The goal of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and, where attainable, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. As a means of meeting this goal, section 303(c) of the CWA requires States and authorized Tribes to adopt water quality standards (WQS) and requires the U.S. Environmental Protection Agency (EPA) to approve or disapprove those standards.

At this time, many Pacific Northwest salmonid species are listed as threatened or endangered under the Endangered Species Act (ESA). As a result, the ESA requires that EPA must insure that its approval of a State or Tribal WQS is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of their critical habitat.

Water temperature is a critical aspect of the freshwater habitat of Pacific Northwest salmonids. Those salmonids listed as threatened or endangered under the ESA and other coldwater salmonids need cold water to survive. Human-caused increases in river water temperatures have been identified as a factor in the decline of ESA-listed salmonids in the Pacific Northwest. State and Tribal temperature WQS can play an important role in helping to maintain and restore water temperatures to protect Pacific Northwest salmonids and aid in their recovery. For these reasons, EPA in collaboration with others, developed this guidance to better describe appropriate water temperatures to protect Pacific Northwest salmonids.

The *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* is intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the Clean Water Act (CWA) and the Endangered Species Act (ESA). This guidance document, however, does not substitute for applicable legal requirements; nor is it a regulation itself. Thus, it does not impose legally binding requirements on any party, including EPA, other federal agencies, the states, or the regulated community. Comments and suggestions from readers are encouraged and will be used to help improve the available guidance as EPA continues to build experience and understanding of water temperature and salmonids.

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Table of Contents

EPA Region 10 Guidance
for
Pacific Northwest State and Tribal Temperature Water Quality Standards

I. Introduction

This guidance describes an approach that EPA Region 10 encourages States and authorized Tribes (Tribes) in the Pacific Northwest to use when adopting temperature water quality standards (WQS) to protect coldwater salmonids. The recommendations in this guidance are intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the Clean Water Act (CWA) and the Endangered Species Act (ESA). This guidance specifically addresses the following coldwater salmonid species in the Pacific Northwest: chinook, coho, sockeye, chum, and pink salmon; steelhead and coastal cutthroat trout; and bull trout. The information provided in this guidance may also be useful for States and Tribes to protect other coldwater salmonid species that have similar temperature tolerances but are not explicitly addressed in this guidance.

This guidance provides recommendations to States and Tribes on how they can designate uses and establish temperature numeric criteria for waterbodies that help meet the goal of "protection and propagation of fish, shellfish, and wildlife" in section 101(a)(2) of the CWA. States or Tribes that choose to adopt new or revised temperature WQS must submit those standards to EPA for review and approval or disapproval. CWA section 303(c)(2)(A). EPA expects to be able to expedite its review of revised temperature standards that follow the recommendations in this guidance. States and Tribes that choose to follow the recommendations in this guidance, particularly those described in Section V, may wish to reference this guidance when submitting new or revised salmonid use designations and supporting criteria to EPA for approval.

EPA action on State and Tribal WQS that are consistent with this guidance is expected to be significantly expedited because the scientific rationale in support of the State and Tribal WQS would in large part already be described and supported by EPA, and by the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services). However, because this is a guidance document and not a regulation, EPA cannot bind itself to approve a WQS submission that follows the recommendation of this guidance. Furthermore, the Services cannot bind themselves to future consultation determinations (i.e., a "no jeopardy" determination) under the ESA. So even though EPA expects the review process to be significantly expedited if this guidance is followed, EPA and the Services must still examine every WQS submission on a case-by-case basis, taking into consideration any public comments received or other new information.

It is also important to note that this guidance does not preclude States or Tribes from adopting temperature WQS different from those described here. EPA would approve any temperature

WQS that it determines are consistent with the applicable requirements of the CWA and its obligations under the ESA. Because this guidance reflects EPA's current analysis of temperature considerations for Pacific Northwest salmonid species, EPA intends to consider it when reviewing Pacific Northwest State and Tribal temperature WQS or promulgating federal temperature WQS in Idaho, Oregon, or Washington.

Temperature WQS are viewed by EPA and the Services as an important tool for the protection and recovery of threatened and endangered salmonid species in the Pacific Northwest. Attaining criteria and protecting existing cold temperatures for waters used by these salmonids will help maintain and improve their habitat and aid in their recovery. Meeting temperature WQS, however, should be viewed as part of the larger fish recovery efforts to restore habitat. Wherever practicable, implementation actions to restore water temperatures should be integrated with implementation actions to improve habitat in general, and should be targeted first toward those reaches within a basin that will provide the biggest benefit to the fish. It should also be noted that the actions needed to improve water temperatures are, in many cases, the same as those needed to improve other fish habitat features. For example, restoring a stream's riparian vegetation can reduce water temperature as well as reduce sediment erosion, provide over bank micro-habitat, and add fallen wood to the river that over time creates pools and a more diverse stream habitat preferred by salmonids.

This guidance was developed with the assistance of representatives of the Pacific Northwest States, the Services, and the Columbia River Inter-Tribal Fish Commission (CRITFC) Tribes. As part of developing this guidance, EPA, with the assistance of technical experts from Federal, State, and Tribal organizations, developed five technical issue papers and a technical synthesis report summarizing technical issues related to water temperature and salmonids. These reports represent the technical foundation of this guidance and summarize the latest literature related to temperature and salmonids. See Section X, References, at the end of this guidance for a list of these technical papers.

II. Regulatory Background

The goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters and, where attainable, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. See CWA section 101(a)(2). As a means of meeting this goal, section 303(c) of the CWA requires States and Tribes to adopt WQS that include designated uses and water quality criteria to protect those designated uses. In addition, Federal WQS regulations require States and Tribes to adopt a statewide antidegradation policy and identify methods to implement such policy. See 40 C.F.R. § 131.12. States and Tribes may also adopt into their standards policies generally affecting the application and implementation of WQS, such as mixing zones and variances. See 40 C.F.R. § 131.13.

EPA is required to approve or disapprove new or revised State and Tribal WQS under section 303(c) of the CWA to ensure they are consistent with the requirements of the CWA and EPA's implementing regulations. See CWA section 303(c)(3). New or revised State and Tribal WQS are not in effect for CWA purposes until they are approved by EPA. If EPA disapproves a new or revised WQS submitted by a State or Tribe, or if the EPA Administrator determines that a new or revised WQS is necessary to meet the requirements of the CWA, EPA must propose and promulgate appropriate WQS itself, unless appropriate changes are made by the State or Tribe. See CWA section 303(c)(4).

Where EPA determines that its approval of State or Tribal WQS may affect threatened or endangered species or their critical habitat, the approval action is subject to the procedural and substantive requirements of section 7(a)(2) of the ESA. Section 7(a)(2) of the ESA requires EPA to ensure, in consultation with the Service(s), that any action it takes is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat. Under the ESA regulations, such consultations can be concluded informally where EPA determines that its action is not likely to adversely affect listed species or critical habitat, and where the Service(s) concur with that finding in writing. See 50 C.F.R. § 402.13. Where EPA does not make such a determination, or where the Service(s) do not concur in writing, the ESA regulations require EPA to engage in formal consultation, which results in the issuance of a biological opinion by the Service(s). See 50 C.F.R. § 402.14. If the Service(s) anticipate that "take" will occur as a result of the action, the opinion in most cases will include required reasonable and prudent measures and associated terms and conditions to minimize such take, along with an incidental take statement providing EPA legal protection from ESA section 9 take liability for its approval action. See 50 C.F.R. § 402.14(i). Section 7(a)(1) of the ESA requires EPA to use its authorities to carry out programs for the conservation of endangered and threatened species. The ESA, however, does not expand EPA's authorities under the CWA. EPA approval or disapproval decisions regarding State and Tribal WQS must be authorized by the CWA and EPA's implementing regulations.

In addition, EPA has a federal trust relationship with federally recognized Pacific Northwest tribes. In the Pacific Northwest, federal courts have affirmed that certain tribes reserved through treaty the right to fish at all usual and accustomed fishing places and to take a fair share of the fish destined to pass through such areas. *See* Puyallup Tribe v. Department of Game, 391 U.S. 392 (1968); Washington v. Passenger Fishing Vessel, 443 U.S. 658 (1979); United States v. Winans, 198 U.S. 371 (1905). EPA's approval of a State or Tribal WQS, or promulgation of its own WQS, may impact the habitat that supports the treaty fish. EPA has a responsibility to ensure that its WQS actions do not violate treaty fishing rights.

Water Quality Standards set the water quality goals for specific waterbodies and serve as a regulatory basis for other programs, such as National Pollutant Discharge Elimination System (NPDES) permits, listings of impaired water bodies under CWA section 303(d), and total maximum daily loads (TMDLs). In general, NPDES permits contain effluent limitations to meet WQS; section 303(d) lists identify those water bodies where the WQS are not being met; and TMDLs are mathematical calculations indicating the pollutant reductions needed to meet WQS.

III. Relationship of Guidance to EPA's 304(a) Criteria for Water Temperature

Under CWA section 304(a), EPA issues national criteria recommendations to guide States and Tribes in developing their WQS. When EPA reviews a State or Tribal WQS submission for approval under section 303(c) of the CWA, it must determine whether the adopted designated uses and criteria are consistent with the CWA and EPA's regulations. See CWA section 303(c)(3). Specifically, 40 C.F.R § 131.11 requires States and Tribes to adopt water quality criteria that are based on sound scientific rationale and contain sufficient parameters or constituents to protect the designated uses. For waters with multiple use designations, the criteria must support the most sensitive use. See 40 C.F.R. § 131.11(a). When establishing criteria, States should: (1) establish numerical values based on 304(a) guidance, or 304(a) guidance modified to reflect site-specific conditions, or other scientifically defensible methods; or (2) establish narrative criteria or criteria based upon biomonitoring methods where numerical criteria cannot be established or to supplement numerical criteria. See 40 C.F.R. § 131.11(b).

EPA develops its section 304(a) criteria recommendations based on a uniform methodology that takes into account a range of species' sensitivities to pollutant loadings using certain general assumptions; therefore, the national recommendations are generally protective of aquatic life. However, these criteria recommendations may not be protective of all aquatic life designated uses in all situations. It may be appropriate for States and Tribes to develop different water quality criteria using current data concerning the species present, and taking into account site-specific or regional conditions. EPA approval or disapproval would not depend on whether a criterion adopted by a State or Tribe is consistent with a particular guidance document, such as this guidance or the national 304(a) criteria recommendations, but rather on whether the State or Tribe demonstrates that the criterion protects the most sensitive designated use, as required by section 303(c) of the CWA and EPA's WQS regulations.

EPA's current 304(a) criteria recommendations for temperature can be found in *Quality Criteria for Water 1986*, commonly known as the "gold book." The freshwater aquatic life criteria described in this 1986 document were first established in 1977, and were not changed in the 1986 document. In general, EPA's national temperature recommendations for salmonids and other fish consist of formulas to calculate the protective temperatures for short-term exposure and a maximum weekly average exposure. Protective short term temperature exposure is based on subtracting 2°C from the upper incipient lethal temperature (the temperature at which fifty percent of the sample dies). Protective weekly average temperature exposure is based on the optimal growth temperature plus 1/3 the difference between the optimal growth temperature and the upper incipient lethal temperature. Using these formulas and EPA data for coho and sockeye salmon, the 1986 document calculates suggested temperature criteria for short-term exposure as 22°C (sockeye) and 24°C (coho) and a maximum weekly average exposure of 18°C for both species.

Based on extensive review of the most recent scientific studies, EPA Region 10 and the Services believe that there are a variety of chronic and sub-lethal effects that are likely to occur to Pacific Northwest salmonid species exposed to the maximum weekly average temperatures calculated using the current 304(a) recommended formulas. These chronic and sub-lethal effects include reduced juvenile growth, increased incidence of disease, reduced viability of gametes in adults prior to spawning, increased susceptibility to predation and competition, and suppressed or reversed smoltification. It may be possible for healthy fish populations to endure some of these chronic impacts with little appreciable loss in population size. However, for vulnerable fish populations, such as the endangered or threatened salmonids of the Pacific Northwest, EPA and the Services are concerned that these chronic and sub-lethal effects can reduce the overall health and size of the population.

For these reasons, the national assumptions made when developing the section 304(a) criteria recommendations for temperature may not necessarily protect the vulnerable coldwater salmonids in the Pacific Northwest. EPA Region 10, therefore, has developed this guidance to assist Pacific Northwest States and Tribes in developing temperature criteria that protect the coldwater salmonids in the Pacific Northwest identified above.

IV. Water Temperature and Salmonids

IV.1. Importance of Temperature for Salmonids

Water temperatures significantly affect the distribution, health, and survival of native salmonids in the Pacific Northwest. Since salmonids are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse health effects when exposed to temperatures outside their optimal range. Salmonids have evolved and thrived under the water temperature patterns that historically existed (i.e., prior to significant anthropogenic impacts that altered temperature patterns) in Pacific Northwest streams and rivers. Although evidence suggests that historical water temperatures exceeded optimal conditions for salmonids at times during the summer months on some rivers, the temperature diversity in these unaltered rivers provided enough cold water during the summer to allow salmonid populations as a whole to thrive.

Pacific salmon populations have historically fluctuated dramatically due to climatic conditions, ocean conditions, and other disturbances. High water temperatures during drought conditions likely affected the historical abundance of salmon. In general, the increased exposure to stressful water temperatures and the reduction of suitable habitat caused by drought conditions reduce the abundance of salmon. Human-caused elevated water temperatures significantly increase the magnitude, duration, and extent of thermal conditions unsuitable for salmonids.

The freshwater life histories of salmonids are closely tied to water temperatures. Cooling rivers in the autumn serve as a signal for upstream migrations. Fall spawning is initiated when water temperatures decrease to suitable temperatures. Eggs generally incubate over the winter or early spring when temperatures are coolest. Rising springtime water temperatures may serve as a cue for downstream migration.

Because of the overall importance of water temperature for salmonids in the Pacific Northwest, human-caused changes to natural temperature patterns have the potential to significantly reduce the size of salmonid populations. Of particular concern are human activities that have led to the excess warming of rivers and the loss of temperature diversity.

IV.2. Human Activities That Can Contribute to Excess Warming of Rivers and Streams

Rivers and streams in the Pacific Northwest naturally warm in the summer due to increased solar radiation and warm air temperature. Human changes to the landscape have magnified the degree of river warming, which adversely affects salmonids and reduces the number of river segments that are thermally suitable for salmonids. Human activities can increase water temperatures by increasing the heat load into the river, by reducing the river's capacity to absorb heat, and by eliminating or reducing the amount of groundwater flow which moderates temperatures and provides cold water refugia. Specific ways in which human development has caused excess warming of rivers are presented in Issue Paper 3 and are summarized below:

1) Removal of streamside vegetation reduces the amount of shade that blocks solar radiation and increases solar heating of streams. Examples of human activities that reduce shade include forest harvesting, agricultural land clearing, livestock grazing, and urban development.

2) Removal of streamside vegetation also reduces bank stability, thereby causing bank erosion and increased sediment loading into the stream. Bank erosion and increased sedimentation results in wider and shallower streams, which increases the stream's heat load by increasing the surface area subject to solar radiation and heat exchange with the air.

3) Water withdrawals from rivers for purposes such as agricultural irrigation and urban/municipal and industrial use result in less river volume and generally remove cold water. The temperatures of rivers with smaller volumes equilibrates faster to surrounding air temperature, which leads to higher maximum water temperatures in the summer.

4) Water discharges from industrial facilities, wastewater treatment facilities and irrigation return flows can add heat to rivers.

5) Channeling, straightening, or diking rivers for flood control and urban and agricultural land development reduces or eliminates cool groundwater flow into a river that moderates summertime river temperatures. These human actions can reduce two forms of groundwater flow. One form is groundwater that is created during over-bank flooding and is slowly returned to the main river channel to cool the water in the summer. A

second form is water that is exchanged between the river and the riverbed (i.e. hyporheic flow). Hyporheic flow is plentiful in fully functioning alluvial rivers systems.

6) Removal of upland vegetation and the creation of impervious surfaces associated with urban development increases storm runoff and reduces the amount of groundwater that is stored in the watershed and slowly filters back to the stream in the summer to cool water temperatures.

7) Dams and their reservoirs can affect thermal patterns in a number of ways. They can increase maximum temperatures by holding waters in reservoirs to warm, especially in shallow areas near shore. Reservoirs, due to their increased volume of water, are more resistant to temperature change which results in reduced diurnal temperature variation and prolonged periods of warm water. For example, dams can delay the natural cooling that takes place in the late summer-early fall, thereby harming late summer-fall migration runs. Reservoirs also inundate alluvial river segments, thereby diminishing the groundwater exchange between the river and the riverbed (i.e., hyporheic flow) that cools the river and provides cold water refugia during the summer. Further, dams can significantly reduce the river flow rate, thereby causing juvenile migrants to be exposed to high temperatures for a much longer time than they would under a natural flow regime.

It should also be noted that some human development can create water temperatures colder than an unaltered river. The most significant example of this occurs when cold water is released from the bottom of a thermally stratified reservoir behind a dam.

IV.3. Human-Caused Elevated Water Temperature as a Factor in Salmonid Decline

Many reports issued in the past decade have described the degradation of freshwater salmonid habitat, including human-caused elevated temperatures, as a major factor in salmonid decline. The following provides a brief summary of some of these reports:

National Marine Fisheries Service's Listing and Status Reviews for Pacific Northwest Salmonids

The National Marine Fisheries Service (NMFS) identified habitat concerns (including alteration of ambient stream water temperatures) as one of the factors for decline of listed west coast steelhead (NMFS 1996), west coast chinook (NMFS 1998), and Snake River spring/summer chinook salmon (Mathews and Waples 1991). Specific effects attributed to increased temperatures by NMFS include increased juvenile mortality, increased susceptibility and exposure to diseases, impaired ability to avoid predators, altered migration timing, and changes in fish community structure that favor competitors of salmonids. NMFS included high water temperatures among risk factors related to the listings under the ESA of the following evolutionarily significant units (ESUs) of chinook salmon: Puget Sound, Lower Columbia River, Snake River spring/summer, and Upper Willamette (Myers et al. 1998). NMFS also noted high water temperatures in its analyses of risk factors related to the ESA listings of Upper Willamette River steelhead and Ozette Lake sockeye.

U.S. Fish and Wildife Service Listing and Status Reviews for Bull Trout

When listing bull trout in the Columbia River and Coastal-Puget Sound population segments, USFWS identified activities such as forestry, agriculture, and hydropower that have degraded bull trout habitat and specifically have resulted in increased stream temperatures. Bull trout are found primarily in colder streams, although individual fish are found in larger river systems. Water temperature above 15°C is believed to limit bull trout distribution and this may partially explain their patchy distribution within a watershed. The strict cold water temperature needs of bull trout make them particularly vulnerable to human activities identified by USFWS that warm spawning and rearing waters.

Return to the River Reports by the Independent Science Group

The Independent Scientific Group is a group of scientists chartered by the Northwest Power Planning Council to provide independent scientific advice to the Columbia River Basin Fish and Wildlife Program. In their 1996 Return the River report (updated in 2000), they include a section discussing the effects of elevated temperature on salmonids as part of their overall discussion of freshwater habitats. The report states:

> "Temperature is a critical habitat variable that is very much influenced by regulation of flow and impoundments. The mainstem reservoirs are relatively shallow and heat up in late summer causing concern for salmon survival. The lower reaches of some key tributaries also are very warm in late summer because they are dewatered by irrigation withdrawals. Due to the extreme importance of temperature regimes to the ecology of salmonids in the basin, temperature information merits special attention as a key habitat descriptor (Coutant 1999)."

> "Water temperatures in the Columbia River basin have been altered by development and are, at times, suboptimal or clearly detrimental for salmonids. High temperatures alone can be directly lethal to both juvenile and adult salmonids in the Snake River in summer under recent conditions based on generally accepted thermal criteria and measured temperatures."

Oregon Coastal Salmon Restoration Initiative

The Oregon Coastal Salmon Restoration Initiative (1997) included water temperature as a factor for decline in populations of Oregon coastal coho salmon, noting that:

> "Water temperatures are too warm for salmonids in many coastal streams. Altered water temperatures can adversely affect spawning, fry emergence, smoltification, maturation

> period, migratory behavior, competition with other aquatic species, growth and disease resistance."

Summer Chum Salmon Conservation Initiative

The Summer Chum Salmon Conservation Initiative (2000) for the Hood Canal and Strait of Juan de Fuca region listed elevated water temperature in its limiting factor analysis, noting that:

> "Elevated temperatures impede adult passage, cause direct mortality, and accelerate development during incubation leading to diminished survival in subsequent life stages."

Interior Columbia Basin Ecosystem Management Project

The aquatic habitat assessment for the Interior Columbia Basin Ecosystem Management Project (Lee et al. 1997) indicates that:

1. Changes in riparian canopy and shading, or other factors influencing stream temperatures, are likely to affect some, if not most, bull trout populations.
2. In desert climates, the loss of riparian canopy has been associated with elevated water temperature and reduced redband trout abundance.
3. Loss of vegetation has resulted in stream temperatures that have far exceeded those considered optimal for Lahontan Cutthroat Trout.
4. Water temperatures in reaches of the John Day, upper Grande Ronde, and other basins in eastern Oregon commonly exceed the preferred ranges and often exceed lethal temperatures for chinook salmon.

Northwest Indian Fisheries Commission - Critical Habitat Issues by Basin for Natural Chinook Stocks in the Coastal and Puget Sound Areas of Washington State

In this report, the Northwest Indian Fisheries Commission reviewed the habitat issues for the basins in the coastal and Puget Sound areas of Washington State, and identified elevated temperature as a critical habitat issue in 12 out of 15 basins reviewed.

Other Basin and Watershed Studies

Numerous scientific studies of habitat and elevated water temperature impacts on salmon, steelhead and resident native fish have been completed in the Pacific Northwest over the past two decades. The Northwest Power Planning Council is in the process of developing habitat assessments and restoration strategies for all the sub-basins of the Columbia River Basin. In many of these sub-basin summaries (e.g., Okanogan, Methow, Wenatchee, Yakima, Tucannon, Grande Ronde, Umatilla, and John Day draft summaries - see www.cbfwa.org) elevated temperatures are cited as a major factor contributing to salmonid decline. These and other studies elsewhere in the Pacific Northwest provide a consistent view of the importance of restoring temperatures suitable for coldwater salmonds to aid in their recovery.

One specific study worth noting is by Theurer et al. (1985) in the Tucannon River in southeastern Washington. This study shows how human-caused changes in riparian shade and channel morphology contributed to increased water temperatures, reduced available spawning and rearing space, and diminished production of steelhead and chinook salmon. Using a physically-based water temperature model, the authors concluded that approximately 24 miles of spawning and rearing habitat had been made unusable in the lower river due to temperature changes. If the temperatures were restored, they estimated chinook adult returns would increase from 884 that currently exist to 2240 (near historic levels) and that chinook rearing capacity would increase from 170,000 to 430,000. The authors state that the change in temperature regime caused by the loss of riparian vegetation alone is sufficient to explain the reduction in salmonid population in the Tucannon River, while noting that increased sediment input also has played a subsidiary role.

Another similar analysis was done by Oregon Department of Environmental Quality (ODEQ, 2000) for the upper Grande Ronde River as part of their TMDL for this river. ODEQ modeling showed that restoration of riparian shade, channel width and depth, and water flow would drastically reduce maximum temperatures. As shown in Figure 1 (Figures 11 and 12 in ODEQ 2000), over 90% of the river currently exceeds 68°F (20°C), but with full restoration that percentage drops to less than 5%. Similarly, the percentage of the river that exceeds 64°F (18°C) is reduced from over 90% to less than 50% with full restoration. This represents nearly 50 additional miles that are colder than 18°C, which is a very large increase in available rearing habitat. Although actual estimates of increased fish production were not calculated in this study, one might expect similar results as those calculated for the Tucannon River.

Although temperature is highlighted here as a factor in the decline of native salmonid populations, it by no means is the only factor in their decline. Certainly, degradation of habitat unrelated to temperature (e.g., impassable barriers to spawning and rearing areas and physical destruction or inundation of spawning grounds), fishing harvest, and hatchery operations have all played a role in their decline. However, as described above, elevated temperatures are an important factor in the decline of salmonids and restoring suitable temperature regimes for salmonids is a critical element in protecting salmonid populations.

UPPER GRANDE RONDE SUB-BASIN TMDL

Figure 11. Grande Ronde River Temperatures at Current Conditions and Site Potential

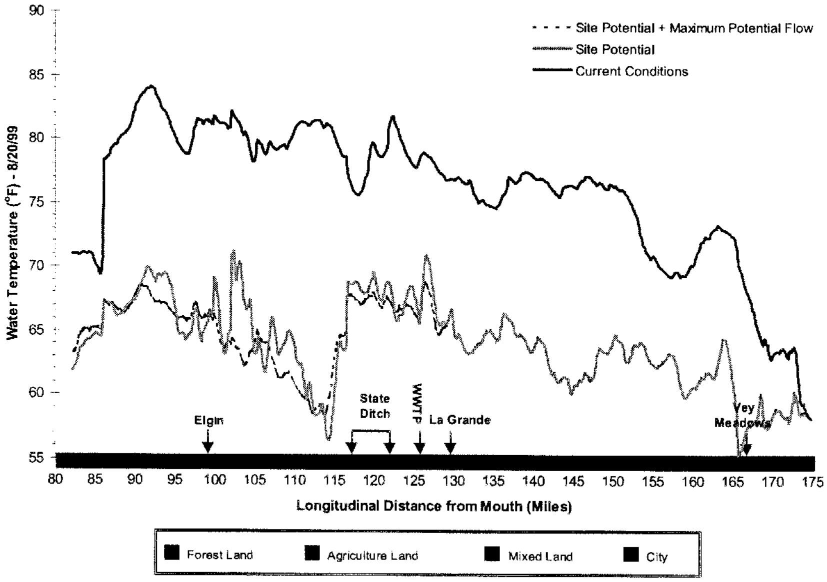
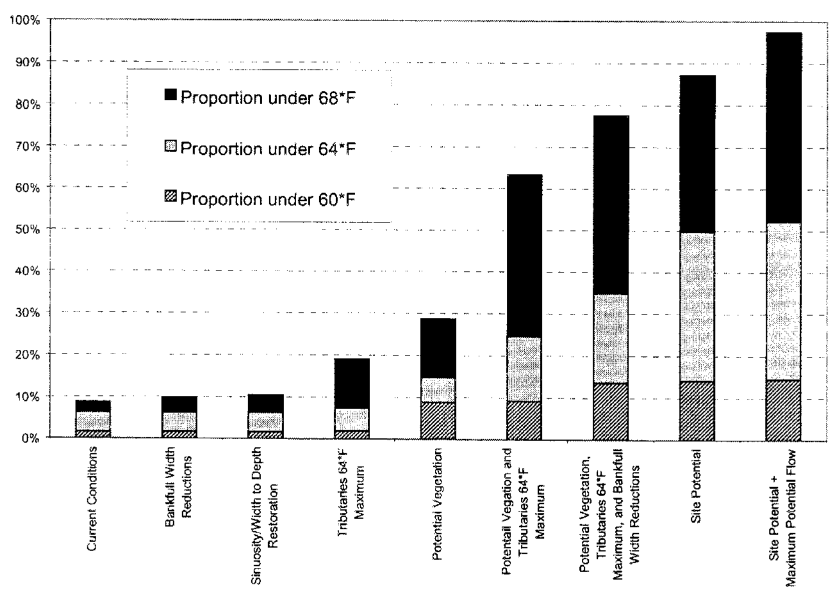


Figure 12. Percent of River Temperatures Below Specified Temperature



OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY PAGE 29

APRIL, 2000

Figure 1. Grande Ronde River temperature modeling using ODEQ's Heat Source Model, showing site potential.

IV.4. General Life Histories of Salmonids and When Human-Caused Elevated Water Temperatures May Be a Problem

Different salmonid species have evolved to take advantage of the Pacific Northwest's cold water environment in different ways. Each species has a unique pattern of when and where they use the rivers, and even for a specific species this pattern of use may change from year to year. This diversity in freshwater life history is a critical evolutionary trait that has allowed salmonids to persist in a freshwater environment that naturally fluctuates and has natural disturbances.

Below is a general summary of the freshwater life history strategies for some of the coldwater salmonids. This summary is intended to provide a "big picture" understanding of how each of these fish use Pacific Northwest rivers and to highlight when and where human elevated water temperatures have impacted these fish. As noted above, because of their life history diversity, the discussion below may be an over-generalization for some situations. Further, because this general discussion on fish distribution is simplified for purposes of understanding, it is not intended to be used as a basis for salmonid use designations.

Chinook Salmon

Adult spring chinook salmon generally leave the ocean and enter Pacific Northwest rivers in the spring (April - June) and swim upstream to hold and spawn in the mid-to-upper reaches of river basins. Spawning generally occurs in late summer and fall (August - October). Egg and alevin incubation extends over the winter and fry generally emerge in the early spring (March - May). Juveniles rear in their natal streams and lower in the basin for a year, then migrate out to the ocean the following spring. Human-caused elevated temperatures can adversely affect spring chinook when adults hold and begin to spawn in the late-summer/early fall and throughout the summer when juveniles rear. Human-caused elevated temperatures in these mid-to-upper reaches can "shrink" the available habitat for adult holding/spawning and juvenile rearing limiting spring chinook to habitat higher in the watershed.

Adult fall chinook salmon generally enter Pacific Northwest rivers in the summer (July - August) and swim upstream to hold and spawn in the lower reaches of mainstem rivers and large tributaries. Spawning generally occurs in the fall (October - December). For example, Snake River fall chinook migrate past Bonneville dam from August-October and spawn in the Snake River below Hells Canyon Dam and the lower reaches of the Clearwater, Grand Ronde, Imnaha, and Tucannon rivers. Fry emerge from March through April and begin their downstream migration several weeks after emergence. Downstream migration occurs mainly in the spring under existing conditions, but may extend throughout the summer in some areas (e.g., Columbia River). Historically, juvenile fall chinook out-migrated throughout the summer months, but today human-caused elevated temperatures have made this impossible in some rivers (e.g., Yakima river). Human-caused elevated temperatures can adversely affect fall chinook in lower river reaches during the summer months when the adults are migrating upstream and holding to spawn and when juveniles are migrating downstream. Human-caused elevated temperatures in the early fall may also delay spawning.

Coho Salmon

Adult coho salmon generally enter Pacific Northwest rivers in the fall (late September through October) and spawn in low gradient 4th and 5th order streams in fall-winter. Fry emerge in the spring. Juvenile coho rear for 1 to 2 years prior to migrating to sea during the spring. Juvenile coho salmon may migrate considerable distances upstream to rear in lakes or other river reaches suitable for rearing. Coho salmon are most predominant in the rivers of the coastal mountains of Washington and Oregon and the west-slopes of the Washington Cascades. Wild coho populations were extirpated years ago in the Umatilla (OR), Yakima (WA), and Clearwater (ID) rivers but they are now being re-introduced in these rivers. Human-caused elevated temperatures can adversely affect coho salmon in the summer months when juveniles are rearing and in early fall when adults start migrating. Human-caused elevated temperatures may render waters unsuitable for rearing, thereby "shrinking" the amount of available habitat.

Sockeye Salmon

Adult sockeye salmon generally enter freshwater from mid summer through early fall and migrate up to lakes and nearby tributaries to spawn in the fall. Juveniles generally rear in lakes from 1 to 3 years, then migrate to the ocean in the spring. Pacific Northwest lakes that support sockeye include Redfish (Idaho), Okanogan, Wenatchee, Baker, Washington, Sammamish, Quinault, and Osoyoos. Historically, there were many other lakes in the Pacific Northwest used by sockeye. Human-caused elevated temperatures can adversely affect sockeye adult salmon as they migrate upstream in the mid-to-late summer.

Chum Salmon

Adult chum salmon generally enter freshwater in late-summer and the fall and spawn (October - December) in the low reaches and side channels of major rivers just upstream from tidewater areas. Upon emergence, juveniles begin their short migration to saltwater which generally occurs between March and June. Juveniles will rear in estuaries for a while prior to entering the ocean.   Human-caused elevated temperatures can adversely affect adult chum salmon as they migrate upstream in the late summer.

Pink Salmon

Adult pink salmon generally enter freshwater in late summer and spawn in the lower reaches of large rivers in late summer and early fall. Like chum, juveniles will migrate to saltwater soon after emerging in the late winter. Human-caused elevated temperatures can adversely affect adult pink salmon as they migrate upstream in the late summer.

Steelhead Trout

Adult steelhead enter Pacific Northwest rivers throughout the year, but can generally be divided into a summer run (May - October) and a winter run (November-June). Both runs typically spawn in the spring. Summer steelhead enter freshwater sexually immature and generally travel greater distances to spawn than winter steelhead, which enter freshwater sexually mature (i.e. with well-developed gonads). All steelhead runs upstream of the Dalles Dam are summer steelhead. Fry generally emerge from May through July and juvenile steelhead will rear in the mid-upper reaches of river basins for 1-2 years (sometimes 3 or 4 years) before migrating to the ocean in the spring. Human-caused elevated temperatures can adversely affect steelhead in the summer months when the juveniles are rearing in the mid-upper reaches. Human-caused elevated temperatures may render waters unsuitable for rearing, thereby “shrinking” the amount of available habitat. Human-caused elevated temperatures also can adversely affect summer run adults as they migrate upstream during the summer as well as eggs and fry that incubate into July in some watersheds.

Bull Trout

Bull trout generally are freshwater fish (although the adults of a few populations enter saltwater estuaries). Adult bull trout generally migrate upstream in the spring and summer from their feeding grounds (lower reaches in a basin for migrating fluvial forms or a lake for adfluvial forms) to their spawning grounds higher in the basin. Bull trout generally spawn in September-October, but in some watersheds spawning can occur as early as July. Bull trout have a long incubation time with fry emergence generally from March through May. Juveniles will rear in their natal streams for 2-4 years, then the migratory forms will migrate downstream to more productive feeding grounds (i.e., lower river reaches or lakes) in the spring, but some fall downstream migration has also been noted. Human-caused elevated temperatures can adversely affect summer juvenile rearing in the upper reaches where elevated temperatures have rendered water unsuitable for rearing, thereby “shrinking” the amount of available habitat. Adults migrating upstream to spawn in the summer can also experience adverse effects from human-elevated temperatures. Additionally, migratory adults can be adversely affected by the loss of cold water refugia due to human activities.

V. EPA Region 10 Recommendations for Pacific Northwest State and Tribal Temperature WQS

EPA Region 10 offers the following recommendations to assist States and Tribes in adopting temperature WQS that fully support coldwater salmonids in the Pacific Northwest. The recommendations are intended to assist States and Tribes to adopt temperature WQS that EPA can approve consistent with its obligations under the CWA and the ESA. As noted in Section I, Pacific Northwest States and Tribes that adopt temperature WQS consistent with these recommendations can expect an expedited review by EPA and the Services, subject to new data and information that might be available to during that review.

EPA Region 10 recommends that States and Tribes adopt new or revised temperature WQS that incorporate each of the following elements for the protection of salmonid designated uses. Each of these elements is discussed in more detail below:

1) Coldwater Salmonid Uses and Numeric Criteria to Protect Those Uses;

2) Provisions to Protect Water Temperatures That Are Currently Colder Than the Numeric Criteria; and

3) Provisions to Protect Salmonids from Thermal Plume Impacts.

If a State or Tribe decides to adopt new or revised temperature WQS, it is free, of course, to adopt WQS that are different than these recommendations. EPA would evaluate these submissions on a case-by-case basis to determine if it can approve the WQS consistent with its obligations under the CWA and the ESA.

V.1. Coldwater Salmonid Uses and Numeric Criteria to Protect Those Uses

Tables 1 and 2 provide a summary of the important water temperature considerations for each life stage for salmon and trout, and bull trout: spawning, egg incubation, and fry emergence; juvenile rearing; and adult migration. Each temperature consideration and associated temperature values noted in Tables 1 and 2 includes a reference to the relevant technical issue papers prepared in support of this guidance (or other studies) that provide a more detailed discussion of the supporting scientific literature. The temperatures noted in Tables 1 and 2 form the scientific basis for EPA's recommended numeric criteria to protect coldwater salmonids in the Pacific Northwest, which are presented in Tables 3 and 4.

<u>V.1.A. Overall Context for Recommended Uses and Criteria</u>

In addition to Tables 1 and 2, there are a number of other general factors that EPA considered in recommending coldwater salmonid uses and numeric criteria to protect those uses. These factors

Table 1 - Summary of Temperature Considerations For Salmon and Trout Life Stages

Life Stage	Temperature Consideration	Temperature & Unit	Reference
Spawning and Egg Incubation	*Temp. Range at which Spawning is Most Frequently Observed in the Field	4 - 14°C (daily avg)	Issue Paper 1; pp 17-18 Issue Paper 5; p 81
	* Egg Incubation Studies - Results in Good Survival -Optimal Range	 4 - 12°C (constant) 6 - 10°C (constant)	 Issue Paper 5; p 16
	*Reduced Viability of Gametes in Holding Adults	> 13°C (constant)	Issue Paper 5; pp 16 and 75
Juvenile Rearing	*Lethal Temp. (1 Week Exposure)	23 - 26°C (constant)	Issue Paper 5; pp 12, 14 (Table 4), 17, and 83-84
	*Optimal Growth - unlimited food - limited food	 13 - 20°C (constant) 10 - 16°C (constant)	 Issue Paper 5; pp 3-6 (Table 1), and 38-56
	*Rearing Preference Temp. in Lab and Field Studies	10 - 17°C (constant) < 18°C (7DADM)	Issue Paper 1; p 4 (Table 2). Welsh et al. 2001.
	*Impairment to Smoltification	12 - 15°C (constant)	Issue Paper 5; pp 7 and 57-65
	*Impairment to Steelhead Smoltification	> 12°C (constant)	Issue Paper 5; pp 7 and 57-65
	*Disease Risk (lab studies) -High - Elevated - Minimized	 > 18 - 20°C (constant) 14 - 17°C (constant) 12 - 13°C (constant)	Issue Paper 4, pp 12 - 23
Adult Migration	*Lethal Temp. (1 Week Exposure)	21- 22°C (constant)	Issue Paper 5; pp 17, 83 - 87
	*Migration Blockage and Migration Delay	21 - 22°C (average)	Issue Paper 5; pp 9, 10, 72-74. Issue Paper 1; pp 15 - 16
	*Disease Risk (lab studies) - High - Elevated - Minimized	 > 18 - 20°C (constant) 14 - 17°C (constant) 12- 13°C (constant)	 Issue Paper 4; pp 12 - 23
	*Adult Swimming Performance - Reduced - Optimal	 > 20°C (constant) 15 - 19°C (constant)	 Issue Paper 5; pp 8, 9, 13, 65 - 71
	* Overall Reduction in Migration Fitness due to Cumulative Stresses	> 17-18°C (prolonged exposures)	Issue Paper 5; p 74

Table 2 - Summary of Temperature Considerations For Bull Trout Life Stages

Life Stage	Temperature Consideration	Temperature & Unit	Reference
Spawning and Egg Incubation	*Spawning Initiation	< 9°C (constant)	Issue Paper 5; pp 88 - 91
	*Temp. at which Peak Spawning Occurs	< 7°C (constant)	Issue Paper 5; pp 88 - 91
	*Optimal Temp. for Egg Incubation	2 - 6°C (constant)	Issue Paper 5; pp 18, 88 - 91
	*Substantially Reduced Egg Survival and Size	6 - 8°C (constant)	Issue Paper 5; pp 18, 88 - 91
Juvenile Rearing	*Lethal Temp. (1 week exposure)	22 - 23°C (constant)	Issue Paper 5; p 18
	*Optimal Growth - unlimited food - limited food	 12 - 16 °C (constant) 8 - 12°C (constant)	Issue Paper 5; p 90. Selong et al 2001. Bull trout peer review, 2002.
	*Highest Probability to occur in the field	12 - 13 °C (daily maximum)	Issue Paper 5; p 90. Issue Paper 1; p 4 (Table 2). Dunham et al., 2001. Bull trout peer review, 2002.
	*Competition Disadvantage	>12°C (constant)	Issue Paper 1; pp 21- 23. Bull trout peer review, 2002.

and EPA's recommended approach for considering these factors (described below) provide the overall context for EPA's salmonid use and criteria recommendations.

Coldwater Salmonid Uses

Coldwater salmonids are considered a sensitive aquatic life species with regard to water temperatures and are a general indicator species of good aquatic health. EPA, therefore, believes it is appropriate for States and Tribes in the Pacific Northwest to focus on coldwater salmonids when establishing temperature criteria to support aquatic life.

Under EPA's WQS regulations, States and Tribes must adopt appropriate uses and set criteria to protect those uses. See 40 C.F.R § 131.10(a). Because Pacific Northwest salmonids have multiple freshwater life stages with differing temperature tolerances, it is generally appropriate to designate uses based on life stages. In addition, EPA's WQS regulations allow States and Tribes to adopt seasonal uses where a particular use applies for only a portion of the year. See 40 C.F.R § 131.10(f). EPA's recommended approach is for States and Tribes to utilize both of these use designation options in order to more precisely describe where and when the different coldwater salmonid uses occur.

In this guidance, EPA recommends seven coldwater salmonid uses (see Tables 3 and 4). Four uses apply to the summer maximum temperature condition and three apply to specific locations and times for other times of the year (except for some instances when these uses may apply during the period of summer maximum temperatures).

Focus on Summer Maximum Conditions

In general, increased summertime temperatures due to human activities are the greatest water temperature concern for salmonids in the Pacific Northwest, although temperatures in the late spring and early fall are also a concern in some areas. EPA therefore believes it is appropriate that temperature criteria focus on the summer maximum conditions to protect the coldwater salmonid uses that occur then. Generally, improving river conditions to reduce summer maximum temperatures will also reduce temperatures throughout the summer and in the late spring and early fall (i.e., shift the seasonal temperature profile downward). Thus, the data indicate that, because of the natural annual temperature regime, providing protective temperatures during the summer maximum period will in many areas provide protective temperatures for more temperature sensitive uses that occur other times of the year.

In some areas, however, more temperature-sensitive salmonid uses (e.g., spawning, egg incubation, and steelhead smoltification) that occur in the spring-early summer or late summer-fall may not be protected by meeting the summer maximum criterion. Thus, in addition to summer maximum criteria, EPA also recommends criteria be adopted to protect these more temperature-sensitive uses when and where they occur. Doing so provides an added degree of protection for those situations where control of summer maximum temperatures is inadequate to protect these more temperature-sensitive uses. An additional reason for having these seasonal uses is to provide protection for rivers that are flow-regulated, which can alter the natural annual temperature pattern.

In recommending protective summer maximum criteria, EPA took into consideration that meeting a criterion during the warmest period of the summer (e.g., warmest week) will result in cooler temperatures during other times in the summer. The duration of exposure to near summer maximum conditions, however, can vary from one to two weeks in some areas to over a month in other areas.

Optimal, Harmful, and Lethal Temperatures for Salmonids

Each salmonid life stage has an optimal temperature range. Physiological optimum temperatures are those where physiological functions (e.g., growth, swimming, heart performance) are optimized. These temperatures are generally determined in laboratory experiments. Ecological optimum temperatures are those where fish do best in the natural environment considering food availability, competition, predation, and fluctuating temperatures. Both are important considerations when establishing numeric criteria. Exposure to temperatures above the optimal range results in increased severity of harmful effects, often referred to as sub-lethal or chronic effects (e.g., decreased juvenile growth which results in smaller, more vulnerable fish; increased susceptibility to disease which can lead to mortality; and decreased ability to compete and avoid predation), as temperatures rise until at some point they become lethal (See Table 1 and 2). Water temperatures below the optimal range also cause sub-lethal effects (e.g., decreased growth); however, this is generally a natural condition (with the exception of cold water releases from a storage dam) and is not the focus of this guidance.

When determining the optimal range for bull trout and salmon/trout juvenile rearing, EPA looked at both laboratory and field data and considered both physiological and ecological aspects. Optimal growth under limited food rations in laboratory experiments, preference temperatures in laboratory experiments where fish select between a gradient of temperatures, and field studies on where rearing predominately occurs are three independent lines of evidence indicating the optimal temperature range for rearing in the natural environment. As highlighted in Tables 1 and 2 (and shown in detail in the technical issue papers) these three lines of evidence show very consistent results, with the optimal range between 8 - 12°C for bull trout juvenile rearing and between 10 - 16°C for salmon and trout juvenile rearing.

Use of the 7 Day Average of the Daily Maximum (7DADM) Unit of Measurement

The recommended metric for all of the following criteria is the maximum 7 day average of the daily maxima (7DADM). This metric is recommended because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day. Thus, it reflects an average of maximum temperatures that fish are exposed to over a week-long period. Since this metric is oriented to daily maximum temperatures, it can be used to protect against acute effects, such as lethality and migration blockage conditions.

This metric can also be used to protect against sub-lethal or chronic effects (e.g., temperature effects on growth, disease, smoltification, and competition), but the resultant cumulative thermal exposure fish experience over the course of a week or more needs to be considered when selecting a 7DADM value to protect against these effects. EPA's general conclusion from studies on fluctuating temperature regimes (which is what fish generally experience in rivers) is that fluctuating temperatures increase juvenile growth rates when mean temperatures are colder than the optimal growth temperature derived from constant temperature studies, but will reduce growth when the mean temperature exceeds the optimal growth temperature (see Issue Paper 5, pages 51-56). When the mean temperature is above the optimal growth temperature, the "mid-point" temperature between the mean and the maximum is the "equivalent" constant temperature. This "equivalent" constant temperature then can be directly compared to laboratory studies done at constant temperatures. For example, a river with a 7DADM value of 18°C and a 15°C weekly mean temperature (i.e., diurnal variation of ± 3°C) will be roughly equivalent to a constant laboratory study temperature of 16.5°C (mid-point between 15°C and 18°C). Thus, both maximum and mean temperatures are important when determining a 7DADM value that is protective against sub-lethal/chronic temperature effects.

For many rivers and streams in the Pacific Northwest, the 7DADM temperature is about 3°C higher than the weekly mean (Dunham, et al. 2001; Chapman, 2002). Thus, when considering what 7DADM temperature value protects against chronic effects, EPA started with the constant temperatures that scientific studies indicate would be protective against chronic effects and added 1-2°C degrees (see Table 1 for summary of studies done under constant temperatures). For bull trout waters, EPA started with the constant temperatures that scientific studies indicate would be protective for chronic effects and added about 0.5°C because bull trout waters typically have less diurnal variation. Following this general procedure takes into account the maximum and mean temperature (i.e., reflects a "mid-point") when protecting for growth and other sub-lethal effects.

It is important to note that there are also studies that analyzed sub-lethal effects based on maximum or 7DADM temperature values which need not be translated for purposes of determining protective 7DADM temperatures. For example, there are field studies that assess probability of occurrence or density of a specific species based on maximum temperatures (Issue Paper 1, Haas (2001), Welsh et al. (2001)). These field studies represent an independent line of evidence for defining upper optimal temperature thresholds, which complements laboratory studies.

It is also important to note that there are confounding variables that are difficult to account for but are important to recognize. For instance, the amount of diurnal variation in rivers and streams in the Pacific Northwest varies considerably; therefore, the difference between the 7DADM and the weekly mean will vary. The difference between the 7DADM temperature and the weekly mean may be less than 1°C for rivers with little diurnal variation and as high as 9°C for streams with high diurnal variation (Dunham et al., 2001). Another variable is food availability. The temperature for which there is optimal juvenile growth depends on the food supply. Optimal growth temperatures under limited food supply are lower than those under unlimited/satiated food supply. Generally, EPA believes that laboratory studies under limited food availability are most reflective of environmental conditions fish typically experience. However, there are likely situations where food is abundant, with the result that optimal growth temperatures would be higher. Thus, a particular 7DADM numeric criteria will be more protective in situations where there is high diurnal variation and/or abundant food and will be less protective in situations where there is low diurnal variation and limited food.

Unusually Warm Conditions

In order to have criteria that protect designated uses under the CWA, EPA expects that the criteria would need to apply nearly all the time. However, EPA believes it is reasonable for a State or Tribe to decide not to apply the numeric temperature criteria during unusually warm conditions for purposes of determining if a waterbody is attaining criteria. One possible way for a State or Tribe to do this would be to explain in its WQS that it will determine attainment with the numeric temperature criterion based on the 90th percentile of the yearly maximum 7DADM values calculated from a yearly set of values of 10 years or more. Thus, generally speaking, the numeric criteria would apply 9 out 10 years, or all but the hottest year. Another way may be to exclude water temperature data when the air temperature during the warmest week of the year exceeds the 90th percentile for the warmest week of the year based on a historical record (10 years or more) at the nearest weather reporting station.

A State or Tribe wishing to consider adopting a provision to account for unusually warm conditions might be able to justify that decision by pointing out that extreme annual peaks in water temperature typically caused by drought conditions are a natural component of the environment and then concluding, as a matter of policy, that these infrequent conditions should not drive attainment determinations. Salmonids may experience some adverse effects during these periods, but by definition, they would be infrequent. It is important to note that not taking into account unusually warm conditions should only be for CWA 303(d) listing purposes when determining if a waterbody is in attainment with temperature WQS. NPDES permitted facilities should not be exempt from applicable temperature effluent limits during these periods.

Even assuming that a State or Tribe decides to account for unusually warm conditions in its temperature WQS, attainment determinations should be based on all climatic conditions except for the extreme condition in order to protect the salmonid designated uses. Thus, given that river temperatures exhibit year-to-year variation in their maximum 7DADM values, the average maximum 7DADM value from a yearly series, as a statistical matter, would need to be lower than the numeric criteria in order to meet the criteria 9 out of 10 years. Therefore, in most years, the maximum 7DADM temperature would also probably need to be lower than the numeric criteria in order to meet the criteria in the warm years. EPA took this into consideration when it formulated its numeric criteria recommendations.

A De Minimis Temperature Increase Allowance

A State or Tribe may, if it has not already done so, wish to consider adopting a provision in its WQS that allows for a de minimis temperature increase above the numeric criteria or the natural background temperature. A State or Tribe might choose to include a de minimis increase allowance as a way of accounting for monitoring measurement error and tolerating negligible human impacts. The data and information currently available to EPA appear to indicate that an increase on the order of 0.25°C for all sources cumulatively (at the point of maximum impact) above fully protective numeric criteria or natural background temperatures would not impair the designated uses, and therefore might be regarded as de minimis.

Numeric Criteria Should Apply Upstream of the Furthest Downstream Extent of Use

Water quality criteria must protect the relevant designated uses. See 40 C.F.R. § 131.11(a). Therefore, a criterion should apply to all the river miles for which a particular use is designated, including the lowest point downstream at which the use is designated. Because streams generally warm progressively in the downstream direction, waters upstream of that point will generally need to be cooler in order to ensure that the criterion is met downstream. Thus, a waterbody that meets a criterion at the furthest downstream extent of use will in many cases provide water cooler than the criterion at the upstream extent of the use. EPA took this into consideration when it formulated its numeric criteria recommendations.

EPA also believes that the numeric criteria should apply upstream of the areas of actual use because temperatures in upstream waters significantly affect the water temperatures where the actual use occurs and upstream waters are usually colder. Of course, if a more sensitive use is designated upstream, the more protective criterion would apply upstream. See 40 C.F.R. § 131.11(a).

Selection of Protective Criteria for the Recommended Salmon Uses

As described above, numeric criteria that apply to uses that occur during the summer maximum period are intended to apply to the warmest times of the summer, the warmest years (except for extreme conditions), and the lowest downstream extent of use. Because of the conservative nature of this application, EPA believes that it is appropriate to recommend numeric criteria near the warmer end of the optimal range for uses intended to protect high quality bull trout and salmon/trout rearing (see Section V.1.C for use descriptions). EPA expects that adopting a numeric criterion near the warmer end of the optimal range that is applied to the above conditions is likely to result in temperatures near the middle of the optimal range for most of the spring through fall period in the segments where most of the rearing use occurs. EPA has identified two reasons for this. First, if the criterion is met at the summer maximum, then temperatures will be lower than the criterion during most of the year. Second, because the criterion would apply at the furthest point downstream where the use is designated, temperatures will generally be colder across the full range of the designated use.

EPA also recognizes that salmonids will use waters that are warmer than their optimal thermal range and further recognizes that some portions of rivers and streams in the Pacific Northwest naturally (i.e., absent human impacts) were warmer than the salmonid optimal range during the period of summer maximum temperatures. To account for these realities, EPA is also recommending two salmonid uses (see Section V.1.C) during the period of summer maximum temperatures where the recommended numeric criteria exceed the optimal range, but provide protection from lethal conditions and sub-lethal effects that would significantly adversely affect these uses.

If applied collectively, EPA believes its recommended salmonid uses and associated numeric criteria, if attained, will support healthy sustainable salmonid populations. However, EPA notes that it must still consider any new or revised temperature WQS submitted by a State or Tribe on a case-by-case basis and must take into account any new information made available to EPA at that time.

Determining the Spatial Extent of the Recommended Salmonid Uses

It is well recognized that the current distribution of salmonids in the Pacific Northwest has significantly shrunk and is more fragmented than their historical distribution due to human development. It is also unlikely that the current distribution of salmonids will provide for sustainable salmonid populations. EPA believes that, in order to meet the national goal of providing for the protection and propagation of fish wherever attainable, salmonid use designations should be of sufficient geographic and temporal scope to support sustainable levels of use. This is because, unless the designated use specifically provides otherwise, a salmonid use reasonably implies a healthy and sustainable population. Because of the importance of restoring healthy salmonid populations in the Pacific Northwest, EPA Region 10 advises States and Tribes not to limit salmonid use designations to where and when salmonid uses occur today when assigning uses in areas with thermally degraded habitat.

For areas with degraded habitat, EPA recommends that coldwater salmonid uses be designated in waters where the defined use currently occurs or is suspected to currently occur, and where there is reasonable potential for that use to occur (e.g., if temperatures or other habitat features, including fish passage improvements, were to be restored in areas of degraded habitat). In most areas of degraded habitat, temperatures have risen, thereby forcing salmonids upstream to find suitable water temperatures for rearing and spawning. As a result, the downstream extent of current use is likely farther upstream than it was prior to habitat degradation. For areas with minimal habitat degradation, where human impacts have not likely altered fish distribution, EPA recommends use designations based on where the use currently occurs or is suspected to currently occur.

EPA's recommendations for designating the spatial extent of the various salmonid uses are described below in Sections V.1.C and V.1.D. The goal of these recommendations is to include the potential use areas for each salmonid use where the habitat has been degraded due to human impacts. For example, for the bull trout rearing use and the salmon/trout core rearing use, which are intended to protect waters of moderate to high density rearing use, EPA recommends that for areas of degraded habitat, these uses cover the downstream extent of low density rearing that currently occurs during the period of maximum summer temperatures (typically July and August). The concept here is that waters where rearing currently occurs in low density during the summer is a reasonable approximation of waters that could support moderate to high density use if the temperature were reduced.

EPA fully recognizes the difficulties in spatially designating the recommended salmonid uses. First, information on fish distribution, particularly juvenile rearing distribution, is sparse in many locations. For example, in some situations there may be fairly good information on spawning areas, but minimal information on juvenile rearing distribution. In those situations, a State or

Tribe could consider using the spawning distribution along with inferences drawn from what information exists on juvenile rearing as the primary basis for designating the bull trout and the core salmon and trout rearing uses.   Second, there is a fair degree of both inter-annual and seasonal variability in fish distribution. Third, there is no bright line that defines degraded habitat; rather there is a spectrum from non-degraded to highly degraded.

States and Tribes, therefore, should use the best available scientific information (e.g., the types of information described in Sections V.1.C and V.1.D) and make well-reasoned judgments when designating the various salmonid uses. In some cases, that may mean extrapolating from limited information and making generalizations based on stream order, size, and elevation. Thus, EPA recognizes there is an inherent element of subjectivity to designating the recommended salmonid uses. However, because the recommended salmonid uses are fairly broad scale (applying to large areas of a river basin), EPA believes that the recommended use designations are reasonable given the current level of information. If a State or Tribe decides to revise its salmonid use designations and submit them to EPA for approval, it should include a description of the information and judgments it made to determine the spatial extent of its salmonid uses.

Lastly, EPA also believes that better information on fish distribution is valuable for both CWA and ESA purposes and that adopting the recommended salmonid use designations (or others justified by the best available scientific information) will provide impetus to acquire more and better information in the future.

V.1.B. EPA Region 10's Recommended Salmonid Uses and Numeric Criteria

EPA Region 10's recommended coldwater salmonid uses and criteria to protect those uses are presented in Tables 3 and 4. Table 3 describes uses that occur during the summer maximum temperature conditions. Designating the uses in Table 3 would result in apportioning a river basin to up to 4 salmonid use categories with associated criteria (e.g., 12°C, 16°C, 18°C, and 20°C). The colder criteria would apply in the headwaters and the warmer criteria would apply in the lower river reaches, which is consistent with the typical thermal and salmonid use patterns of rivers in the Pacific Northwest during the summer. It should be noted, however, that there may be situations where a warmer use and criteria would apply upstream of a colder use and criteria (e.g., where a relatively large cold tributary enters a warmer river, which significantly cools the river).

Table 4 describes coldwater salmonid uses that generally occur at times other than during the summer maximum period, except for some circumstances. EPA recommends that these criteria apply when and where these uses occur and may potentially occur.

Table 3. Recommended Uses & Criteria That Apply To Summer Maximum Temperatures

Notes: 1) "7DADM" refers to the Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, Sockeye, Pink, and Chum salmon; 3) "Trout" refers to Steelhead and coastal cutthroat trout

Salmonid Uses During the Summer Maximum Conditions	Criteria
Bull Trout Juvenile Rearing	12°C (55°F) 7DADM
Salmon/Trout "Core" Juvenile Rearing *(Salmon adult holding prior to spawning, and adult and sub-adult bull trout foraging and migration may also be included in this use category)*	16°C (61°F) 7DADM
Salmon/Trout Migration plus Non-Core Juvenile Rearing	18°C (64°F) 7DADM
Salmon/Trout Migration .	20°C (68°C) 7DADM, plus a provision to protect and, where feasible, restore the natural thermal regime

Table 4. Other Recommended Uses & Criteria

Notes: 1) "7DADM" refers to the Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, Sockeye, Pink, and Chum salmon; 3) "Trout" refers to Steelhead and coastal cutthroat trout;

Salmonid Uses	Criteria
Bull Trout Spawning	9°C (48°F) 7DADM
Salmon/Trout Spawning, Egg Incubation, and Fry Emergence	13°C (55°F) 7DADM
Steelhead Smoltification	14°C (57°F) 7DADM

V.1.C. Discussion of Uses and Criteria Presented in Table 3

Bull Trout Juvenile Rearing - 12°C 7DADM

EPA recommends this use for the protection of moderate to high density summertime bull trout juvenile rearing near their natal streams in their first years of life prior to making downstream migrations. This use is generally found in a river basin's upper reaches.

EPA recommends a 12°C maximum 7DADM criterion for this use to: (1) safely protect juvenile bull trout from lethal temperatures; (2) provide upper optimal conditions under limited food for juvenile growth during the period of summer maximum temperature and optimal temperature for other times of the growth season; (3) provide temperatures where juvenile bull trout are not at a competitive disadvantage with other salmonids; and (4) provide temperatures that are consistent with field studies showing where juvenile bull trout have the highest probability to occur (see Table 2).

EPA recommends that the spatial extent of this use include: (1) waters with degraded habitat where high and low density juvenile bull trout rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures, except for isolated patches of a few fish that are spatially disconnected from more continuous upstream low density use; (2) waters with minimally-degraded habitat where moderate to high density bull trout rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures; (3) waters where bull trout spawning currently occurs; (4) waters where juvenile rearing may occur and the current 7DADM temperature is 12°C or lower; and (5) waters where other information indicates the potential for moderate to high density bull trout rearing use during the period of maximum summer temperatures (e.g., recovery plans, bull trout spawning and rearing critical habitat designations, historical distributions, current distribution in reference streams, studies showing suitable rearing habitat that is currently blocked by barriers that can reasonably be modified to allow passage, or temperature modeling).

Salmon and Trout "Core" Juvenile Rearing - 16°C 7DADM

EPA recommends this use for the protection of moderate to high density summertime salmon and trout juvenile rearing. This use is generally found in a river basin's mid-to-upper reaches, downstream from juvenile bull trout rearing areas. However, in colder climates, such as the Olympic mountains and the west slopes of the Cascades, it may be appropriate to designate this use all the way to the saltwater estuary.

Protection of these waters for salmon and trout juvenile rearing also provides protection for adult spring chinook salmon that hold throughout the summer prior to spawning and for migrating and foraging adult and sub-adult bull trout, which also frequently use these waters.

EPA recommends a 16°C maximum 7DADM criterion for this use to: (1) safely protect juvenile salmon and trout from lethal temperatures; (2) provide upper optimal conditions for juvenile growth under limited food during the period of summer maximum temperatures and optimal temperatures for other times of the growth season; (3) avoid temperatures where juvenile salmon and trout are at a competitive disadvantage with other fish; (4) protect against temperature-induced elevated disease rates; and (5) provide temperatures that studies show juvenile salmon and trout prefer and are found in high densities (see Table 1).

EPA recommends that the spatial extent of this use include: (1) waters with degraded habitat where high and low density salmon and trout juvenile rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures, except for isolated patches of a few fish that are spatially disconnected from more continuous upstream low density use; (2) waters with minimally-degraded habitat where moderate to high density salmon and trout juvenile rearing currently occurs or is suspected to currently occur during the period of maximum summer temperatures; (3) waters where trout egg incubation and fry emergence and salmon spawning currently occurs during the summer months (mid-June through mid-September); (4) waters where juvenile rearing may occur and the current 7DADM temperature is 16°C or lower; (5) waters where adult and sub-adult bull trout foraging and migration occurs during the period of summer maximum temperatures; and (6) waters where other information indicates the potential for moderate to high density salmon and trout rearing use during the period of maximum summer temperatures (e.g., recovery plans, critical habitat designations, historical distributions, current distribution in reference streams, studies showing suitable rearing habitat that is currently blocked by barriers that can reasonably be modified to allow passage, or temperature modeling).

Please note that at this time EPA is recommending that adult and sub-adult bull trout foraging and migration be included in this use category as opposed to establishing a separate use and associated criterion. Our current knowledge of bull trout migration timing and their *main channel* temperature preference is limited, but we do know that they prefer water temperatures less than 15°C, that they take advantage of cold water refugia during the period of summer maximum temperatures, and that spawning adults move toward spawning grounds during the period of summer maximum temperatures. EPA, therefore, believes its recommended approach would protect migrating and foraging bull trout because average river temperatures will likely be below 15°C, a fair amount of cold water refugia is expected in rivers that attain a maximum 7DADM of 16°C, and maximum temperatures below 16°C are likely to occur upstream of the downstream point of this use designation where most bull trout migration and foraging is likely to occur during the period of summer maximum temperatures. As more is learned about adult and sub-adult bull trout foraging and migration, EPA, in consultation with the U.S. Fish and Wildlife Service, may reconsider this recommendation.

Salmon and Trout Migration Plus Non-Core Juvenile Rearing - 18°C 7DADM

EPA recommends this use for the protection of migrating adult and juvenile salmonids and moderate to low density salmon and trout juvenile rearing during the period of summer maximum temperatures. This use designation recognizes the fact that salmon and trout juveniles will use waters that have a higher temperature than their optimal thermal range. For water bodies that are currently degraded, there is likely to be very limited current juvenile rearing during the period of maximum summer temperatures in these waters. However, there is likely to be more extensive current juvenile rearing use in these waters during other times of the year. Thus, for degraded waters, this use designation could indicate a potential rearing use during the period of summer maximum temperatures if maximum temperatures are reduced.

This use is generally found in the mid and lower part of a basin, downstream of the Salmon and Trout Core Juvenile Rearing use. In many river basins in the Pacific Northwest, it may be appropriate to designate this use all the way to a river basin's terminus (i.e., confluence with the Columbia River or saltwater).

EPA recommends an 18°C maximum 7DADM criterion for this use to: (1) safely protect against lethal conditions for both juveniles and adults; (2) prevent migration blockage conditions for migrating adults; (3) provide optimal or near optimal juvenile growth conditions (under limited food conditions) for much of the summer, except during the summer maximum conditions, which would be warmer than optimal; and (4) prevent adults and juveniles from high disease risk and minimize the exposure time to temperatures that can lead to elevated disease rates (See Table 1).

The upstream extent of this use designation is largely driven by where the salmon and trout core juvenile rearing use (16°C) is defined. It may be appropriate to designate this use downstream to the basin's terminus, unless a salmon and trout migration use (20°C) is designated there. Generally, for degraded water bodies, this use should include waters where juvenile rearing currently occurs during the late spring-early summer and late summer-early fall, because those current uses could indicate potential use during the period of summer maximum temperatures if temperatures were to be reduced.

Salmon and Trout Migration - 20°C 7DADM plus a provision to protect and, where feasible, restore the natural thermal regime

EPA recommends this use for waterbodies that are used almost exclusively for migrating salmon and trout during the period of summer maximum temperatures. Some isolated salmon and trout juvenile rearing may occur in these waters during the period of summer maximum temperatures, but when it does, such rearing is usually found only in the confluence of colder tributaries or other areas of colder waters. Further, in these waters, juvenile rearing was likely to have been mainly in cold water refugia areas during the period of maximum temperatures prior to human alteration of the landscape. It should also be noted that most fish migrating in these waters do so in the spring-early summer or in the fall when temperatures are cooler than the summer maximum temperatures, but some species (e.g., late migrating juvenile fall chinook; adult summer chinook, fall chinook, summer steelhead, and sockeye) may migrate in these waters during the period of summer maximum temperatures.

This use is probably best suited to the lower part of major rivers in the Pacific Northwest, where based on best available scientific information, it appears that the natural background maximum temperatures likely reached 20°C. When designating the spatial extent of this use, EPA expects the State or Tribe to provide information that suggests that natural background maximum temperatures reached 20°C. However, EPA does not expect the State or Tribe to have conducted a process-based temperature model (see Section VI.3 below for a discussion on methods to demonstrate natural background temperatures). If a State or Tribe determines that the natural background temperature is higher than 20°C for a particular location and wants to establish a numeric criterion higher than 20°C, it should follow the procedures described in Section VI.1.B for the establishment of site-specific numeric criteria based on natural background conditions.

To protect this use, EPA recommends a 20°C maximum 7DADM numeric criterion *plus* a narrative provision that would require the protection, and where feasible, the restoration of the natural thermal regime. EPA believes that a 20°C criterion would protect migrating juveniles and adults from lethal temperatures and would prevent migration blockage conditions. However, EPA is concerned that rivers with significant hydrologic alterations (e.g., rivers with dams and reservoirs, water withdrawals, and/or significant river channelization) may experience a loss of temperature diversity in the river, such that maximum temperatures occur for an extended period of time and there is little cold water refugia available for fish to escape maximum temperatures. In this case, even if the river meets a 20°C criterion for maximum temperatures, the duration of exposure to 20°C temperatures may cause adverse effects in the form of increased disease and decreased swimming performance in adults, and increased disease, impaired smoltification, reduced growth, and increased predation for late emigrating juveniles (e.g., fall chinook in the Columbia and Snake Rivers). Therefore, in order to protect this use with a 20°C criterion, it may be necessary for a State or Tribe to supplement the numeric criterion with a narrative provision to protect and, where feasible, restore the natural thermal regime for rivers with significant hydrologic alterations.

Critical aspects of the natural thermal regime that should be protected and restored include: the spatial extent of cold water refugia (generally defined as waters that are 2°C colder than the surrounding water), the diurnal temperature variation, the seasonal temperature variation (i.e., number of days at or near the maximum temperature), and shifts in the annual temperature pattern. The narrative provision should call for the protection, and where feasible, the restoration of these aspects of the natural temperature regime. EPA notes that the *protection* of existing cold water refugia should already be provided by the State's or Tribe's antidegradation provisions or by the cold water protection provisions discussed in Section V.2 below. Thus, the new concept introduced by the narrative provision EPA recommends here is the *restoration* of the natural thermal regime, where feasible.

Although some altered rivers, such as the Columbia and Snake, experience similar summer maximum temperatures today as they did historically, there is a big difference between the temperatures that fish experience today versus what they likely experienced historically. Unaltered rivers generally had a high degree of spatial and temporal temperature diversity, with portions of the river or time periods that were colder than the maximum river temperatures. These cold portions or time periods in an otherwise warm river provided salmonids cold water refugia to tolerate such situations. The loss of this temperature diversity may be as significant to salmon and trout in the Columbia and Snake Rivers and their major tributaries as maximum temperatures. Therefore, protection and restoration of temperature diversity is likely critical in order for salmonids to migrate through these waters with minimal thermal stress.

The areas where relatively cold tributaries join the mainstem river and where groundwater exchanges with the river flow (hyporheic flow) are two critical areas that provide cold water refugia for salmonids to escape maximum temperatures. As described in Issue Paper 3 and the *Return to the River* report (2000), alluvial floodplains with a high level of groundwater exchange historically provided high quality habitat that served as cold water refugia during the summer for large rivers in the Columbia River basin (and other rivers of the Pacific Northwest). These alluvial reaches are interspersed between bedrock canyons and are like beads on a string along the river continuum. Today, most of the alluvial floodplains are either flooded by dams, altered through diking and channelization, or lack sufficient water to function as refugia. Efforts to restore these alluvial river functions and maintain or cool down tributary flows will probably be critical to protect this use.

As noted above, EPA recommends that States and Tribes include a natural thermal regime narrative provision to accompany the 20°C numeric criterion. If a State or Tribe chooses to do so, TMDL allocations would reflect the protection, and where feasible, the restoration of the cold water refugia and other aspects of the natural thermal regime described above. If it is impracticable to quantify allocations to restore the natural thermal regime in the TMDL load allocations, then the TMDL assessment document should qualitatively address the human impacts that alter the thermal regime. Plans to implement the TMDL (e.g., watershed restoration plans) should include measures to restore the potential areas of cold water refugia and the natural daily and seasonal temperature patterns. See Section VI.2.B below for a similar discussion regarding TMDLs designed to meet temperature targets exceeding 18°C.

V.1.D. Discussion of Uses and Criteria Presented in Table 4

As discussed in Section V.1.B above, EPA recommends additional uses and criteria that would generally apply during times other than the period of summer maximum temperatures. These additional uses and criteria are intended to provide an added degree of protection for those situations where control of the summer maximum temperature is inadequate to protect these sensitive uses. EPA's recommendations assume that when these uses do occur during the time of summer maximum temperatures, these more sensitive uses and associated numeric criteria would apply.

In many situations, if the summer maximum criteria are attained (e.g., 12°C, 16°C, 18°C, 20°C), EPA expects that temperatures will be low enough due to typical spring warming and fall cooling patterns to support the uses described below. However, in developing this guidance, EPA did not assess data in sufficient detail to determine the extent to which these uses are protected vis-a-vis the summer maximum criterion. With respect to spawning and egg incubation, EPA is most concerned about protecting spawning and egg incubation that occurs during, or soon before or after, the period of summer maximum temperatures (e.g., spring chinook, summer chum, and bull trout spawning that occurs in the mid-to-late summer, and steelhead trout egg incubation that extends into the summer months).

In waters where there is a reasonable basis in concluding that control of the summer maximum criterion sufficiently protects some or all of the uses described below, it may be reasonable not to designate some of all of these specific salmonid uses (i.e., the use will be protected by the summer maximum criterion).

Bull Trout Spawning - 9°C 7DADM

EPA recommends this use for the protection waterbodies used or potentially used by bull trout for spawning, which generally occurs in the late summer-fall in the upper basins (the same waters that bull trout juveniles use for summer rearing). EPA recommends a 9°C maximum 7DADM criterion for this use and recommends that the use apply from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins). Meeting this criterion at the onset of spawning will likely provide protective temperatures for egg incubation (2 - 6°C) that occurs over the winter assuming the typical annual thermal pattern.

Salmon and Trout Spawning, Egg Incubation, and Fry Emergence - 13°C 7DADM

EPA recommends this use for the protection of waterbodies used or potentially used for salmon and trout spawning, egg incubation, and fry emergence. Generally, this use occurs: (a) in spring-early summer for trout (mid-upper reaches); (b) in late summer-fall for spring chinook (mid-upper reaches) and summer chum (lower reaches); and (c) in the fall for coho (mid-reaches), pink, chum, and fall chinook (the latter three in lower reaches). EPA recommends a 13°C maximum 7DADM criterion to protect these life stage uses for salmon and trout and recommends that this use apply from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins). Meeting this criterion at the onset of spawning for salmon and at the end of incubation for steelhead trout will likely provide protective temperatures for egg incubation (6 - 10°C) that occurs over the winter (salmon) and spring (trout), assuming the typical annual thermal pattern.

Steelhead Trout Smoltification - 14°C 7DADM

EPA recommends this use for the protection of waters where and when the early stages of steelhead trout smoltification occurs or may occur. Generally, this use occurs in April and May as steelhead trout make their migration to the ocean. EPA recommends a 14°C maximum 7DADM steelhead smoltification criterion to protect this sensitive use. As described in Table 1, steelhead smoltification can be impaired from exposure to greater than 12°C constant temperatures. The greatest risk to steelhead is during the early stages of smoltification that occurs in the spring (April and May). For the Columbia River tributaries, 90% of the steelhead smolts are typically past Bonneville dam by the end of May (Issue Paper 5, pg 59), indicating that applying this criterion at the mouths of major tributaries to the Columbia River in April and

May will likely protect this use. Applying this criterion to the Columbia River itself is probably unnecessary because the more temperature-sensitive early stages of smoltification occur in the tributaries. If steelhead in the early smoltification process are exposed to higher temperatures than the recommended criterion, they may cease migration or they may migrate to the ocean undeveloped, thereby reducing their estuary and ocean survival.

V.2. Provisions to Protect Water Temperatures That Are Currently Colder Than The Numeric Criteria

One of the important principles in protecting populations at risk for any species is to first protect the existing high quality habitat and then to restore the degraded habitat that is adjacent to the high quality habitat. Further, EPA's WQS regulations recognize the importance of protecting waters that are of higher quality than the criteria (in this case, waters that are colder than numeric temperature criteria). See 40 C.F.R. § 131.12. EPA, therefore, believes it is important to have strong regulatory measures to protect waters with ESA-listed salmonids that are currently colder than EPA's recommended criteria. These waters likely represent the last remaining strongholds for these fish.

Because the temperatures of many waters in the Pacific Northwest are currently higher than the summer maximum criteria recommended in this guidance, the high quality, thermally optimal waters that do exist are likely vital for the survival of ESA-listed salmonids. Additional warming of these waters will likely cause harm by further limiting the availability of thermally optimal waters. Further, protection of these cold water segments in the upper part of a river basin likely plays a critical role in maintaining temperatures downstream. Thus, in situations where downstream temperatures currently exceed numeric criteria, upstream temperature increases to waters currently colder than the criteria may further contribute to the non-attainment downstream, especially where there are insufficient fully functioning river miles to allow the river to return to equilibrium temperatures (Issue Paper 3). Lastly, natural summertime temperatures in Pacific Northwest waters were spatially diverse, with areas of cold-optimal, warm-optimal, and warmer than optimal water. The 18°C and 20°C criterion described in Table 3 and the natural background provisions and use attainability pathways described in Section VI are included in this guidance as suggested ways to address those waters that are warmer than optimal for salmonids. EPA believes it is important, however, for States and Tribes to balance the effects of the warmer waters by adopting provisions to protect waters that are at the colder end of their optimal thermal range.

EPA, therefore, recommends that States and Tribes adopt strong regulatory provisions to protect waterbodies with ESA-listed salmonids that currently have summer maximum temperatures colder than the State's or Tribe's numeric criteria. EPA believes there are several ways a State or Tribe may do this. One approach could be to adopt a narrative temperature criterion (or alternatively include language in its antidegradation rules) that explicitly prohibits more than a de minimis increase to summer maximum temperatures in waters with ESA-listed salmonids that are currently colder than the summer maximum numeric criteria. Another approach could be to identify and designate waterbodies as ecologically significant for temperature and either establish site-specific numeric criteria equal to the current temperatures or prohibit temperature increases above a de minimis level in these waters. States and Tribes following this latter approach should conduct a broad survey to identify and designate such waters within the state (or tribal lands). For non-summer periods it may be appropriate to set a maximum allowable increase (e.g., 25% of the difference between the current temperature and the criterion) for waters with ESA-listed salmonids where temperatures are currently lower than the criteria.

Provisions to protect waters currently colder than numeric criteria can also be important to ensure numeric criteria protect salmonid uses. As discussed in Section V.1.A, the recommended criteria in this guidance are based in part on the assumption that meeting the criteria at the lowest downstream point at which the use is designated will likely result in cooler waters upstream. Cold water protection provisions as described here provide more certainty that this will be true. Further, if a State chooses to protect some or all of the sensitive uses in Table 4 (e.g., spawning) by using only the summer maximum criteria, it may also be necessary to protect waters currently colder than the summer maximum numeric criteria in order to assure that these sensitive uses are protected. Further, as described in Section V.1.B, protecting existing cold water is likely important in river reaches where a 20°C numeric criterion applies to protect salmon and trout migration use.

V.3. Provisions to Protect Salmonids from Thermal Plume Impacts

EPA recommends that States and Tribes add specific provisions to either their temperature or mixing zone sections in their WQS to protect salmonids from thermal plume impacts. Specifically, language should be included that ensures that thermal plumes do not cause instantaneous lethal temperatures; thermal shock; migration blockage; adverse impact on spawning, egg incubation, and fry emergence areas; or the loss of localized cold water refugia. The following are examples from the scientific literature of potential adverse impacts that may result from thermal plumes, and EPA's recommendations to avoid or minimize those impacts.

- Exposures of less than10 seconds can cause instantaneous lethality at 32°C (WDOE, 2002). Therefore, EPA suggest that the maximum temperature within the plume after 2 seconds of plume travel from the point of discharge does not exceed 32°C.

- Thermal shock leading to increased predation can occur when salmon and trout exposed to near optimal temperatures (e.g., 15°C) experience a sudden temperature increase to 26 - 30°C for a short period of time (Coutant, 1973). Therefore, EPA suggests that thermal plumes be conditioned to limit the cross-sectional area of a river that exceeds 25°C to a small percent of the river (e.g., 5 percent or less).

- Adult migration blockage conditions can occur at 21°C (Table 1). Therefore, EPA suggests that the cross-sectional area of a river at or above 21°C be limited to less than 25% or, if upstream temperature exceeds 21°C, the thermal plume be limited such that 75% of the cross-sectional area of the river has less than a de minimis (e.g., 0.25°C) temperature increase.

- Adverse impacts on salmon and trout spawning, egg incubation, and fry emergence can occur when the temperatures exceed 13°C (Table 1). Therefore, EPA suggests that the thermal plume be limited so that temperatures exceeding 13°C do not occur in the vicinity of active spawning and egg incubation areas, or that the plume does not cause more than a de minimis (e.g., 0.25°C) increase in the river temperature in these areas.

VI. Approaches to Address Situations Where the Numeric Criteria are Unachievable or Inappropriate

There are likely to be some streams and rivers in the Pacific Northwest where the criteria recommended in this guidance cannot be attained or where the criteria recommendations would otherwise be inappropriate. The following approaches are available under EPA's regulations to address these circumstances. See 40 C.F.R. Part 131. EPA describes these approaches below and recommends when it believes each approach may be appropriate.

It is important to note that most of these approaches are subject to EPA review and approval on a case-by-case basis (either in the form of a WQS, TMDL, or a 303(d) list approval), and where appropriate, are subject to consultation with the Services and affected Tribes.

VI.1. Alternative Criteria

The following are three possible ways to establish alternative numeric criteria that would apply to a specific location.

<u>VI.1.A. Site-Specific Numeric Criteria that Supports the Use</u>

Under this approach, the State or Tribe would demonstrate that conditions at a particular location justify an alternative numeric criterion to support the designated salmonid use. See 40 C.F.R. § 131.11(b)(1)(ii). One example may be the adoption of a 13°C 7DADM criterion (instead of EPA's recommended 12°C criterion) to protect bull trout rearing use in areas where competition with other fish is minimal and food sources are abundant. Another example may be where there is exceptionally high natural diurnal temperature variation and where the maximum weekly mean temperature is within the optimal temperature range but, because of the high diurnal variation, summer maximum temperatures exceed the State or Tribe's numeric criteria. In this situation, a State or Tribe may choose to develop a site-specific numeric criterion based on a metric other that the 7DADM (e.g., a maximum weekly mean criterion plus a daily maximum criterion). There may be other situations as well when an alternative site-specific criterion would be appropriate. The State or Tribe would need to provide a clear description of the technical basis and methodology for deriving the alternative criterion and describe how it fully supports the designated use when it submits the criterion to EPA for approval. See 40 C.F.R. § 131.11(a).

VI.1.B. Numeric Criteria Based on Estimates of Natural Background Temperatures

Under this approach a State or Tribe could establish numeric criteria based on an estimate of the natural background temperature conditions. This would be another form of site-specific criteria under 40 C.F.R. § 131.11(b)(1)(ii). Natural background temperatures are those that would exist in the absence of human-activities that alter stream temperatures. States or Tribes following this approach may elect to adopt a single numeric criterion for a particular stream segment, such as a lower mainstem river, or adopt a numeric profile (i.e., a range of numbers typically colder in the headwaters and warmer downstream) for a whole watershed or sub-basin.

EPA views numeric criteria that reflect natural background conditions to be protective of salmonid designated uses because river temperatures prior to human impacts clearly supported healthy salmonid populations. Thus, when establishing site-specific numeric criteria in this manner, EPA believes it is unnecessary to modify the use designations. For example, if a State has designated a waterbody as salmon/trout core juvenile rearing use with an associated numeric criterion of 16°C 7DADM and later estimates the natural background temperature is 18°C 7DADM, the 18°C 7DADM could be adopted as a site-specific criterion that fully supports the salmon and trout core juvenile rearing use. A State or Tribe may also want to modify the spatial extent of its various salmonid use designations within the basin if the estimates of natural background provide new information that warrants such revisions. Additionally, at the time the State revises a salmonid use for a waterbody (e.g., designating a salmon/trout migration use), it could choose to establish a numeric criterion based on natural background conditions for that particular waterbody (e.g., 22°C 7DADM), which may be different from the generally applicable numeric criterion to support that use in the State's WQS (e.g., 20°C 7DADM).

States and Tribes following this approach will need to submit any such new or revised numeric criteria to EPA for approval and must include the methodology for determining the natural background condition. See 40 C.F.R. §§ 131.6 & 131.11(a). An alternative to establishing numeric criteria based on natural background conditions as described here is to adopt a narrative natural background provision, which would then be used in CWA section 303(d) listings, TMDLs, and NPDES permits as described in Section VI.2.

VI.1.C. Numeric Criteria In Conjunction with a Use Attainability Analysis

In situations where it appears that the numeric criterion or natural background provision (see Section VI.2) cannot be attained and the appropriateness of the designated use is in question, a State or Tribe could conduct a use attainability analysis (UAA) pursuant to 40 C.F.R. §§ 131.3(g) & 131.10. If it can be demonstrated that the current designated use is not attainable due to one of the factors at 40 C.F.R § 131.10(g), the State or Tribe must then adopt a different use appropriate to that water. See 40 C.F.R. § 131.10(a). In most cases, EPA expects that the appropriate use would be the most protective salmonid use that is attainable. The State or Tribe must then adopt a temperature criterion sufficient to protect that new use. See 40 C.F.R. § 131.11. EPA notes that, in all cases, uses attained since 1975, referred to as "existing uses," must be protected. See 40 C.F.R Part 131.10(h)(1). The new use could be described as a "compromised" or "degraded" salmonid use. It should be noted that a "compromised" or "degraded" level of use may be appropriate during part of the year (e.g., summer), but that an unqualified, healthy salmonid use may be attainable other times of the year and therefore may be the appropriate use then.

Examples of factors at 40 C.F.R. § 131.10(g) that could preclude attainment of the use include: human caused conditions or sources of pollution that cannot be remedied or would cause more environmental damage to correct than to leave in place; dams, diversions or other types of hydrologic modifications that cannot be operated in such a way as to result in the attainment of the use; and controls more stringent than those required by sections 301(b) and 306 of the CWA that would result in substantial and widespread economic and social impact.

Whenever a State or Tribe adopts new or revised designated uses, such as those described here, it is changing its WQS. Therefore, the State or Tribe must make the proposed change available for public notice and comment and must submit the new use and associated criteria, together with the supporting UAA, to EPA for review and approval. See CWA section 303(c)(1) & (c)(2)(A); 40 C.F.R. §§ 131.5 & 131.6. EPA recommends that a UAA seeking to demonstrate human impacts (including dams, diversions, or other hydrologic modifications) that prevent attainment of the current use, should include a full assessment of all possible mitigation measures and their associated costs when demonstrating which mitigation measures are not feasible. EPA's decision to approve or disapprove a use and criteria change associated with a UAA will need to be made on a case-by-case basis, taking into account the information available at the time, and where appropriate, after consultation with the Services and affected Tribes.

VI.2. Use of a State's or Tribe's "Natural Background" Provisions

If it has not already done so, a State and Tribe may wish to consider adopting *narrative* natural background provisions in its WQS that would automatically take precedence over the otherwise applicable numeric criteria when natural background temperatures are higher than the numeric criteria. See 40 C.F.R. § 131.11(b)(2). If adopted by a State or Tribe and approved by EPA, narrative natural background provisions would be the applicable water quality criteria for CWA purposes when natural background temperatures are higher than the numeric criteria and would be utilized in 303(d) listings of impaired waterbodies, TMDLs, and NPDES permits in such situations. As discussed in Section V.1.B above, a State could also consider adopting a specific numeric criterion that reflects natural background temperatures (rather than leave natural background temperatures to case-by-case interpretation). The discussion here, however, assumes that a State or Tribe has not done so and instead has adopted a *narrative* natural background provision and would interpret it when necessary for CWA purposes.

VI.2.A. 303(d) Listings

If it can be demonstrated that a particular waterbody exceeds a temperature numeric criterion due to natural conditions (or natural conditions plus a de mimimis human impact, if a State or Tribe has this allowance in its WQS - see Section V.1.A), then the waterbody need not be listed on a State's or Tribe's 303(d) list. Such waterbodies would not be considered impaired because they would be meeting the narrative natural background provisions of the WQS. These waterbodies should be identified as an attachment to a State's or Tribe's section 303(d) list submission to EPA along with the demonstration that these waters do not exceed the natural background provision.

For situations where waterbodies exceed the applicable numeric criteria due to a combination of apparent natural background conditions and known or suspected human impacts (above a de minimis impact level, if applicable), it would be appropriate to list those waters on the 303(d) list because the waters would be exceeding the narrative natural background provision because of the human impacts. The TMDL process, described below, will provide the opportunity to distinguish the natural sources from the human caused sources.

VI.2.B. TMDLs

A State's or Tribe's narrative natural background provisions can be utilized in TMDLs to set water quality targets and allocate loads when natural background conditions are higher than the otherwise applicable numeric criteria. When doing so, estimated temperatures associated with natural background conditions would serve as the water quality target for the TMDL and would be used to set TMDL allocations. Thus, the TMDL would be written to meet the WQS natural background provision, and the load reductions contemplated by the TMDL would be equivalent to the removal of the human impacts (or all but de minimis human impacts, if applicable). It should be noted that if a State or Tribe has a de minimis temperature increase allowance above natural background temperatures (see Section V.1.A), the TMDL allocations should be based on attaining the natural background temperature plus the de minimis temperature allowance (e.g., natural background temperature plus 0.25°C).

When estimating natural background conditions, States and Tribes should use the best available scientific information and the techniques described in Section VI.3 below. For TMDLs, this usually includes temperature models. Those human impacts that cannot be captured in a model (e.g., loss of cooling due to loss of hyporheic flow, which is water that moves between the stream and the underlying streambed gravels) should be identified in the TMDL assessment document (i.e., supporting material to the TMDL itself) along with rough or qualitative estimates of their contribution to elevated water temperatures. Estimates of natural conditions should also be revisited periodically as our understanding of the natural system and temperature modeling techniques advance.

When using natural background maximum temperatures as TMDL targets and to set TMDL allocations, the TMDL assessment document should assess other aspects of the natural thermal regime including the spatial extent of cold water refugia (which, generally are defined as waters that are ≥2°C colder than the surrounding water), the diurnal temperature variation, seasonal temperature variation (i.e., number of days at or near the maximum temperature), and shifts in the annual temperature pattern. Findings from this assessment should be integrated into the TMDL and its allocations to the extent possible. For example, if possible, TMDL allocations should incorporate restoration of the diurnal and seasonal temperature regime and cold water refugia that reflect the natural condition. If it is impracticable to address these impacts quantitatively through allocations, then the TMDL assessment document should qualitatively discuss the human activities that modify these aspects of the natural thermal regime. Plans to implement the TMDL should include measures to restore and protect these unique aspects of the natural condition.

EPA believes it is particularly important for the TMDL itself or the TMDL assessment document to address the above aspects of the natural thermal regime for waterbodies where the natural background maximum 7DADM temperature exceeds 18°C and where the river has significant hydrologic alterations (e.g., dams and reservoirs, water withdrawals, and/or significant river channelization) that have resulted in the loss of temperature diversity in the river or shifted the natural temperature pattern. For example, there may be situations where the natural background maximum temperatures exceed 18°C, but historically the exposure time to maximum temperatures was limited due to the comparatively few number of hours in a day that the water reached these temperatures, the comparatively few number of days that reached these temperatures, and plentiful cold water refugia from cold tributary flows and hyporheic flow in alluvial floodplains where salmonids could avoid the maximum water temperatures.

If human impacts as identified at 40 C.F.R. 131.10(g) are determined to prevent attainment of the natural background conditions, the State or Tribe should follow the UAA process described in Section VI.1.C above and revise the use and adopt numeric criteria that would support a revised use. This new numeric criteria, if approved by EPA, would then be the temperature target in the TMDL and used to set load allocations.

Before determining that some of the human impacts preclude use attainment and pursuing a UAA, EPA Region 10 encourages States to develop and begin implementing TMDLs that reflect the applicable numeric criteria or natural background provisions and allow some time for implementation to proceed. EPA Region 10 encourages this approach because it is often the case that at the time a TMDL is developed there is little information on all the possible implementation measures and their associated costs, which may be important to justify a UAA. Further, after feasible implementation measures are completed, there will be better information as to what is the actual attainable use and associated water temperatures. If information is available at the time, however, it is possible for a State to conduct a UAA concurrently with the TMDL development process and, if appropriate, to revise the designated use and adopt new applicable numeric criteria for use when establishing the TMDL.

VI.2.C. NPDES Permits

When a permitting authority is establishing a temperature water quality-based effluent limit for an NPDES source, it must base the limit on the applicable water quality standards, which could be the numeric criteria or, if applicable, the narrative natural background provision. See 40 C.F.R. § 122.44(d)(1). EPA expects that, in most cases, the natural background temperature will be interpreted and expressed for the first time in a TMDL, but it is possible for the natural background temperature to be determined outside the context of a TMDL, although this would be unusual given the complexities involved in estimating natural background temperatures.

VI.3. Overview of Methods to Estimate Natural Background Temperatures

There are a number of different ways of estimating natural background temperature conditions for the purposes of either adopting a site-specific criterion (see Section VI.1.B) or interpreting a narrative natural background provision (see Section VI.2). These include: (1) demonstrating that current temperatures reflect natural background conditions, (2) using a non-degraded reference stream for comparison, (3) using historical temperature data, (4) using statistical or computer simulation models, and (5) assessing the historical distribution of salmonids. There may be other ways as well. Each approach has its strengths and weaknesses and therefore may or may not be most appropriate for a given situation. Moreover, all of these approaches have uncertainty, which should be quantitatively described where possible. EPA encourages the use of a combination of approaches to estimate natural background temperatures, where feasible. Below is an overview of the five approaches listed above.

Demonstrating That Current Temperatures Reflect Natural Background Conditions

Under this approach, the past and present human activities that could impact the river temperatures are documented and a technical demonstration is made that the human activities do not currently impact temperatures. This approach is most applicable to non-degraded watersheds (e.g., state and national parks, wilderness areas, and protected state and national lands). These watersheds can be used as “reference” streams for estimating the natural background temperatures of degraded streams (see below). If there is a small human impact on temperatures, it may also be possible to estimate the human impact and subtract it from current temperatures to calculate the natural background temperatures.

Comparisons to a Reference Stream

It is often reasonable to assume that the natural background temperatures of a thermally degraded stream are similar to that of a non-degraded stream, so long as the location, landscape context, and physical structure of the stream are sufficiently similar. The challenge to this approach is finding a reference stream that is of similar location, landscape context, and physical structure. Because large rivers are unique and most in the Pacific Northwest have been significantly impacted by human activities, this approach is most applicable to smaller streams where a reference stream with current temperatures at natural background conditions exist.

Historical Data

For some rivers, historical temperature data are available that reflect temperatures prior to human influences on the river's temperature regime, and can be used as an estimate of natural background temperatures. Factors that lend uncertainty to historic temperature data are the uncertain nature of the quality of the data and whether or not humans affected temperature prior to data collection. Further, historical temperature data often do not adequately capture the spatial and/or temporal variability in stream temperature due to limited spatial or temporal sampling. Historical data may be useful, however, for verifying estimates of modeled natural background temperatures.

Temperature Models

Two major methods have been commonly used for water quality modeling in the United States over the last 20 years: 1) statistical models, which are based on observed relationships between variables and are often used in conjunction with measurements from a reference location, and 2) process-based models, which attempt to quantify the natural processes acting on the waterbody. Process-based models are often employed when no suitable reference locations can be identified.

Statistical models, also referred to as empirical models, estimate the thermal conditions of streams by using statistics to find correlations between stream temperature and those landscape characteristics that control temperature (e.g., elevation, latitude, aspect, riparian cover, etc.). The equations in statistical models describe the observed relationships in the variables as they were measured in a specific location. If the specific location is a non-degraded reference stream, then the model can be used to estimate natural background conditions in degraded streams. Statistical models have the advantage of being relatively simple, as they rely on general data and statistics to develop correlations.

The comparability between the reference waterbody where the statistical correlations are generated and the assessment waterbody strongly affects the applicability of statistical models. Uncertainties in statistical model results increase with increasing dissimilarity between the landscape characteristics of the reference and assessment water bodies. Uncertainties also increase when models do not include landscape characteristics that control important processes affecting the water temperature. For these reasons, statistical models are best suited for small headwater streams or for generalized predictions across a large landscape.

Process models, also referred to as simulation models, are based on mathematical characterizations of the current scientific understanding of the critical processes that affect water temperature in rivers. The equations are constructed to represent the observed or expected relationships and are generally based on physical or chemical principles that govern the fate and transport of heat in a river (e.g., net heat flux from long-wave radiation, direct short wave radiation, convection, conduction, evaporation, streamside shading, streambed friction, and water's back radiation) (Bartholow, 2000).

Estimating water temperature with a process model is generally a two-step process. As a first step, the current river temperatures are estimated with the input parameters (e.g., amount of shade provide by the canopy and river depth, width, and flow) reflecting current conditions and the model error is calculated by comparisons of the model estimate to actual temperature measurements. The second step involves changing the model input parameters to represent natural conditions, which results in a model output that predicts the natural background conditions. In recent years, increases in computer processing power have led to the development of distributed process models, which incorporate a high degree of spatial resolution. These models use Geographical Information Systems (GIS), remotely-sensed data, and site-specific data to vary the model's input parameters at different locations in the waterbody or the landscape.

Unlike statistical models, process models do not rely upon data from reference locations, so they can be used for rivers that have no suitable natural reference comparisons available. Thus, process models are well suited for estimating natural conditions for larger streams and rivers. Although powerful, process models are by no means infallible. Errors can arise when there are locally important factors that the model does not address, or when there is a great deal of uncertainty in input parameters that strongly influence the model results.

In addition to estimating natural background conditions, process-based models are useful for understanding the basic mechanisms influencing water temperature in a watershed, understanding the relative contributions from different sources at different locations, understanding cumulative downstream impacts from various thermal loads, performing "what if" scenarios for different mitigation options, and setting TMDL allocations.

Historical Fish Distributions

Maps of historic salmonid distributions and their time of use can provide rough estimates of natural background temperatures. Where and when salmonids existed historically likely provided temperatures suitable for salmonids and, as described in this guidance, we have a fairly good understanding of suitable temperatures for various life stages of salmonids.

VII. Using EPA's Guidance to Change Salmonid Use Designations

The States of Idaho, Oregon, Washington and Pacific Northwest Tribes with WQS currently have salmonid use designations that are less spatially and temporally specific than those recommended in Section V.1 of this guidance. For instance, several States and Tribes employ broad salmonid use designations (e.g., migration, rearing, spawning) that apply generally to an entire basin or watershed. EPA's recommendations in Section V.1 are intended to assist States and Tribes with broad use designations to more precisely define when and where the different salmonid uses currently occur or may potentially occur within a basin.

For example, at the present time, a State may have a spawning use designated for an entire basin (or large waterbody), but not specify the waterbody segments or times of year to which that use designation should apply. After considering information that indicates where and when spawning currently occurs or may potentially occur, that State might decide that only certain locations and times in the basin should be designated for spawning. This same situation may also occur in the context of rearing and migration uses.

The intent of EPA's recommendations is to encourage States and Tribes, through these types of use refinements, to adopt a suite of interdependent salmonid uses. This suite of uses, in essence, would function as a single aquatic life use designation for the protection, at all life stages, of a sustainable salmonid population. Consequently, EPA believes that, as a general matter, use designations within a basin that reflect, at the appropriate times and places, the complete suite of uses to protect healthy salmonid populations at all life stages would fully protect the CWA section 101(a)(2) aquatic life uses. EPA, therefore, would not expect a UAA to accompany such use refinements as long as the overall sustainable salmonid population use is still being protected. See 40 C.F.R. § 131.10(k). It should be noted, however, that these types of use refinements are changes to a State's of Tribe's WQS and therefore require public notice and review and EPA approval.

VIII. Temperature Limits for NPDES Sources

Section 301(b)(1)(C) of the CWA requires the achievement of NPDES effluent limitations as necessary to meet applicable WQS. EPA Region 10's general practice is to require that numeric criteria be met at end-of-pipe in impaired waterbodies (i.e., those that exceed water quality criteria). However, EPA Region 10 believes that in some situations numeric criteria end-of-pipe effluent limits for temperature may not be necessary to meet applicable WQS and protect salmonids in impaired waters. This is because the temperature effects from point source discharges generally diminish downstream quickly as heat is added and removed from a waterbody through natural equilibrium processes. The effects of temperature are unlike the effects of chemical pollutants, which may remain unaltered in the water column and/or accumulate in sediments and aquatic organisms. Further, temperature impairments in Pacific Northwest waters are largely caused by non-point sources. However, there may be situations where numeric criteria (or near numeric criteria) end-of-pipe effluent limits would be warranted, such as where a point source heat discharge is significant relative to the size of the river.

If a facility discharging heat into an impaired waterbody is seeking an effluent limit that is different than end-of-pipe numeric criteria, it should undertake a comprehensive temperature study. EPA recommends that regulatory authorities develop guidance on the content of these studies and on how alternative effluent limits may be developed that protect salmonids. EPA recommends that a temperature study, at a minimum, should consist of the following:

- A detailed engineering evaluation of sources of heat and possible measures to eliminate/reduce the heat sources and/or mitigate the effect of the heat sources. This could, for example, take the form of an engineering analysis of manufacturing processes or an investigation of sources of heat into publically-owned treatment plants. The engineering evaluation should include cost estimates for the possible temperature reduction measures.

- A modeling evaluation to determine a preliminary temperature effluent limit that meets the numeric criterion for the waterbody (or natural background temperature if applicable - see Section VI.2.C). For instance, it may be appropriate to use a simple energy balance equation (U.S. EPA, 1996) to calculate an effluent temperature that would ensure any downstream temperature increase above the numeric criterion (or natural background temperature) is de minimis (e.g., less than 0.25°C) after complete mixing. This approach assumes the State's or Tribe's WQS includes a de minimis temperature allowance as described in Section V.1.A. When using this approach, EPA recommends that the upstream water temperatures be assumed to be at the numeric criterion (or natural background temperature) and that a river flow be used that minimizes the percentage of the flow utilized for mixing purposes (e.g., 25% of 7Q10). The preliminary temperature effluent limit using this method should not exceed the current effluent temperature. In some situations it may be appropriate to utilize more complex modeling than described here (e.g., waters with multiple point source impacts).

- An evaluation of localized impacts of the thermal plume on salmonids based on plume modeling. The physical characteristics of the thermal plume (e.g., a 3-dimensional profile of temperatures) can be estimated using a near-field dilution model and adequate input data to run the model (e.g., river and effluent temperatures and flows). The preliminary effluent temperature derived from above (i.e., the effluent temperature derived from the energy balance equation or the current effluent temperature, whichever is lower) should be used in the model along with the current river temperature and flow for the seasons of concern. The preliminary effluent limit should be lowered, if necessary, to ensure that the localized adverse impacts on salmonids described in Section V.3 are avoided or minimized.

The results of these evaluations should be used to assist in the development of the final permit effluent limit in waters where a temperature TMDL has yet to be completed. Modeling evaluations, such as those described above, should be used in temperature TMDLs to help set wasteload allocations that can be used as temperature limits in NPDES permits. It may not be practicable, however, to complete near-field plume modeling for some or all point sources in large-scale temperature TMDLs. In these situations, the TMDL should indicate that the thermal plume modeling be done during permit development, which may result in an effluent limit lower than the TMDL wasteload allocation.

EPA Region 10 also believes that water quality trading may hold some promise to meet temperature WQS in a cost-effective manner that is beneficial for salmonids. In particular, a point source may be able to seek trades with non-point sources as a mechanism to meet its NPDES obligations. For example, a point source may help secure non-point controls beyond minimum state requirements, such as re-vegetation of a river's riparian zone, and use those temperature reductions to help meet its temperature reduction obligations. EPA encourages the use of this potentially valuable approach to help attain temperature WQS.

IX. The Role of Temperature WQS in Protecting and Recovering ESA-Listed Salmonids and Examples of Actions to Restore Suitable Water Temperatures

EPA Region 10 and the Services believe that State and Tribal temperature WQS can be a valuable tool to protect and aid in the recovery of threatened and endangered salmonid species in the Pacific Northwest. The following are three important ways that temperature WQS, and measures to meet WQS, can protect salmonid populations and thereby aid in the recovery of these species. The first is to protect existing high quality waters (i.e., waters that currently are colder than the numeric criteria) and prevent any further thermal degradation in these areas. The second is to reduce maximum temperatures in thermally degraded stream and river reaches immediately downstream of the existing high quality habitat (e.g., downstream of wilderness areas and unimpaired forest lands), thereby expanding the habitat that is suitable for coldwater salmonid rearing and spawning. The third is to lower maximum temperatures and protect and restore the natural thermal regime in lower river reaches in order to improve thermal conditions for migration.

The following are examples of specific on-the-ground actions that could be done to meet temperature WQS, protect salmonid populations and also aid in the recovery of threatened and endangered salmonid species. Logically, these example actions are oriented toward reversing the human activities that can contribute to excess warming of river temperatures described in Section IV.2. See Issue Paper 3, Coutant (1999), and Return to the River (2000) for more detailed discussion. EPA encourages and hopes to help facilitate these types of actions and recognizes that collaborative efforts with multiple stakeholders holds the most promise to implement many of these measures.

- Replant native riparian vegetation
- Install fencing to keep livestock away from streams
- Establish protective buffer zones to protect and restore riparian vegetation
- Reconnect portions of the river channel with its floodplain

- Re-contour streams to follow their natural meandering pattern
- Increase flow in the river derived from more efficient use of water withdrawals
- Discharge cold water from stratified reservoirs behind dams
- Lower reservoirs to reduce the amount of shallow water in "overbank" zones
- Restore more natural flow regimes to allow alluvial river reaches to function
- Restore more natural flow regimes so that river temperatures exhibit a more natural diurnal and seasonal temperature regime

EPA and the Services acknowledge that efforts are underway on the part of some landowners, companies, non-profit organizations, tribes, local and state governments, and federal agencies in the Pacific Northwest to take actions to protect and restore suitable temperatures for salmonids and improve salmonid habitat generally. A few examples of broad-scale actions to improve temperatures for salmonids are: the Aquatic Conservation Strategy of the Northwest Forest Plan (federal lands); the State of Washington's forest protection regulations; and timber company Habitat Conservation Plans (HCPs), particularly the Simpson HCP, which was done concurrent with a temperature TMDL. Additionally, there are small-scale projects, which are too numerous to list here (e.g., tree plantings, fencing, and re-establishing the natural meandering channel of small streams), that have already contributed or will contribute to improved thermal conditions for salmonids. These efforts represent a good direction and start in the process of restoring stream temperatures in the Pacific Northwest.

EPA and the Services believe it is important to highlight these examples of on-the-ground actions to recognize their contribution to improving water temperatures, to demonstrate their feasibility, and to provide a model for others to take similar actions.

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Brown AND Caldwell

Prepared for

Perpetua Resources Idaho, Inc., Valley County, Idaho

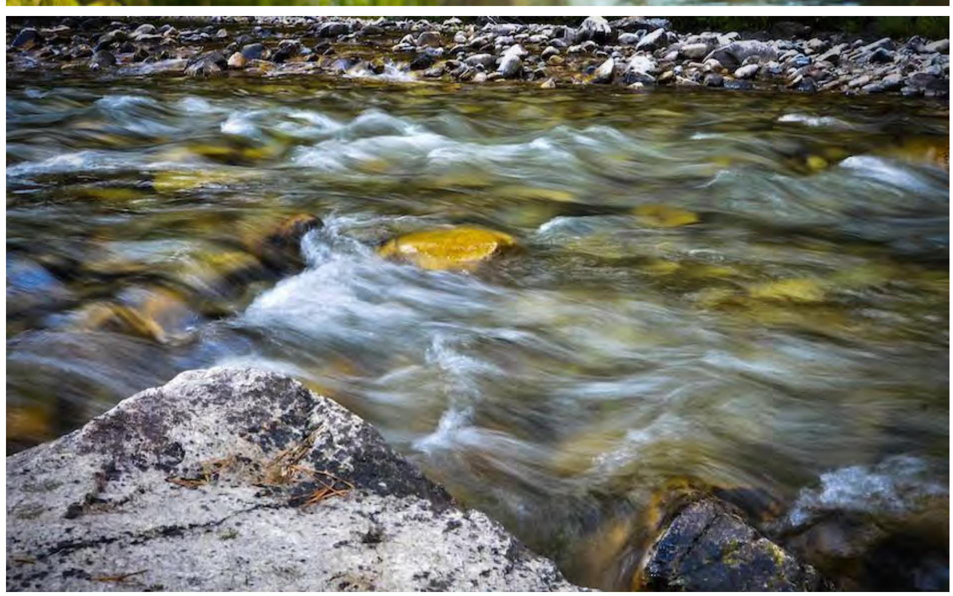
Perpetua Resources

FINAL

Stream and Pit Lake Network Temperature Model

Refined Proposed Action (ModPRO2) Report

July 2021



FINAL

Stibnite Gold Project
Stream and Pit Lake Network Temperature Model
Refined Proposed Action (ModPRO2) Report

Prepared for

Perpetua Resources Idaho, Inc.

Valley County, Idaho

July 2021

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Table of Contents

Brown AND Caldwell

List of Figures

List of Tables

List of Abbreviations

°C	degree Celsius
°F	degree Fahrenheit
Avg	average
BC	Brown and Caldwell
BT	bull trout
cms	cubic meters per second
CS&S	Chinook salmon, steelhead
CW	Cold Water
DO	dissolved oxygen
EFMC	East Fork Meadow Creek
EFSFSR	East Fork South Fork Salmon River
EIS	environmental impact statement
EOY	End of Year
EPA	United States Environmental Protection Agency
FA	functioning acceptably
FC	Fiddle Creek
FR	functioning at risk
FS	Feasibility Study
GC	Garnet Creek
GLM	General Lake Model
GMS	growth media stockpile
IDEQ	Idaho Department of Environmental Quality
Inc	incubation
IPDES	Idaho Pollutant Discharge Elimination System
Max	maximum
MC	Meadow Creek
MDAT	Maximum Daily Average Temperature
MDMT	Maximum Daily Maximum Temperature
Midas Gold	Midas Gold Idaho, Inc.
Migr	Migration
ModPRO	Modified Plan of Restoration and Operations
ModPRO2	Refined Modified Plan of Restoration and Operations
MWMT	Maximum Weekly Maximum Temperature
NA	No Action
N/A	not applicable
NEPA	National Environmental Policy Act
PA	Proposed Action
Perpetua Resources	Perpetua Resources Idaho, Inc.
PRO	Plan of Restoration and Operations

Project	Stibnite Gold Project
RC	Rabbit Creek
Rear	rearing
Rio ASE	Rio Applied Science and Engineering
SC	season cold
SC	Sugar Creek
SGP	Stibnite Gold Project
SHSM	Stibnite Hydrologic Site Model
SPLNT	stream and pit lake network temperature
Spwn	spawning
SS	Salmonid Spawning
PRO	Plan of Restoration and Operations
TSF	tailings storage facility
TSF-B	tailings storage facility buttress
UR	unacceptable risk
USFS	United States Forest Service
WEC	West End Creek
WE PL	West End pit lake
WTP	Water Treatment Plant
WW	Warm Water
YPP	Yellow Pine pit
YPPL	Yellow Pine pit lake

Executive Summary

Perpetua Resources Idaho, Inc. (Perpetua Resources), formerly Midas Gold Idaho, Inc. (Midas Gold) proposes to redevelop portions of the Stibnite Mining District in the headwaters of the East Fork of the South Fork of the Salmon River (EFSFSR), Valley County, central Idaho as outlined in the Plan of Restoration and Operations (PRO; Midas Gold 2016) for the Stibnite Gold Project (SGP or Project). Brown and Caldwell (BC) has prepared this report to summarize the results of Perpetua Resources Stream and Pit Lake Network Temperature (SPLNT) modeling of the Modified Proposed Action 2 (ModPRO2) Alternative (Perpetua Resources 2021). The ModPRO2 is Perpetua Resources refined modified proposed action and was developed to further reduce potential environmental impacts of the Stibnite Gold Project (SGP) in alignment with Perpetua Resources Core Values as set out in the PRO (Midas Gold 2016; Section 2), Conservation Principles (Midas Gold 2016; Section 2), its Sustainability Goals (Midas Gold 2016; Section 2.4) and its Environmental Goals (Midas Gold 2016; Section 6.2).

The PRO was submitted to the United States Forest Service (USFS) and the Idaho Department of Lands in September 2016 and deemed complete by the USFS in December 2016. Concurrent with preparing the environmental impact statement (EIS), federal and state permitting, and agency and stakeholder consultations, Perpetua Resources has advanced the Project's engineering design to the Canadian National Instrument 43-101 Feasibility Study level. Some Project elements have changed relative to the PRO and the other alternatives in the Draft EIS (USFS 2020) as designs have proceeded and additional information has been learned. The ModPRO2 is the refined Modified PRO (ModPRO) Alternative and results from the culmination of these analyses and a suite of mitigation measures designed to improve water quality and restore the Project Area to an improved condition. The ModPRO2 presents an alternative with a smaller footprint and reduced environmental impacts compared to the PRO and the ModPRO. The ModPRO2 is intended to be included in the Final EIS as the further refined Alternative 2 to replace Alternative 2 (ModPRO) as described in the Draft EIS. This is consistent with the National Environmental Policy Act (NEPA); per 40 CFR 1503.4, an agency preparing a Final EIS has the option to "Modify alternatives including the proposed action" (40 CFR 1503.4(a)(1).

The ModPRO2 incorporates information derived from agency and public scoping for Perpetua Resources original Proposed Action (the PRO), the alternatives development process, baseline data collection and analysis, and predictive modeling (hydrologic, geochemical, water quality, stream temperature, and air quality). SPLNT modeling results were used to support ModPRO2 project refinements and simulate environmental effects. The ModPRO2 was also informed by Perpetua Resources interactions with the public; federal, state, and local governments; Native American tribes; and other Project stakeholders, and considers comments submitted during the public comment period for the Draft EIS.

Mining methods, ore processing, exploration activities, water management, and supporting features including structures, access and haul roads, and infrastructure remain identical to the PRO and/or the ModPRO or are slightly modified. In all cases, these proposed refinements address environmental concerns raised or identified by various sources or through the effects analysis of the Draft EIS and are targeted at addressing them accordingly. These refinements align with the purpose and intent of the National Environmental Policy Act.

The ModPRO2 includes additional refinements beyond the ModPRO that aim to lower stream temperatures and improve water quality. Changes relative to ModPRO include changes to the

QUAL2K model configuration to represent changes to the mine plan, wider zones of riparian plantings with taller plants and earlier planting schedules, revised baseflow rates based on the Stibnite Hydrologic Site Model, a General Lake Model (GLM) for Stibnite Lake, and incorporation of treated effluent discharge from the water treatment plant.

The SPLNT Model was developed to simulate temperatures under existing conditions and the No Action (NA) Alternative and to predict changes in stream and pit lake temperatures associated with Project Alternatives. The SPLNT Model was developed using two separate software packages: QUAL2K for stream temperature modeling and the GLM for simulating pit lakes. QUAL2K simulates stream temperature upstream and downstream of the pit lakes and uses GLM-simulated pit lake temperature as an input for the segment downstream of each lake. The steady-state QUAL2K component of the SPLNT Model was designed to simulate (1) low-flow, maximum weekly temperature summer conditions (July through August) and (2) low-flow, maximum weekly temperature fall conditions (September through October) to allow for an assessment of mining impacts based on thermal criteria applicable to these conditions. Appendix A of this report summarizes the development of the SPLNT Model and further details can be found in the SPLNT Existing Condition Report (Brown and Caldwell [BC] 2018) and the SPLNT Proposed Action Report (BC 2019a).

The SPLNT Existing Conditions Report (Brown and Caldwell [BC} 2018) presents the observed flows and temperatures for the two-week periods centering around the representative dates of the maximum weekly summer condition (July 29, 2016) and the maximum weekly fall condition (September 24, 2014). The meteorology and stream hydrology measured on these specific days provide the inputs to the SPLNT model. For existing conditions and the NA Alternative, the model inputs are the same. To evaluate Project Alternatives, the stream baseflows are adjusted based on a percent difference calculated by comparing SGP hydrologic model simulations of NA and each Project Alternative. The meteorology for the evaluations is not altered. A third condition was requested by the review agencies during development of the Proposed Action (PA) models to represent mean August conditions for use in fish habitat occupancy models.

The ModPRO2 offers improvements in stream temperatures relative to the other Project Alternatives. The following general observations can made:

- Simulated temperature effects tend to be more pronounced when comparing maximum temperatures for the maximum weekly summer condition followed by either maximum temperatures for the fall condition or average conditions for the summer condition. The simulated averages for the maximum weekly fall condition are the least affected by the Project and are similar to NA across the SPLNT study area.
- Piping diverted low flows results in fully shaded conveyances that result in temperatures that are similar to, and sometimes lower than NA, depending on the degree of shade present for the NA.
- Improving the riparian planting plan by planting wider buffers, increasing the percentage of taller tree species, including enhanced reaches, and planting earlier in the mine life increases shade and reduces stream temperatures.
- Including Stibnite Lake on the Yellow Pine pit backfill reduces diurnal temperature variation and maximum temperatures.
- The ModPRO2 results in improved stream temperatures relative to the ModPRO, PA, and EFSFSR tailings storage facility (TSF) alternatives (BC 2019b and 2019c). Once the tunnel is removed, maximum stream temperatures in the summer are at or below NA everywhere in the system except on top of the TSF and just upstream of Stibnite Lake. While temperatures are higher than NA on the TSF in the early part of post closure, these reaches are not accessible for

Chinook salmon or steelhead spawning. Once Meadow Creek mixes with East Fork Meadow Creek, maximum stream temperatures are consistently below NA.

- Simulated maximums for the ModPRO2 at the model terminus (EFSFSR below Sugar Creek) are within 1 degree Celsius (°C) of NA for each mine year.
- Under the ModPRO2, temperatures would return to NA when Tamarack Creek enters the system (2.2 river miles downstream of the Sugar Creek confluence) and would not be more than 1°C higher than NA in the EFSFSR downstream of the Project Area.

Section 1

Background and Purpose

Perpetua Resources Idaho, Inc. (Perpetua Resources), formerly Midas Gold Idaho, Inc. (Midas Gold) proposes to redevelop portions of the Stibnite Mining District in the headwaters of the East Fork of the South Fork of the Salmon River (EFSFSR), Valley County, central Idaho as outlined in the Plan of Restoration and Operations (PRO; Midas Gold 2016) for the Stibnite Gold Project (SGP or Project). Brown and Caldwell (BC) has prepared this report to summarize the results of Perpetua Resources Stream and Pit Lake Network Temperature (SPLNT) modeling of the Modified Proposed Action 2 (ModPRO2) Alternative (Perpetua Resources 2021). The ModPRO2 is Perpetua Resources refined modified proposed action and was developed to further reduce potential environmental impacts of the Stibnite Gold Project (SGP) in alignment with Perpetua Resources Core Values as set out in the PRO (Section 2), Conservation Principles (PRO Section 2), its Sustainability Goals (PRO Section 2.4) and its Environmental Goals (PRO Section 6.2).

The PRO was submitted to the United States Forest Service (USFS) and the Idaho Department of Lands in September 2016 and deemed complete by the USFS in December 2016. Concurrent with preparing the environmental impact statement (EIS), federal and state permitting, and agency and stakeholder consultations, Perpetua Resources has advanced the Project's engineering design to the Canadian National Instrument 43-101 Feasibility Study level. Some Project elements have changed relative to the PRO and the other alternatives in the Draft EIS (USFS 2020) as designs have proceeded and additional information has been learned. The ModPRO2 is the refined ModPRO (ModPRO) Alternative and results from the culmination of these analyses and a suite of mitigation measures designed to improve water quality and restore the Project Area to an improved condition. The ModPRO2 presents an alternative with a smaller footprint and reduced environmental impacts compared to the PRO and the ModPRO. The SPLNT modeling results presented here were used to support ModPRO2 project refinements and simulate environmental effects. The ModPRO2 is intended to be included in the Final EIS as the further refined Alternative 2 to replace Alternative 2 (ModPRO) as described in the Draft EIS. This is consistent with National Environmental Policy Act (NEPA); per 40 CFR 1503.4, an agency preparing a Final EIS has the option to "*Modify alternatives including the proposed action*" (40 CFR 1503.4(a)(1).

Perpetua Resources has conducted detailed modeling studies to assess existing and future hydrology, water temperatures, and water quality associated with the Project. Broadly, the objectives of the modeling efforts are to predict the potential for groundwater and surface water impacts from the open pits, backfill, and tailings storage facility (TSF) and TSF buttress associated with each of the Project Alternatives. Numerical predictions are necessary to support analyses of the Proposed Action (PA) and alternatives in the EIS currently being prepared by USFS and to assess compliance with water quality criteria.

Stream and Pit Lake Network Temperature (SPLNT) modeling in support of the PRO and Draft EIS Alternatives is documented in the SGP SPLNT Model Existing Conditions Report (Brown and Caldwell [BC], 2018b), the SGP SPLNT Proposed Action Report (BC, 2019a), the SGP East Fork South Fork Salmon River TSF/DRSF Alternative Modeling Report (BC, 2019b), and the SGP Modified PRO Alternative Modeling Report (BC, 2019c). Application of the four tools that comprise the SPLNT model, data sources, methods, and assumptions have remained consistent across the alternatives described in the Draft EIS and ModPRO2.

1.1 Purpose and Scope

The SPLNT model was designed to provide important inputs to the environmental consequences analyses being completed for the EIS and preparation of the biological assessment for the Section 7 consultation under the Endangered Species Act for Snake River spring/summer chinook salmon (Chinook salmon; Oncorhynchus tshawytscha), Snake River Basin steelhead (steelhead; O. mykiss), and Columbia River bull trout (bull trout; Salvelinus confluentus).

Because the SGP has the potential to affect instream conditions such as stream flows, groundwater interaction, and stream shading, the stream water temperature regime may also be altered. BC developed a SPLNT model for the Project to evaluate the potential changes that may occur as a result of the proposed mining and subsequent reclamation.

In the first phase of SPLNT modeling, the existing conditions model was built and calibrated to observed data to demonstrate the model's suitability for predictive simulations of dissolved oxygen (DO) (pit lakes only) and temperature (streams and pit lakes) (BC 2018). The SPLNT Existing Conditions Modeling Report documented the model fit using statistical and graphical summaries (BC 2018). The approach and methods were then used to complete the second phase of modeling to simulate changes that would occur as a result of the PA (with and without pipes) and to compare those to a No Action (NA) scenario based on the existing conditions model; both the PA and NA alternatives are described in BC 2019a. The NA Alternative models are similar to the existing conditions models with some modifications to methodology based on input from review agencies. The NA Alternative models were developed to provide a direct comparison to the PA Alternative models, and both are documented in BC 2019a. Appendix A provides more detail about how the SPLNT existing conditions and NA Alternative models were developed.

A third phase of modeling was conducted to evaluate additional alternatives to the PA. One alternative included moving the TSF to the upper drainage area of the EFSFSR, and this alternative was named EFSFSR TSF (Alternative 3 in the Draft EIS [USFS 2020]). Another alternative was the ModPRO which retained the TSF in the Meadow Creek drainage and included low flow pipes in diversion channels to shade water and cool temperatures, among other Project improvements (Alternative 2 in the Draft EIS [USFS 2020]). The temperature results of these alternatives were compared to both the PA and NA in the Modified PA Modeling Report (BC 2019c), and these four alternatives were included in the Draft EIS (USFS 2020).

This report describes the fourth phase of SPLNT modeling that was performed as a result of the Feasibility Study (FS) and a desire by Perpetua Resources to identify mitigation measures that would further improve water quality beyond the ModPRO; this refinement to the ModPRO alternative is called ModPRO2. While the ModPRO included several components that improved water quality during some periods and in some locations relative to the PA, additional Project elements have been simulated in the ModPRO2 and adopted for the FS to further improve water quality.

1.2 Importance of Water Temperature to Aquatic Habitat

Water temperature affects biological activity of aquatic organisms such as fish. For example, higher temperatures increase metabolic rates and decrease the solubility of DO, reducing its availability to aquatic organisms (Forney et al. 2013). Because of this effect, a stream's peak temperature in the summer is often a critical characteristic of habitat quality for various aquatic life (Forney et al. 2013). Water temperature studies in the Pacific Northwest have specifically focused on analyzing flow and temperature data observed during summer months (David Duncan and Associates 2002; Tetra Tech 2014).

Previously collected temperature data from the region have shown that even unaltered reference stream temperatures may exceed temperature criteria during the late spring spawning period for salmonids (April through June), peak summer (July and August), and early fall spawning (September) (Shumar and de Varona 2009). Outside these periods, stream temperatures are rarely a problem for spawning and migration activities (Shumar and de Varona 2009, Scranton et al. 2015).

Simulated water temperatures derived from the SPLNT models for the Project alternatives and NA scenario are compared to thermal criteria based on indicators for Chinook salmon, steelhead, and bull trout. Specifically, the SPLNT model output is used to evaluate the following:

- Achievement of USFS stream temperature criteria
- Achievement of Idaho Department of Environmental Quality (IDEQ) stream temperature criteria
- Effects of discharges permitted under the Idaho Pollutant Discharge Elimination System
- Temperature data for the bull trout and Westslope cutthroat trout occupancy models being developed for the EIS based on application of the Isaak et al. (2017) methods for the SGP.

1.3 Thermal Criteria for Evaluation

Thermal criteria describe the temperature thresholds and frequencies that aquatic species can tolerate without suffering adverse effects and are often specified for different seasons and life stages. Published literature, USFS criteria, and IDEQ water temperature standards have been used to develop the thermal criteria for this evaluation.

IDEQ's water quality standards (Idaho Administrative Procedures Act 58.01.02) include relatively complex criteria for temperature, based in part upon seasonal spawning and rearing requirements for salmonids. Idaho first adopted bull trout temperature criteria in 1998. These criteria were revised in 2001 and submitted to the EPA for approval. EPA has not acted, so the bull trout temperature criterion effective for Clean Water Act purposes is the 1997 federally promulgated temperature criterion of 10 degrees Celsius (°C) for 7-day average maximum daily temperatures from June through September for waters specified in the federal rule (40 Code of Federal Regulations 131.33).

The modeling approach developed for the SGP is similar to other temperature evaluations in the Pacific Northwest. For example, in 2011, Tetra Tech used the QUAL2K model to evaluate the effects of different management practices for Nemote Creek in Montana (Tetra Tech 2014). The scenarios they evaluated included baseline conditions (i.e., low flow and warm weather), improved riparian vegetation conditions, and conditions of reduced surface water withdrawals (Tetra Tech 2014). In QUAL2K (Chapra et al. 2008), the heat budget and water temperatures are simulated as a function of meteorology, point and non-point source pollutant loads, and withdrawals from a stream network. The model provides minimum, maximum, and average daily water temperature outputs.

Other studies in the Pacific Northwest have combined empirical data with spatial analyses to model water temperatures under various climate and flow conditions using a linear regression approach (David Duncan and Associates 2002; Forney et al. 2013). For example, a study initiated by the Columbia River Federal Caucus was conducted in the John Day River Basin in Oregon to evaluate the resiliency of salmon habitat to climate change and used a regional database to support development of a summer stream temperature model called NorWeST (Scranton et al. 2015). The NorWeST model database contains stream temperature data and model output for different climate scenarios for various streams and rivers in the western United States.

To evaluate stream temperatures for a given site, the following metrics are commonly used (Scranton et al. 2015):

- **Maximum weekly high temperature** identifies abnormal baseline temperatures for a given site and habitats susceptible to extreme temperatures.
- **Maximum weekly maximum temperature** (MWMT; 7-day average of daily maximums) quantifies weekly maximum stream temperature while limiting the influence of an individual measurement from a single day.
- **Average weekly high temperature** identifies the expected normal baseline temperatures for a given stream network.
- **Modeled mean August temperature reported by NorWeST** database can be used to convert NorWeST database to MWMT.

Thermal criteria can also be established to describe the temperature thresholds and frequencies that aquatic life can tolerate without suffering adverse effects during different life stages. Specific thermal criteria are often established for different seasons and life stages. Previous stream temperature studies recommend prioritizing life stages in selected streams for a month or period of concern. For example, for small tributary streams of the upper Salmon River Basin, Maret et al. (2005) recommended a priority ranking (from high to low) of passage → spawning → adult → juvenile. Therefore, the months of April through September (when migration and spawning activities most often occur) would represent a critical period within the Salmon River Basin.

Table 1-1 summarizes the temperature criteria from the Watershed Indicators and Pathways in the Payette National Forest Land and Resource Management Plan (USFS 2003). For the bull trout criteria, not all temperature values are represented in the published criteria, which are only listed using whole numbers. Some values not represented as whole numbers required interpretation. The values listed in Table 1-2 reflect an interpretation of the USFS criteria for the bull trout life stages. Thermal criteria applied by IDEQ for salmonids are listed in Table 1-3. Both USFS and IDEQ criteria were used to assess the temperature impacts to streams under the ModPRO2 (Section 3.1).

The USFS and IDEQ thermal criteria assessments are relevant to specific fish species (Chinook salmon, steelhead, bull trout) and life stages (spawning, incubation, rearing, migration) and their associated times of year. In the results reported herein, the thermal criteria in each reach of the SPLNT models were evaluated with respect to all of the temperature criteria. However, not every reach currently supports or is accessible to all of these species/life stages or has suitable habitat for these species/life stages. When these SPLNT model results are further analyzed and interpreted, such as in the evaluation of changes in water temperature for the different species/life stages, or when the results are incorporated into the updated Stream Functional Assessment, temperature criteria should be applied for only those species/life stages appropriate on a reach-by-reach basis.

Table 1-1. USFS Thermal Criteria Based on the MWMT

Species/Life Stage	Months	Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Chinook Salmon				
Spawning	Mid-August–September	≤13.9	>13.9–15.5	>15.5
Rearing/Migration	Year-Round	≤13.9	>13.9–17.7	>17.7
Steelhead				
Spawning	March–May	≤13.9	>13.9–15.5	>15.5
Rearing/Migration	Year-Round	≤13.9	>13.9–17.7	>17.7
Bull Trout				
Incubation*	Mid-August–Early February	2.0–5.0	<2.0, 6.0	<1.0, >6.0

Species/Life Stage	Months	Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Rearing*	Year-Round	4.0–12.0	<4.0, 13.0–15.0	>15.0
Spawning*	Mid-August–September	4.0–9.0	<4.0, 10.0	<4.0, >10.0

Notes:

Source: USFS 2003

**See Table 6-2 for interpretations of this guidance*

Abbreviations

°C = degree Celsius

MWMT = maximum weekly (7-day average) maximum temperature

Table 1-2. Interpretation of USFS Temperature Scoring Guidance for Bull Trout

Bull Trout Life Stage Guidance and Interpretation		Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Incubation	Guidance	2–5	<2 or 6	<1 or >6
	Interpretation	2–5	≥1 to <2 or >5 to ≤6	<1 or >6
Rearing	Guidance	4–12	<4 or 13 to 15	>15
	Interpretation	4–12	<4 or >12 to ≤15	> 15
Spawning	Guidance	4–9	<4 or 10	<4 or >10
	Interpretation	4–9	>9 to ≤10	<4 or >10

Sources: USFS 2003; Interim Draft Stream Functional Assessment Ledger (Rio ASE 2018); Stream Functional Assessment Temperature Scoring (Great Ecology 2018)

Abbreviations:

°C = degree Celsius

USFS = United States Forest Service

Table 1-3. Idaho Thermal Criteria

Criteria	Warm Water	Seasonal Cold	Cold Water	Salmonid Spawning	Bull Trout
MDMT	33°C (91°F)	26°C (79°F)	22°C (79°F)	13°C (55°F)	N/A
MWMT	N/A	N/A	N/A	N/A	13°C (55°F)
MDAT	29°C (84°F)	23°C (73°F)	19°C (66°F)	9°C (48°F)	N/A

Notes:

Source: http://www.deq.idaho.gov/water-quality/surface-water/temperature/

Abbreviations:

°C = degree Celsius

°F = degree Fahrenheit

MDAT = maximum daily average temperature

MDMT = maximum daily maximum temperature

MWMT = maximum weekly (7-day average) maximum temperature

N/A = not applicable

1.4 Report Organization

This report describes the development of the SPLNT ModPRO2 models. As noted above, Perpetua Resources has continued to identify mitigation measures that would improve water quality during the Feasibility Study for the Project.

Section 2 includes a narrative description of the ModPRO2 elements that affect stream temperature including use of low flow pipes in diversion channels, modified riparian plantings, and creation of Stibnite Lake on the Yellow Pine pit (YPP) backfill. Section 3 summarizes the model results. Appendix A provides more detail about how the SPLNT existing conditions and NA Alternative models were developed. Appendix B provides the reach level model inputs and outputs for the ModPRO2, as well as summaries of the warmest reach-averaged temperatures simulated for each mine year.

Section 2

Description of the ModPRO2 Alternative and SPLNT Model Inputs

This section provides an overview of the ModPRO2 Alternative in Section 2.1 based on the description provided by Perpetua Resources (Perpetua Resources 2021). Section 2.2 includes the changes to the ModPRO2 relative to the ModPRO and describes how those changes were implemented in the SPLNT models.

2.1 Overview of the ModPRO2

The ModPRO2 incorporates information derived from agency and public scoping for Perpetua Resources original Proposed Action (the PRO), the alternatives development process, baseline data collection and analysis, and predictive modeling (hydrologic, geochemical, water quality, stream temperature, and air quality). It was also informed by Perpetua Resources interactions with the public; federal, state and local governments; Native American tribes; and other Project stakeholders and considers comments submitted during the public comment period for the Draft EIS (USFS 2020).

The ModPRO2 presents a refined and improved Project with a smaller footprint and reduced environmental impacts compared to the PRO and the ModPRO. Mining methods, ore processing, exploration activities, water management, and supporting features including structures, access and haul roads, and infrastructure remain identical to the PRO and/or the ModPRO or are slightly modified. In all cases, these proposed refinements address environmental concerns raised or identified by various sources, or through the effects analysis of the draft EIS, and are targeted at addressing them accordingly. These refinements align with the purpose and intent of the National Environmental Policy Act. The ModPRO2 represents a further refinement of Perpetua Resources Proposed Action and Perpetua Resources considers it to be the best alternative for developing the SGP.

2.2 SPLNT Model – Specific Changes from ModPRO

The ModPRO2 includes additional mitigation measures to lower stream temperatures and improve water quality relative to the ModPRO Alternative. Changes relative to ModPRO modeling include updates to the QUAL2K model configuration to represent ModPRO2 improvements to the mine plan, wider riparian planting zones with taller plants and earlier planting schedules, riparian planting of enhanced reaches of EFSFSR and Meadow Creek, updated baseflow rates based on the Stibnite Hydrologic Site Model (SHSM) ModPRO2 simulation, a General Lake Model (GLM) for Stibnite Lake, and effluent discharge from the water treatment plant.

2.2.1 QUAL2K Configuration

To represent the ModPRO2, the QUAL2K models were reconfigured for the operational and post-closure periods. A summary of the ModPRO2 mine plan is described by Perpetua Resources (Perpetua Resources 2021). QUAL2K reach configuration maps for simulating end of year (EOY) 6, EOY12, early post-closure when low-flow pipes are in place at the TSF (EOY18 to EOY22), and post closure after the low-flow pipes have been removed and the streams have been restored on the TSF (EOY23 to EOY112) are provided in Figure 2-1 through Figure 2-4. Note that the water treatment plant shown on Figure 2-4 will be decommissioned by EOY41.

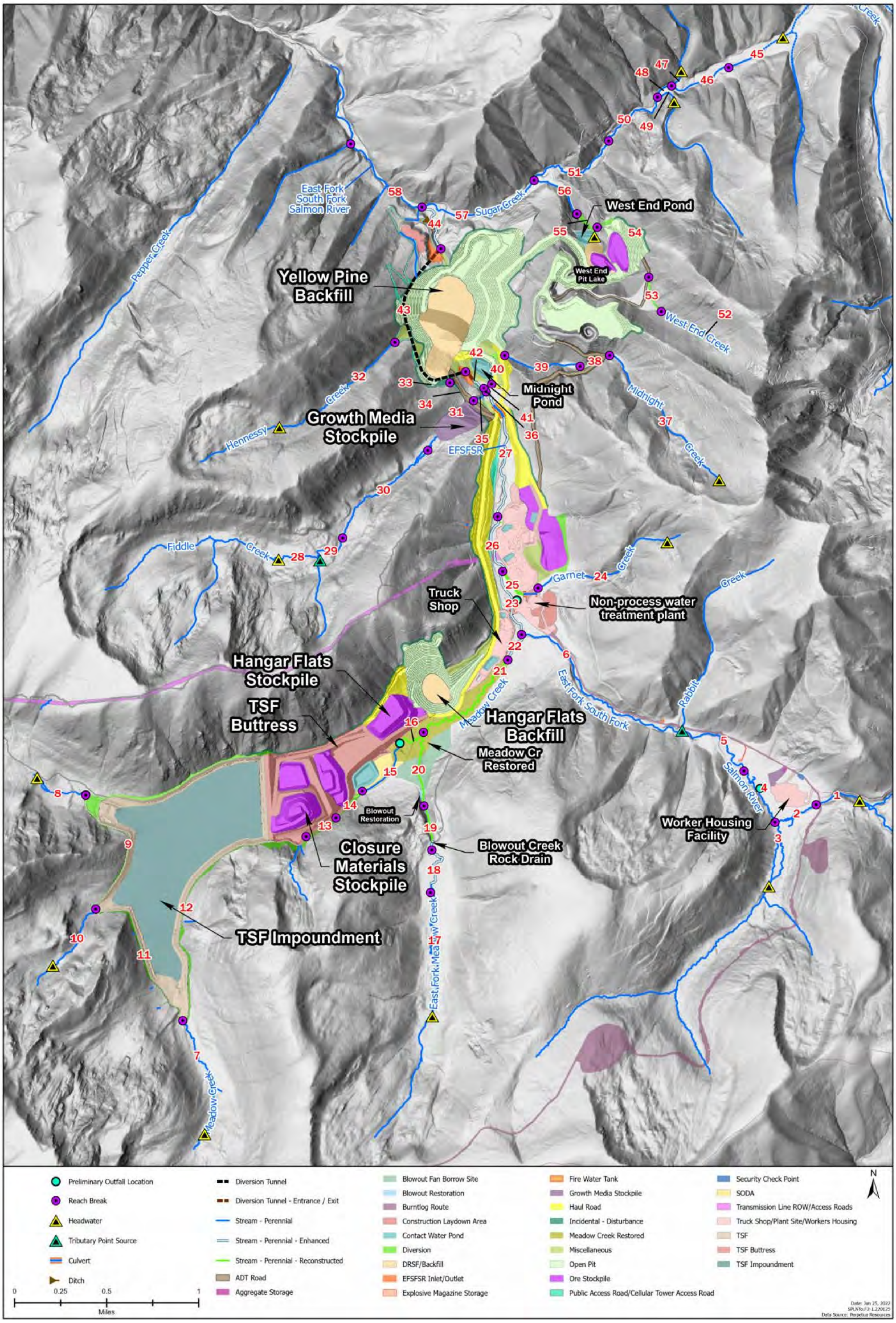


Figure 2-1. SPLNT ModPRO2 Model Configuration for EOY6

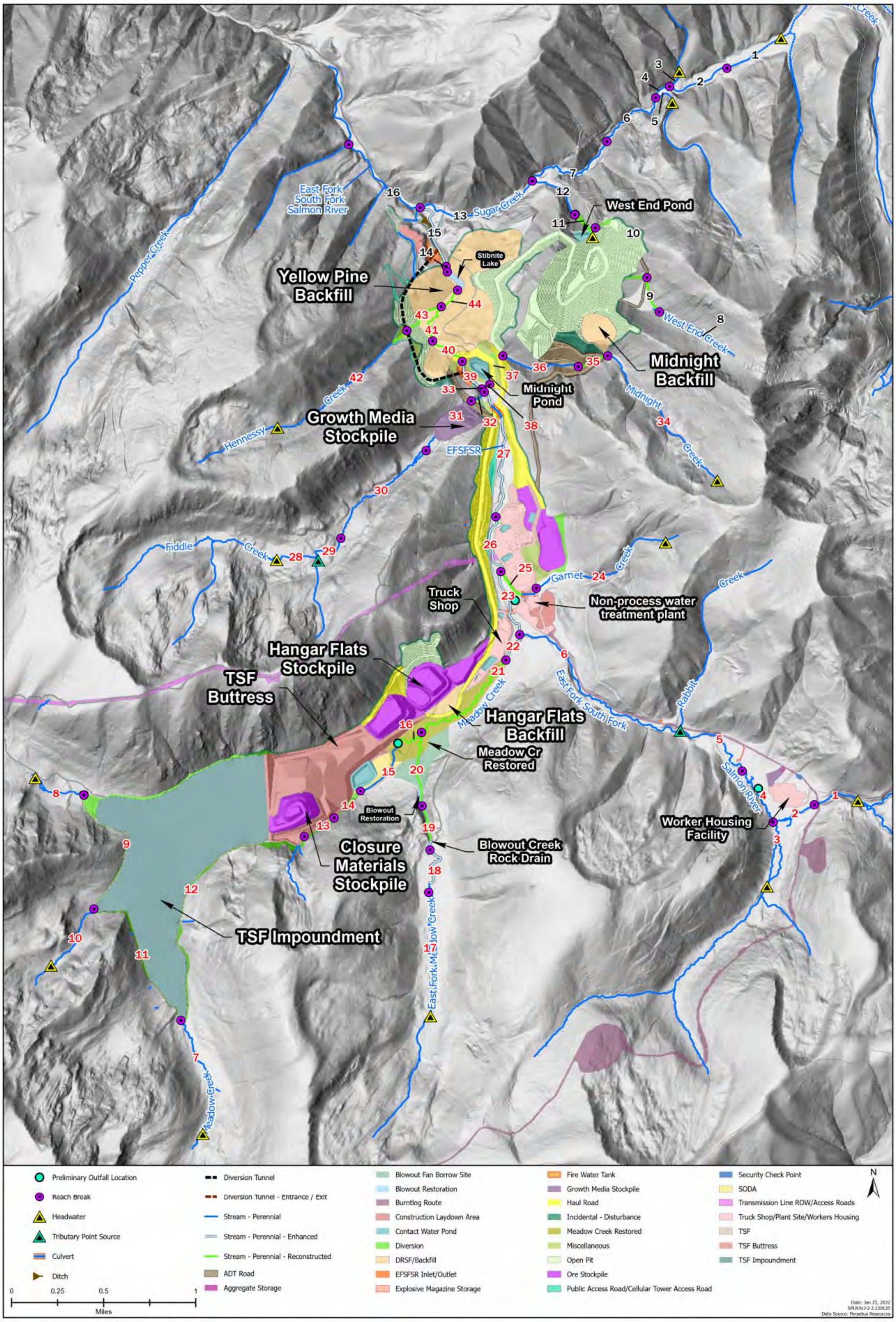


Figure 2-2. SPLNT ModPRO2 Model Configuration for EOY12

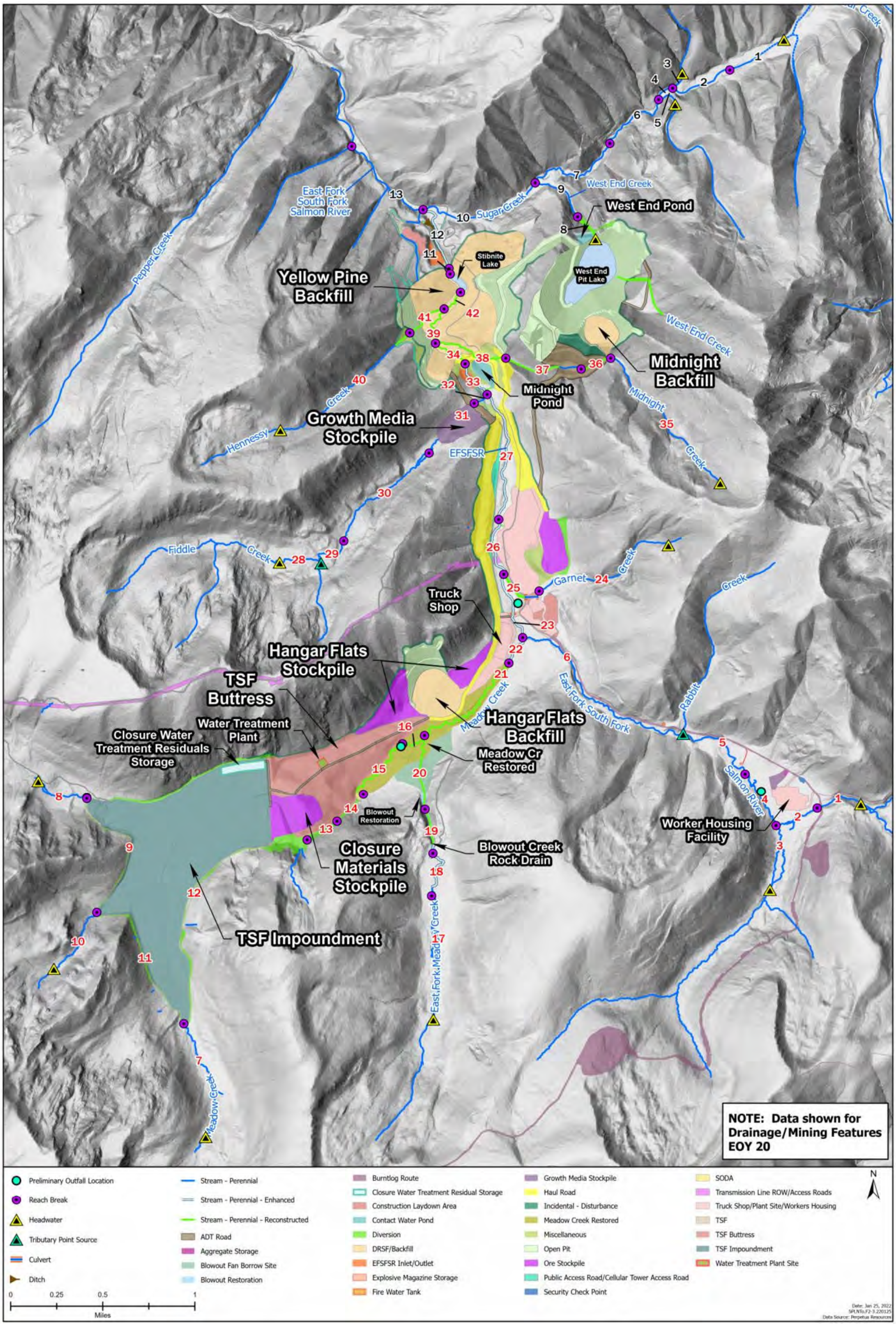


Figure 2-3. SPLNT ModPRO2 Model Configuration for Early Post Closure

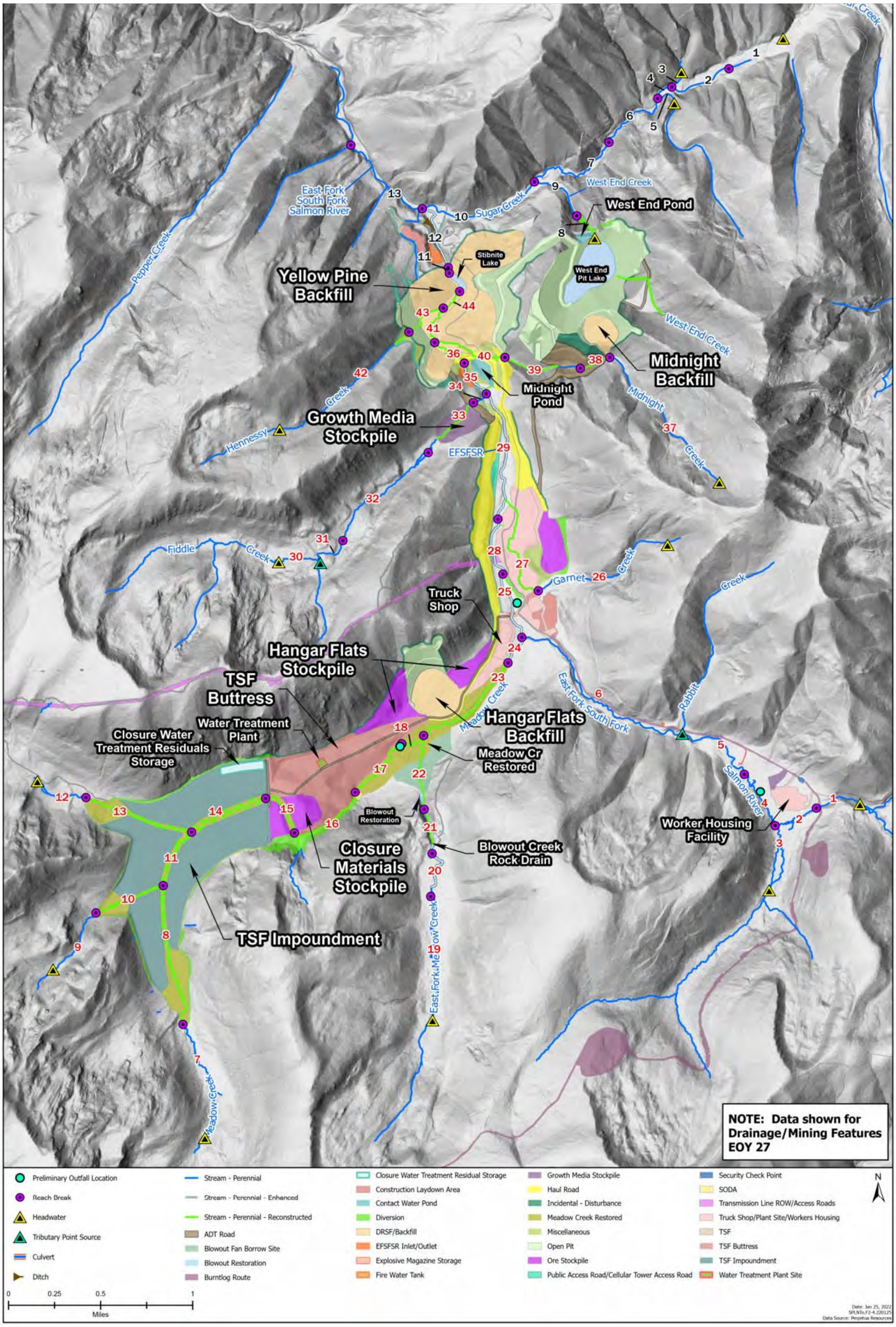


Figure 2-4. SPLNT ModPRO2 Model Configuration for Long-term Post Closure

For much of the SPLNT study area, the configuration for the ModPRO2 is similar to the ModPRO. The configuration changes for ModPRO2 are summarized below by mine period and mine year:

- EOY6:
  - The Fiddle Growth Media Stockpile (GMS) disturbs the lower reaches of Fiddle Creek until EOY23 and restoration and planting occur by EOY24. Upstream of the Fiddle GMS, Fiddle Creek is simulated using the NA configuration and reach characteristics. At the upper end of the GMS, Fiddle Creek is routed underneath, which has the effect of fully shading the water.
  - The water treatment plant is active for EOY6 and is assumed to discharge to Meadow Creek upstream of East Fork Meadow Creek; characteristics of the discharge are described in Section 2.2.4. The discharge location on Meadow Creek is intended to supplement stream flow: during periods when supplementation is not needed, some or all of the discharge may be moved to EFSFSR.
  - Streamflows, including piped low flows, are diverted along the south side of the TSF; this change affects the length of the flow path compared to other alternatives and figures have been adjusted so that major features line up (e.g., tributary confluences).
  - There is a rock drain placed downstream of the meadow in East Fork Meadow Creek, which has the effect of fully shading the water; a liner is utilized in lower East Fork Meadow Creek to prevent water loss.
  - The alignment of lower Garnet creek has been revised to restore lower Garnet Creek early and avoid updated mine infrastructure; this results in moving the confluence with the EFSFSR upstream of the prior location.
  - Updated design information is reflected in the configuration for the following diversions:
    - Hennessy Diversion: This diversion still discharges to Fiddle Creek but is now piped.
    - West End Diversion: The upper part of West End Diversion is open channel lower part is piped.
    - Midnight Creek diversions: The upper two diversion segments are piped; the most downstream segment of the diversion is relatively short and is designed as an open channel.
- EOY12 includes the components above with the following changes:
  - Hangar Flats pit has been backfilled.
  - The YPP backfill area has been restored including the Hennessy Creek diversion; the Midnight diversions remain until EOY13.
  - The uppermost part of West End Creek has been restored.
  - Stibnite Lake has been constructed at the downstream end of the YPP backfill over the liner. This lake is simulated using the GLM model and only receives flow from surface waters (no groundwater interactions). Separate QUAL2K models are configured upstream and downstream of the lake.
  - The water treatment plant is not likely to discharge for EOY12; zero discharge to Meadow Creek is assumed in the SPLNT modeling for EOY12.
- Post-closure (SPLNT model years EOY18 and EOY22):
  - Early post closure prior to the stream restoration on the TSF (EOY18 to EOY22)

   - For the early part of post closure, the low flow pipes around the TSF will remain to convey water in pipes and keep stream temperatures lower. Reaches on top of the TSF are restored by EOY23.
   - Midnight Creek has been restored over the YPP backfill.
   - West End Creek has been restored upstream and downstream of West End pit lake; West End pit lake does not discharge downstream.
   - Active treatment of the TSF runoff, consolidation water, and remaining supernatant continues with effluent discharged to EFSFSR upstream of Garnet Creek.
- Long-term post closure[1] (SPLNT model years EOY27, EOY52, and EOY112):
   - Fiddle GMS has been consumed during TSF restoration, and Fiddle Creek is restored and planted by EOY24 which is reflected in the SPLNT models for EOY27 and beyond.
   - The water treatment plant discharge location is moved to Meadow Creek downstream of East Fork Meadow Creek by EOY23 where the discharge remains through EOY40.
   - Streams on the TSF are restored by EOY23.
   - Water treatment of tailings consolidation water continues through approximately year 40, and the treatment plant is decommissioned by EOY41.

2.2.2 Duration of Low Flow Piping around the TSF

The ModPRO Alternative includes low-flow pipes under, or adjacent to, most of the perennial diversion channels in the Project Area. The purpose of the low-flow pipes is to reduce water temperatures by transporting low flows in a fully shaded conveyance. For the ModPRO, low flow pipes remain in place through EOY12. Under the ModPRO2, the low flow pipes around the TSF remain in place during the early part of post closure until EOY23 when streams on the TSF are restored.

2.2.3 Expanded Riparian Plantings

The ModPRO2 includes several modifications to the riparian planting plan aimed at providing additional shade to the stream reaches. The methods and analysis for accounting for shade are described in the SPLNT PA Modeling Report (BC 2019a). For all of the project alternatives, the streams have been designed to be a natural. dynamic system which would include evolution of the stream channel and vegetation, including expansion and effects of large woody debris recruitment. Planting areas are designed to become self-sustaining with minimal or no required maintenance after vegetation establishment.

The restored streams have been designed based on channel migration measurements at reference sites and literature values (Rio ASE 2021). The rate of expected channel migration for the restored channels, which include vegetated coir mat, is relatively low (0.2 feet per year) compared to the rate of expansion and regeneration of vegetation. For example, there has been no measured migration at the restoration site on lower Meadow Creek since it was constructed. At another meadow stream, Riordan Creek, migration rates at areas of change such as the apexes of channel bends ranged from 0.18 feet per year to 0.26 feet per year; however, the majority of the length was stable with migration observed only in specific areas (Rio ASE 2021).

Outside the stream banks, the riparian planting zone is 16 feet. Based on a migration rate of 0.18 to 0.26 feet per year, it would take 60 to 90 years for the restored channels to move beyond the

[1] Long term post closure shown on Figure 2-4 is the complete stream restoration. Additional site restoration and decommissioning of the water treatment plant continue beyond what is shown in the figure.

riparian planting zone. By the time the stream migrates 16 feet, there will have been new vegetation growing and regenerating across the floodplain, and moving with the channel. Expansion of vegetation would be expected to coincide with migration, similar to other constructed or natural streams.

The following changes are incorporated into the ModPRO2 SPLNT models:

- The planting prescription for Zone 4 plantings has been revised to include a higher percentage of taller species (Table 2-1) relative to what was proposed in the Conceptual Mitigation Plan (Tetra Tech 2018).
- The width of riparian plantings has been increased from 7 feet to 18 feet. The inner two feet of plantings are not altered from the Conceptual Mitigation Plan. Under PA and ModPRO, Zone 4 planting width was 5 feet; under ModPRO2 the Zone 4 planting width is 16 feet. Beyond Zone 4, the wetland planting plan remains the same as described in the Conceptual Mitigation Plan. However, the SPLNT models only account for the riparian planting in the estimates of shade, and wetland plantings are not simulated.
- Enhanced reaches will receive riparian plantings, as well, which adds 2.6 miles of stream length to be planted at SGP. Where space allows, these plantings will include an 18-foot planting zone on either side of the channel. Site constraints limit the planting width in some areas. Shade models for ModPRO2 reflect the planting widths and site constraints.
- Plantings occur as early in mine life as feasible Figure 2-5Figure 2-5 compares the planting schedule for ModPRO2 to the other project alternatives evaluated. Earlier plantings along more streams allows more time for growth and increased stream shading. Planting along EFSFSR and lower Meadow Creek downstream of the lined section (enhanced reaches) would occur by mine year 1. Meadow Creek along the lined stream/floodplain restoration corridor around Hangar Flats pit and lower East Fork Meadow Creek are restored and planted by mine years 1 to 3, depending on the reach. For Meadow Creek around Hangar Flats pit and lower East Fork Meadow Creek, plantings occur 12 years earlier than planned for the other alternatives, and the additional plantings along the enhanced reaches of Meadow Creek and EFSFSR were not part of earlier plans. By the time the diversions and low flow pipes are removed from the TSF by the end of mine year 23, some of these additional plants will have been growing for 20 to 24 years. This is a significant change compared to the planting plans for the other alternatives.

Table 2-1. Planting Prescription for the Riparian Planting Zone (Zone 4)

Scientific Name[1]	Common Name	Percent of Mix
Alnus incana ssp. *tenuifolia*	thinleaf alder	4.1
Calamagrostis canadensis var. *canadensis*	bluejoint reedgrass	12.4
Cornus sericea (*C. alba*)	redosier dogwood	4.1
Geum macrophyllum var. *perincisum*	largeleaf avens	12.4
Lonicera involucrata var. *involucrata*	twinberry honeysuckle	1.0
Picea engelmannii var. *engelmannii*	Engelmann spruce	19.7
Ribes lacustre	prickly currant	1.0
Salix drummondiana	Drummond's willow	15.4
Salix lasiandra	Pacific willow	29.9
Total	**Total**	**100.0**

Notes:

[1] Scientific names based on the PLANTS Database (Natural Resources Conservation Service 2018); names in parentheses are synonyms used in the National Wetland Plant List (Lichvar, et al. 2016).

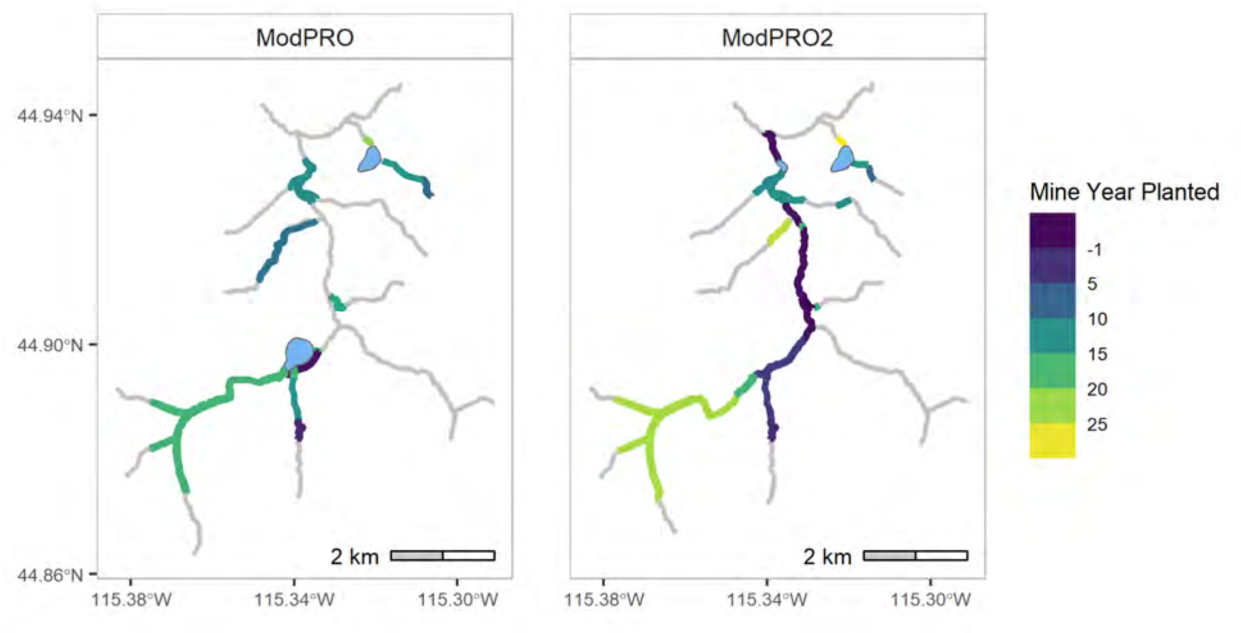


Figure 2-5. Comparison of Riparian Planting Schedules Simulated in SPLNT for PA and ModPRO (left) and ModPRO2 (right)[1]

Note:

[1]Riparian areas along Fiddle Creek and West End Creek shown to be restored in ModPRO and not ModPRO2 are because these areas are not disturbed under ModPRO2.

2.2.4 Water Treatment Plant Discharge

ModPRO2 includes a WTP to treat dewatering and contact water prior to discharge to either Meadow Creek or EFSFSR depending on the stream flow conditions in Meadow Creek (treated discharge can be used to supplement stream flows). The SPLNT model assumes that for EOY6 and EOY12, the discharge location would be to Meadow Creek upstream of East Fork Meadow Creek. For EOY18 and EOY22, the discharge is simulated at EFSFSR upstream of Garnet Creek. By EOY23, the discharge is assumed to Meadow Creek downstream of East Fork Meadow Creek[2]. The post-closure configurations change after EOY23 when low-flow pipes in upper Meadow Creek are removed, the TSF cover is complete, and the streams are restored on the TSF (EOY23 – EOY112) as depicted in Figures 2-3 and 2-4, and water treatment transitions to treating only tailings consolidation water, not contact runoff. The outfall location moves from EFSFSR to Meadow Creek below EFMC coinciding with the removal of the low-flow pipes to supplement stream flows and the reclamation of the TSF[3]. Flows to water treatment decline from approximately 1,000 gpm in mine years 15 through 23, during which time most meteoric water landing on the TSF is treated, along with consolidation water, to less than 150 gpm from EOY23 to EOY40 when the cover is complete and only consolidation water requires treatment. The WTP is downsized and relocated to the TSF buttress at this time to allow for

[2] IPDES outfall locations are preliminary and draft. The final locations will be determined through the IPDES application process with the Idaho Department of Environmental Quality (IDEQ). The locations shown were identified through initial evaluation to support mine planning and are subject to change.

[3] WTP phasing is preliminary and draft. Relocation timing was identified through an initial evaluation to support mine planning and is subject to change.

a shorter, lower-head pipeline between the source and the WTP and allow the location of longer-term treatment on private land per USFS policy.

Methods for determining the temperature of the discharge from the water treatment plant are described in the Water Quality Management Plan (BC 2020). The water balance analysis was updated using the SHSM ModPRO2 simulation output (BC 2021a). Discharge temperature differences among simulated mine years and seasons reflect different source water contributions of treated water (dewatering, contact water) and details related to the active contact water ponds (volume of water in ponds, residence time of water in the ponds, and differences in pond sizes). In some of the periods simulated, there is no storage of water within the ponds; therefore, the temperature of treated water was determined by the contact water temperature and slight warming during the treatment process (BC 2020). The highest discharge temperature is simulated for the maximum weekly summer condition in July of Year 22. The temperature for this month is warmer because the flow rate is low and the residence time in the contact water pond is relatively long, warming the water prior to treatment. Table 2-2 summarizes the discharge flow rate and temperature from the water treatment plant which is decommissioned by EOY41. For some mine years and seasons, there is no discharge (i.e., mine year 12 and mean August and maximum weekly fall conditions in mine years 6 and 18).

The discharge from the sanitary water treatment plant is assumed the same as for the other alternatives as described in the SPLNT PA Modeling Report (BC 2019a).

Table 2-2. Water Treatment Plant Discharge Flow Rates and Temperatures

Mine Year	Season	Discharge Location	Discharge (cms)	Temperature (°C)
EOY6	Maximum Weekly Summer	Meadow Creek above EFMC	0.022	17.7
EOY6	Mean August	Meadow Creek above EFMC	0	No discharge
EOY6	Maximum Weekly Fall	Meadow Creek above EFMC	0	No discharge
EOY12	Maximum Weekly Summer	Meadow Creek above EFMC	0	No discharge
EOY12	Mean August	Meadow Creek above EFMC	0	No discharge
EOY12	Maximum Weekly Fall	Meadow Creek above EFMC	0	No discharge
EOY18	Maximum Weekly Summer	EFSFSR	0.0007	12.7
EOY18	Mean August	EFSFSR	0	No discharge
EOY18	Maximum Weekly Fall	EFSFSR	0	No discharge
EOY22	Maximum Weekly Summer	EFSFSR	0.0163	19.5
EOY22	Mean August	EFSFSR	0.0122	17.7
EOY22	Maximum Weekly Fall	EFSFSR	0.0042	12.0
EOY27	Maximum Weekly Summer	Meadow Creek below EFMC	0.0057	12.7
EOY27	Mean August	Meadow Creek below EFMC	0.0056	12.5
EOY27	Maximum Weekly Fall	Meadow Creek below EFMC	0.0055	10.9
EOY32	Maximum Weekly Summer	Meadow Creek below EFMC	0.0029	12.7
EOY32	Mean August	Meadow Creek below EFMC	0.0030	12.5
EOY32	Maximum Weekly Fall	Meadow Creek below EFMC	0.0028	10.9

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EFMC=East Fork Meadow Creek

EOY = end of year

2.2.5 SHSM ModPRO2 Simulation Output

Several of the Project components included in the ModPRO2 are accounted for in the SPLNT model through the application of the SHSM output (BC 2021a). These modifications have the potential to affect baseflows, which are input to the SPLNT model as diffuse flows: pit dewatering, installing stream liners to prevent stream flow losses, and backfilling Hangar Flats pit and Midnight pit. While the SHSM accounts for the discharge from the water treatment plant, special model runs were provided for the SPLNT modeling that did not include the water treatment plant discharge. This allows the discharge to be accounted for directly in the QUAL2K model to simulate changes to stream temperature.

Diffuse flow input values for each QUAL2K model reach and season (maximum weekly summer condition, maximum weekly fall condition, and mean August condition) are provided in Appendix B for each simulation year: EOY6, EOY12, EOY18, EOY22, EOY27, EOY32, EOY52, and EOY112. SPLNT model inputs for diffuse flow are based on the percent change between the SHSM NA Alternative model and the SHSM ModPRO2 model. The SHSM runs on a monthly time step, and the percent change between the two SHSM model runs is applied to the daily diffuse flow values used to develop the SPLNT NA models. Because the SHSM, and previous SGP hydrologic models, are applied to the SPLNT models as a percent change, the SPLNT NA and existing conditions models do not need to be rerun to evaluate the ModPRO2. Appendix A provides more detail about the SPLNT existing conditions model and NA model development and summarizes how the diffuse flow inputs are assigned.

2.2.6 Stibnite Lake GLM

For the PA and ModPRO Alternatives, daily maximum temperatures in the YPP backfill area were up to 4°C higher than NA during the maximum weekly summer condition (BC2019a and 2019c). This predicted increase in daily maximum temperatures is in large part due to the removal of the YPP lake because the lake dampens the diurnal variability of the water temperatures compared to the EFSFSR upstream of the lake. The ModPRO2 includes creation of Stibnite Lake at the downstream end of the YPP backfill to better mimic the NA Alternative. This lake would be created over the liner to prevent interaction of the lake water with the backfill material and the groundwater system.

The impacts of Stibnite Lake were simulated using the GLM model which has been used to evaluate the YPP lake for the NA Alternative and West End, Midnight, and Hangar Flats pit lakes under the PA and ModPRO Alternatives. A description of the GLM model and its application for the evaluation of lake temperatures associated with the Project Alternatives is provided in BC 2018, 2019a, and 2019c. The characteristics of Stibnite Lake are described in the narrative description of ModPRO2 (Perpetua Resources 2021). The stream flow output from the QUAL2K model for the stream upstream of Stibnite Lake provides the water balance inputs for the lake. Stream flows discharged from Stibnite Lake provide the input to the downstream QUAL2K reach. This approach is similar to the simulation of YPP lake. Because the residence time of YPP lake is less than one week regardless of hydrologic condition (BC 2018), groundwater interactions were not accounted for, and the model assumes only surface flows enter or leave YPP lake. Groundwater interactions are also not modeled for Stibnite Lake which is situated above a liner to separate it from backfill material and has about 55% of the volume of YPP, and, therefore, a shorter residence time of between 1 and 3 days during the summer and fall low-flow period. Over this 1-to-3-day time scale, the water balance is dominated by surface water inflows, and temperature impacts from shallow groundwater interaction will be minimal. During the summer and fall SPLNT modeling periods, groundwater temperatures are cooler than surface water temperatures and any groundwater influx would be expected to reduce lake temperatures relative to values that are modeled and reported here for the summer and fall conditions.

Several sizes of Stibnite Lake, within the constraints of the backfilled area, were tested to evaluate the reductions in daily maximum temperature and increases in daily average temperature. Lake sizes evaluated were between 30 and 100 percent of YPP lake's surface area and between 40 and 100 percent of YPP's volume; maximum depth was maintained to be the same as YPP lake. All lakes in this size range limited the increase in average daily temperature to within 1°C of the average inflow temperature under summer model conditions and reduced the daily maximum temperatures by between 5 and 5.5°C. Ultimately, all lake sizes evaluated were able to mimic the general pattern of reducing the daily temperature extremes while keeping the increase in average temperatures minimal. Stibnite Lake was designed to have approximately 55 percent of YPP's volume and surface area with maximum and average depth the same as the existing YPP lake.

Discharge temperatures and flow rates from Stibnite Lake are summarized by mine year and seasonal condition in Table 2-3. The lakes are simulated with continuous discharges at the maximum weekly maximum temperature for the summer and fall models, and the same temperature is applied 24 hours per day. The conditions under which the lakes would actually discharge at these temperatures would be limited to specific hours of the day and under the warmest seasonal conditions. A comparison of the physical properties and simulated temperatures for Stibnite Lake relative to other simulated pit lakes at SGP, and to data collected upstream and downstream of YPP lake, is provided in BC 2021b. Stibnite Lake was designed to replicate the thermal effects of YPP lake and the simulations and data available at SGP demonstrate that a lake with short residence time (days) located in the same area as YPP lake will provide similar effects. This feature has also been designed to require no long-term maintenance, similar to the existing YPP lake, which is not nor is known or suspected to have ever been actively maintained or managed.

Table 2-3. Stibnite Lake Discharge Flows and Temperatures for the ModPRO2

EOY	Seasonal Condition	Inflow Temperature °C	Flow Rate (cms)	Discharge Temperature °C
18	Maximum summer	12.31	0.4516	13.63
18	Mean August	10.80	0.4516	12.22
18	Maximum fall	9.64	0.3369	10.19
22	Maximum summer	12.33	0.4611	13.63
22	Mean August	10.76	0.4611	12.17
22	Maximum fall	9.51	0.3407	10.08
27	Maximum summer	12.61	0.5095	13.80
27	Mean August	11.09	0.5095	12.38
27	Maximum fall	9.73	0.3668	10.25
32	Maximum summer	12.38	0.5073	13.59
32	Mean August	10.87	0.5073	12.18
32	Maximum fall	9.58	0.3653	10.11
42	Maximum summer	12.13	0.5030	13.37
42	Mean August	10.66	0.5030	11.99
42	Maximum fall	9.41	0.3585	9.96
52	Maximum summer	11.99	0.5031	13.24
52	Mean August	10.54	0.5031	11.87
52	Maximum fall	9.33	0.3583	9.88
112	Maximum summer	11.73	0.5050	13.00

EOY	Seasonal Condition	Inflow Temperature °C	Flow Rate (cms)	Discharge Temperature °C
112	Mean August	10.34	0.5050	11.67
112	Maximum fall	9.20	0.3622	9.75

Abbreviations:

°C = degree Celsius

cms = cubic meters per second

EOY = end of year

West End pit lake is not predicted to discharge in the ModPRO2. This was also predicted for PA and ModPRO Alternatives during the low flow conditions modeled by SPLNT. Under these three Alternatives, a small discharge from West End pit lake has been assumed to provide a conservative (warmer temperature) estimate of temperatures in West End Creek downstream of the pit lake (described in BC 2019a). Midnight pit is fully backfilled under the ModPRO and ModPRO2, so this pit lake is eliminated from these simulations. Hangar Flats pit lake does not form in the ModPRO2 because the pit is fully backfilled.

Section 3

SPLNT Model Results for ModPRO2

The SPLNT Model was developed to simulate temperatures under existing conditions and the NA Alternative and to predict changes in stream and pit lake temperatures associated with Project Alternatives. The SPLNT model was developed using two separate software packages: QUAL2K for stream temperature modeling and the GLM for simulating pit lakes. QUAL2K simulates stream temperature upstream and downstream of the pit lakes and uses GLM-simulated pit lake temperature as an input for the segment downstream of each lake.

The steady-state QUAL2K component of the SPLNT model was designed to simulate (1) low-flow, maximum weekly temperature summer conditions (July through August) and (2) low-flow, maximum weekly temperature fall conditions (September through October) to allow for an assessment of mining impacts based on thermal criteria applicable to these conditions. Because QUAL2K is a steady-state model that simulates a 24-hour period, specific dates with stream flow and temperature observations were selected to represent conditions comparable to thermal criteria. To select dates representative of these two conditions, a review of historical 15-minute observed flows and temperatures was performed. Observed conditions on July 29, 2016, represent recurring flows/temperatures observed over a 2-week period. Steady-state simulations of July 29, 2016, therefore, represent low-flow, maximum weekly temperature, summer conditions. Similarly, the date selected to represent consistently low-flow, maximum weekly temperatures during the fall was September 24, 2014. The SPLNT Existing Conditions Report (BC 2018) presents the observed flows and temperatures for the two-week periods centering around these representative dates. The meteorology and stream hydrology measured on these specific days provide the inputs to the SPLNT model. For existing conditions and the NA Alternative, the model inputs are the same. To evaluate Project Alternatives, the stream baseflows are adjusted based on a percent difference calculated by comparing SHSM simulations of NA and each Project Alternative. The meteorology for the evaluations is not altered. A third condition was requested by the review agencies during development of the PA models to simulate mean August conditions for use in Occupancy Models.

3.1 Comparative Analysis of NA and ModPRO2

As with the PA and ModPRO modeling reports (BC 2019a and BC 2019c), the ModPRO2 temperature simulations are compared to the NA in a series of longitudinal profile figures (Figure 3-1 through Figure 3-28); the longitudinal profiles end at the model terminus on the EFSFSR downstream of Sugar Creek. Simulations were developed to represent the maximum weekly summer condition, maximum weekly fall condition, or the mean August condition. Output from the mean August condition provides temperature data for the bull trout and Westslope cutthroat trout occupancy models being developed for the EIS applying Isaak et al. (2017) methods for the SGP.

Each set of figures shows either the USFS thermal criteria or the IDEQ thermal criteria that are described in BC 2019a. The USFS and IDEQ thermal criteria assessments are relevant to specific fish species (Chinook salmon, steelhead, bull trout) and life stages (spawning, incubation, rearing, migration) and their associated times of year. In most of the results reported below, the thermal criteria in each reach along a flowpath were evaluated with respect to all of the temperature criteria. However, not every reach currently supports or is accessible to all of these species/life stages or has suitable habitat for these species/life stages and the timing of these life-stage activities varies by species. When the SPLNT model results are further analyzed and interpreted, such as in the evaluation of changes in water temperature for the different species/life stages, or when the results are incorporated into the updated Stream Functional Assessment, temperature criteria should only be applied to those species/life stages appropriate on a spatial and temporal basis.

The SPLNT model simulates stream reaches where fish have not been observed and are not anticipated due to the steepness of the stream or low flows associated with small drainages. West End, Midnight, and Hennessy Creeks are small streams with limited or no capacity to support fish, particularly anadromous species. These creeks have very steep gradients that limit fish access and provide limited habitat space, possibly none during summer low flow conditions. Occupancy modeling completed by Ecosystem Sciences (2019) also indicates that based on stream size, gradient, and temperature, Midnight and Hennessy Creeks had little or no probability of occurrence of bull trout and Westslope cutthroat trout.

Another example of this lack of suitability of thermal criteria occurs in Meadow Creek on the TSF for the post closure condition. Under current conditions, the upstream limit of salmon spawning habitat on Meadow Creek is approximately the toe of the keyway dam that is slightly upgradient of the Meadow Creek and East Fork Meadow Creek confluence. With the proposed Project, spawning habitat would extend further upstream by approximately 1.3 miles to the toe of the TSF Buttress. Further upstream, while simulated temperatures are relatively high in the headwater and Meadow Creek reaches on the TSF, migratory/anadromous fish cannot access these areas for spawning, so the criteria are not relevant in this area.

Simply put, although the SPLNT model predicts the water temperature in each stream reach in the model, the species-life stage temperature criteria should only be applied to that reach if it would otherwise support fish. The temperature criteria should be applied only for those species and life stages which would occur in the reach based on their habitat preferences and tolerances and reach accessibility.

The SPLNT modeling period is also an important consideration in the evaluation of the thermal criteria. All of the criteria are shown on each figure for the maximum weekly summer, the maximum weekly fall, and the mean August conditions for reference. However, not every life stage occurs for each species in these three seasons. In addition to previous SPLNT modeling reports that showed simulated maximum and simulated average temperatures, this model report includes a metric that was introduced in the draft EIS following submittal of the SPLNT modeling reports. This metric is called the "constant," and it is calculated as the midpoint between the average and maximum temperatures.

As summarized from multiple sources, Appendix J-2 of the draft EIS shows that only two salmonid species spawn during the SPLNT modeling periods. Chinook salmon spawn primarily in August and bull trout spawn primarily in late August/early September. Appendix J-2 applies the maximum weekly fall "constant" for comparison to the spawning criteria for these two species. Appendix J-2 indicates that fall "constant" temperatures greater than 13 degrees Celsius (°C) cause reduced viability of gametes and for bull trout that the Forest Service considers fall "constant" temperatures greater than 10°C as having "unacceptable risk" in their rating system (USFS 2003). Thus, simulated maximums in the summer or the fall are not the appropriate bases for evaluating potential impacts on salmonid spawning, but the SPLNT reports include all thermal criteria regardless of the season or temperature metric displayed. Whereas the SPLNT modeling reports provide model output in reference to all criteria, the Biological Analysis and the Final EIS should provide the spatial and temporal context for interpretation of the results with respect to impacts on fish.

Simulated temperatures are shown below using consistent formatting from previous reports. To avoid small font on the figure legend, abbreviations used on the figures are listed below:

- Tributaries: East Fork Meadow Creek (EFMC), Rabbit Creek (RC), Meadow Creek (MC), Garnet Creek (GC), Fiddle Creek (FC), Sugar Creek (SC), West End Creek (WEC)
- Facilities: Tailings Storage Facility (TSF), TSF Buttress (TSF-B), Yellow Pine pit lake (YPPL; only present in NA), West End pit lake (WE PL; QUAL2K simulations were not conducted upstream of West End pit lake for the post-closure period because the inflowing stream temperature would have minimal effect on simulated temperatures within the pit lake), Growth Media Stockpile (GMS)
- IDEQ Uses: Warm Water (WW), Seasonal Cold (SC), Cold Water (CW), Salmonid Spawning (SS), Bull Trout (BT)
- IDEQ Rating: Maximum Daily Maximum Temperature (MDMT), Maximum Daily Average Temperature (MDAT), Maximum Weekly Maximum Temperature (MWMT)
- USFS Species: Chinook Salmon and Steelhead (CS&S), Bull Trout (BT)
- USFS Life Stages: Spawning (Spwn), Rearing (Rear), Migration (Migr), Incubation (Inc)
- USFS Rating: Unacceptable Risk (UR), Functioning at Risk (FR), Functioning Acceptably (FA)

3.1.1 Meadow Creek and EFSFSR

For the Meadow Creek and EFSFSR parts of the system, the ModPRO2 has the potential to affect stream temperatures compared to NA, but many of the mitigation measures incorporated into the ModPRO2 mitigate water temperature. The comparative analyses for these flow paths include results for multiple mine years simulated for ModPRO2 as well as NA which is shown for reference on each figure as a dashed navy-blue line. Reach level output for all simulated mine years is provided in Appendix B.

Longitudinal temperature profiles (Figure 3-1 through Figure 3-14) were developed for two flow paths along Meadow Creek and the EFSFSR to compare the ModPRO2 and NA. Both flow paths end at the boundary of the SPLNT model domain just downstream of the Sugar Creek and EFSFSR confluence. One flow path extends to the headwaters of Meadow Creek and the other flow path extends to the headwaters of EFSFSR. These profiles separately display either the simulated average or maximum temperature for the maximum weekly summer, maximum weekly fall, and mean August conditions as well as the IDEQ and USFS thermal criteria. Simulated maximum temperatures for both the maximum weekly summer and fall conditions are more sensitive than simulated averages, and the relative change in average temperatures is less pronounced. Calculated temperature “constants” (the average of the mean and maximum) are included in the longitudinal profile figures for comparison to metrics presented in the draft EIS. The discussion of results focuses on the simulated averages and simulated maximums as with prior reports.

The longitudinal temperature profiles show the following patterns for the ModPRO2 (<u>if no distinction is made between simulated maximums and simulated averages, then the statement applies to both; if distinction is warranted then the text describes these separately</u>):

- Meadow Creek above EFSFSR:
  - During operations and early post closure model runs (EOY6, EOY12, EOY18, EOY22):
    - The ModPRO2 results in water temperatures that are the same as, or up to 2°C cooler than, NA for the diversion channels and streams from the headwaters of Meadow Creek to the confluence with EFSFSR. These mine years include buried pipes to convey low flows around the TSF. Pipes are fully shaded, and this condition blocks the solar radiation that reaches Meadow Creek under NA due to historical mining-related activities.

    - Downstream of the TSF diversions, stream reaches in lower Meadow Creek would be restored and planted by end of year 3, so vegetation begins to establish approximately 20 years earlier than on the TSF.
    - The Water Treatment Plant (WTP) effluent discharge location for EOY6 and EOY12 is modeled at the proposed Idaho Pollutant Discharge Elimination System (IPDES) outfall location on Meadow Creek above East Fork Meadow Creek. For EOY6, this discharge increases average daily temperature by up to 1.9 °C and daily maximum temperatures by up to 1.4 °C in the maximum weekly summer condition. Because streamflow is routed through low-flow pipes in Meadow Creek upstream of the discharge in this mine year, the stream temperatures (daily mean and daily maximum) are below No Action temperatures and remain below No Action temperatures with the WTP discharge; there is zero discharge under the maximum weekly fall condition and the mean August condition for EOY6, and no discharge for any of the model periods for EOY12. By EOY18, the discharge location is on EFSFSR near Garnet Creek. Discharge from the WTP during the EOY18 SPLNT modeling periods is negligible compared to the river flow, and simulated thermal impacts are less than 0.05°C. Discharge from the WTP during the EOY22 modeling periods is greater than for EOY18, but still small compared to river flow; thermal impacts are less than 0.4 °C.
- Long-term post-closure model runs (EOY27 and beyond):
    - By EOY27, the WTP discharge is modeled at the proposed IPDES outfall location on Meadow Creek below East Fork Meadow Creek where it remains through year 40. The WTP decreases stream temperatures by up to 0.8°C under the maximum weekly summer condition for EOY27. The WTP results in stream temperature decreases in the other mine years and seasons while it is at this location with decreases ranging from 0.3°C to 0.6°C.
    - Once the low flow pipes around the TSF are removed in Year 23, warmer temperatures are simulated in Meadow Creek compared to during operations because the water is no longer shaded. For the post-closure condition, channels are restored over the TSF and TSF Buttress. Hangar Flats pit is backfilled so there is no discharge from a pit lake to Meadow Creek.
    - Downstream of East Fork Meadow Creek to the EFSFSR confluence, daily <u>maximum</u> temperatures in the summer and fall are 1°C to 5°C cooler than NA for each mine year simulated; daily <u>average</u> temperatures are at or below NA except for EOY27 which is approximately 1°C warmer than NA for the maximum weekly summer condition.
    - Upstream of East Fork Meadow Creek daily <u>average</u> temperatures are approximately 1°C to 2°C cooler than NA by EOY112. For the maximum weekly summer condition, daily <u>average</u> temperatures are similar to NA by EOY52; EOY27 and EOY32 have simulated averages that are 1.5°C to 3°C warmer than NA. For the maximum weekly fall condition, daily average temperatures are below NA by EOY32; EOY27 has simulated averages that are approximately 1°C warmer than NA.
    - Daily maximum temperatures on the TSF can be up to 11°C warmer than NA during Year 27 for the maximum weekly summer condition when restoration plantings are relatively young; headwater reaches on the TSF are approximately 3°C warmer than NA by EOY112 for this condition. For the maximum weekly fall condition, the daily maximums are up to 5°C warmer for EOY27 and are at or below NA by EOY112.

- EFSFSR above Meadow Creek (upper EFSFSR):
  - During operations model runs (EOY6 and EOY12) and post-closure model runs (EOY18 and beyond):
    - Upstream of Meadow Creek, the ModPRO2 results in temperatures that are the same as the NA in the upper EFSFSR because no disturbance is proposed in this area except the worker housing facility and Burntlog Route, which do not affect shade near the EFSFSR.
- Downstream of the confluence of Meadow Creek and EFSFSR:
  - During operations (EOY6 and EOY12) and post-closure (EOY18 and beyond):
    - For the ModPRO2, simulated maximum and average stream temperatures in the EFSFSR between Meadow Creek and YPP backfill are at or below NA for all simulated mine years and seasons.
    - Within or downstream of the YPP area:
      - Simulated averages are within plus or minus 0.5 °C of NA in the maximum weekly summer condition, with temperatures less than NA by EOY52. In the maximum weekly fall condition, simulated averages are less than NA for every simulation year.
      - Daily maximum temperatures in the summer and fall conditions in the tunnel around YPP are up to 2.5°C warmer than NA for EOY6. At the model terminus downstream of Sugar Creek, daily maximum temperatures are 0.5°C to 1°C warmer than NA for EOY6.
      - Once Stibnite Lake has been constructed by EOY12, maximum stream temperatures in the EFSFSR downstream of the lake are within 0.5°C of NA; by EOY52, maximum temperatures are less than NA.
      - Daily maximum temperatures in the summer in the restored reaches on the YPP backfill upstream of Stibnite Lake for EOY12, 18, 22, and 27 are up to 1.5°C warmer than NA in the summer; maximum summer temperatures are at or below NA by EOY32 in this area. In the fall, daily maximum temperatures are less than 1°C warmer than NA in the EOY12 model simulation, and by EOY18, maximum temperatures in the fall are at or below NA.

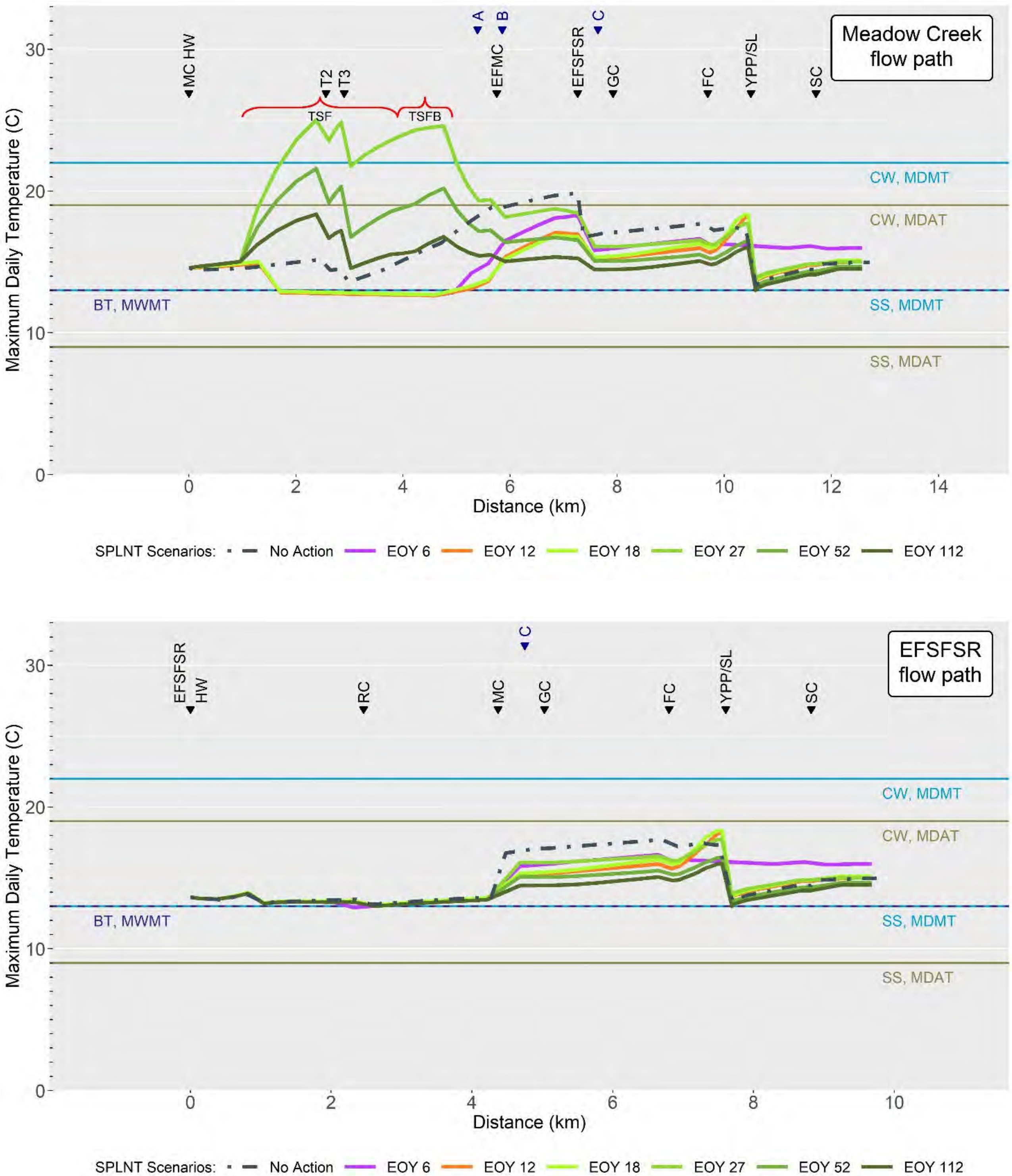


Figure 3-1. Simulated Maximum Temperatures for the Maximum Weekly Summer Condition Compared to IDEQ Criteria for Meadow Creek (top panel) and EFSFSR Flow Paths

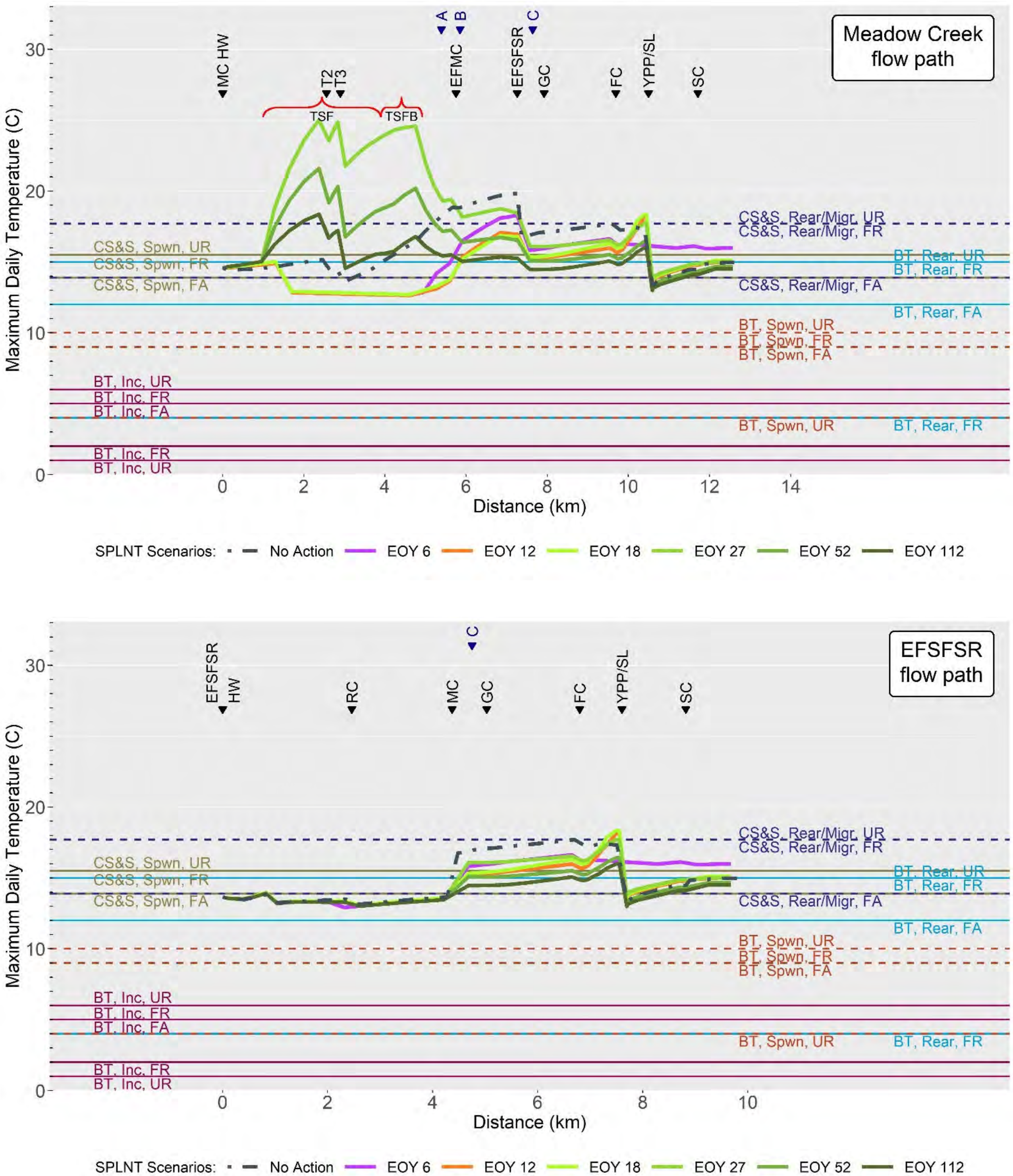
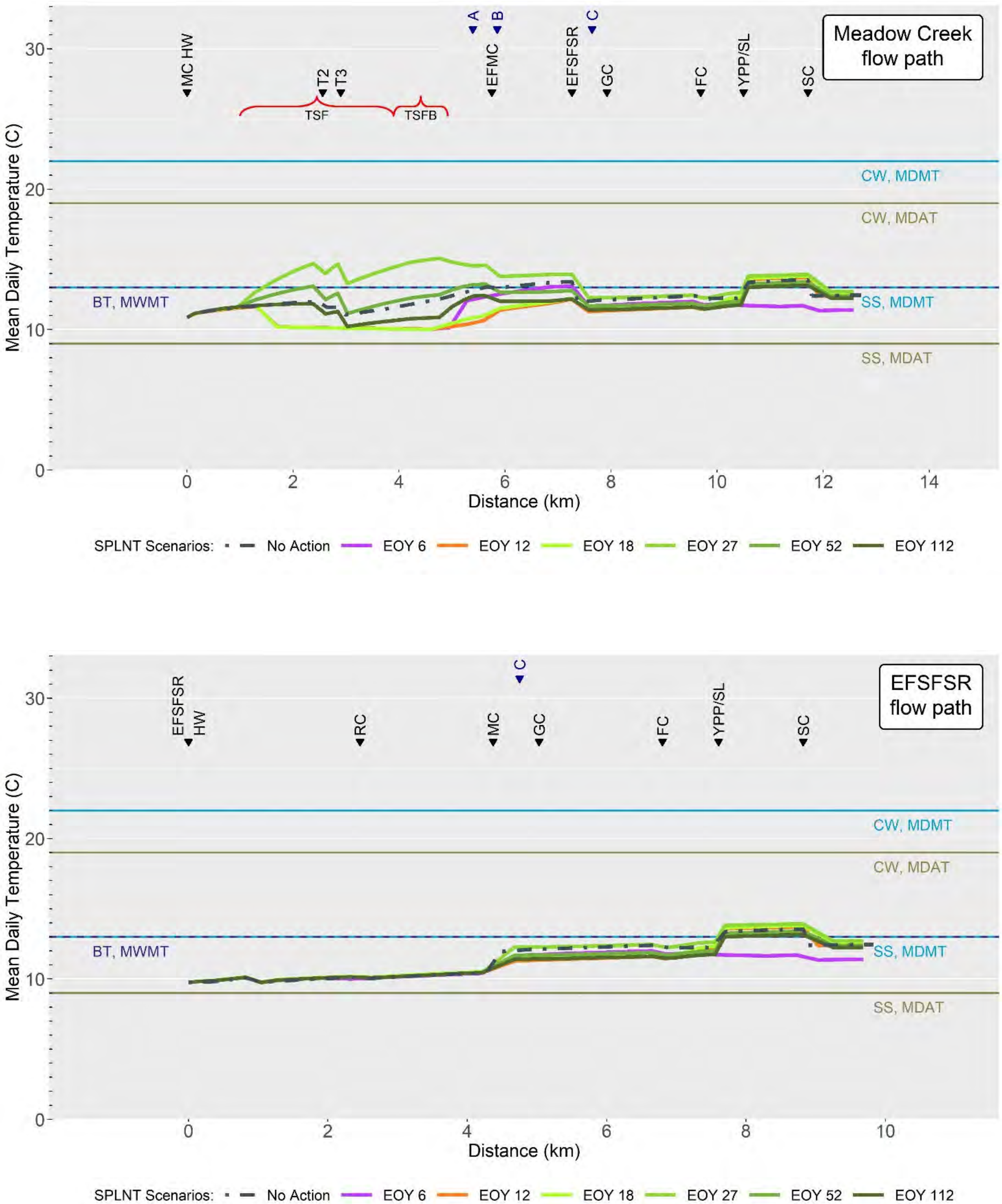


Figure 3-2. Simulated Maximum Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths



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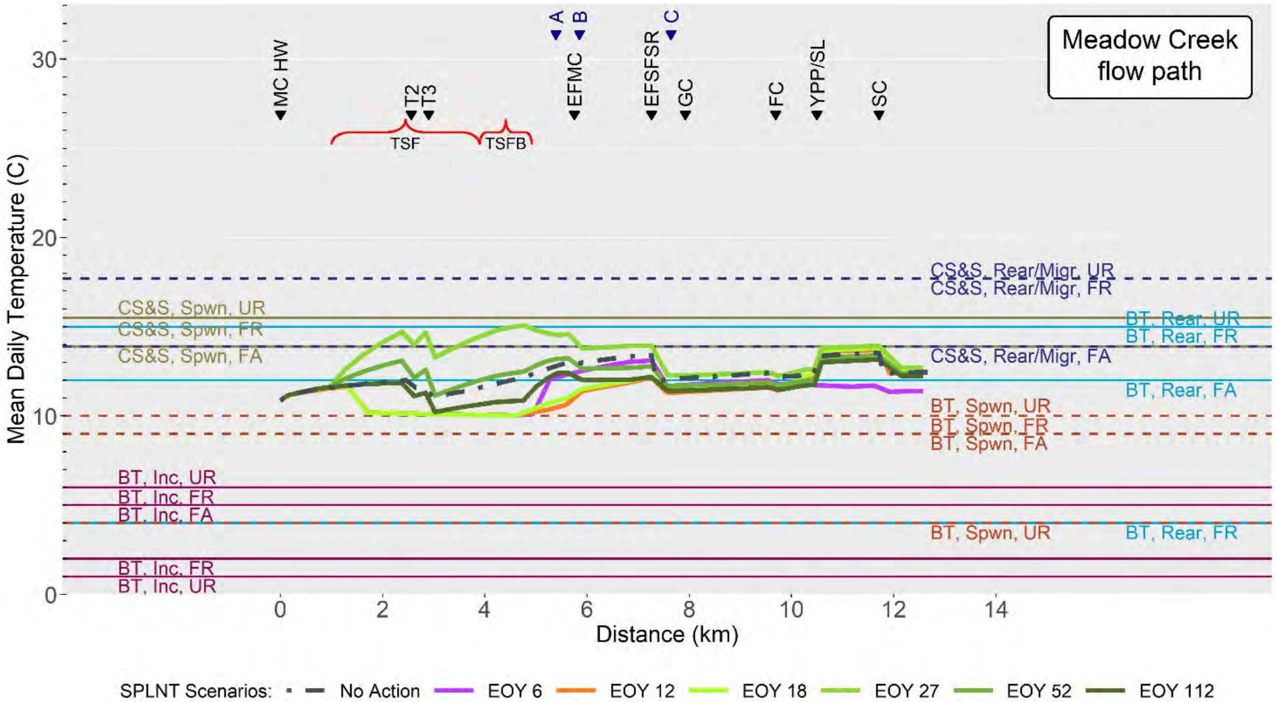


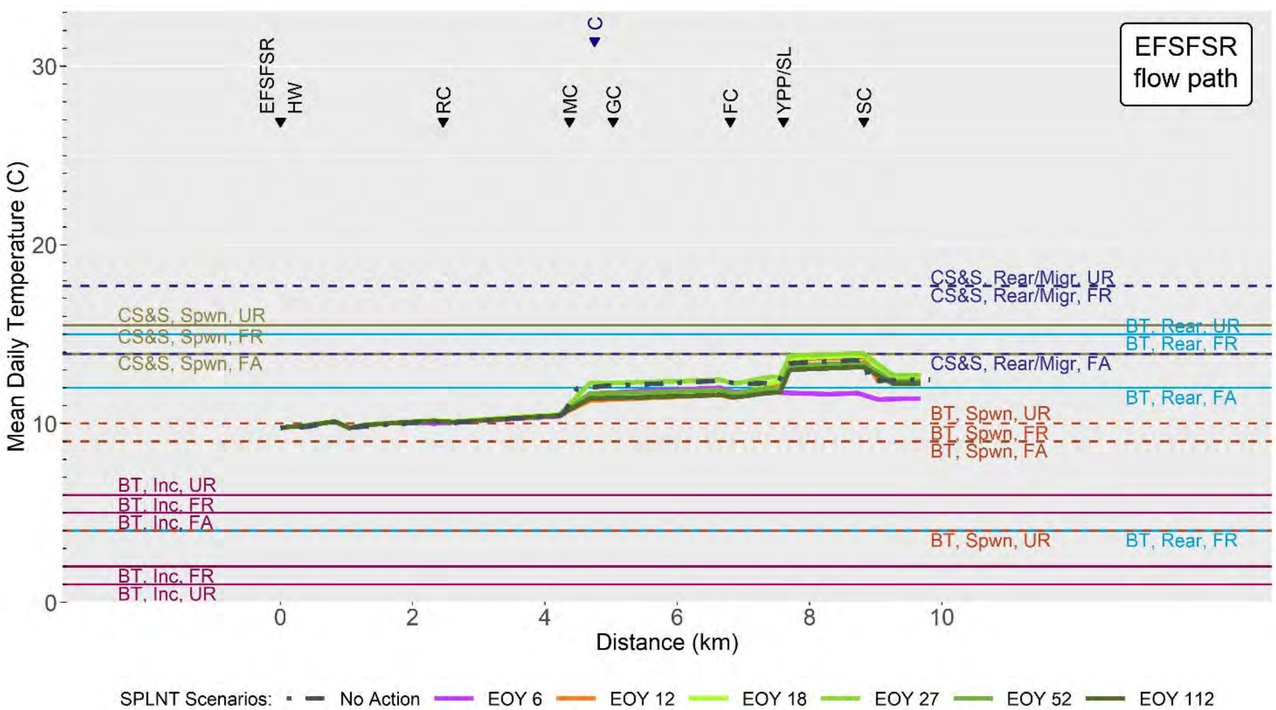


Figure 3-4. Simulated Average Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths

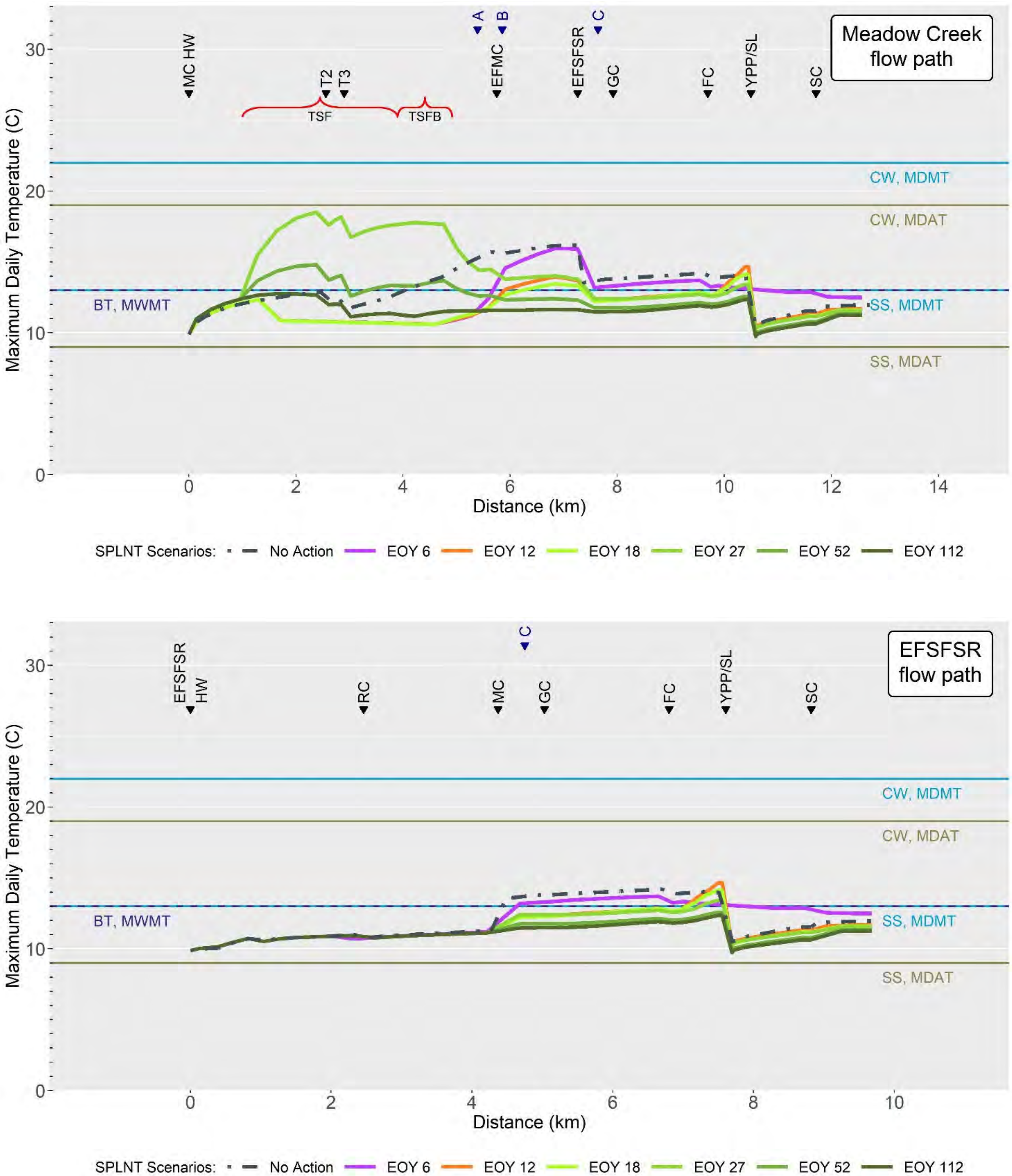
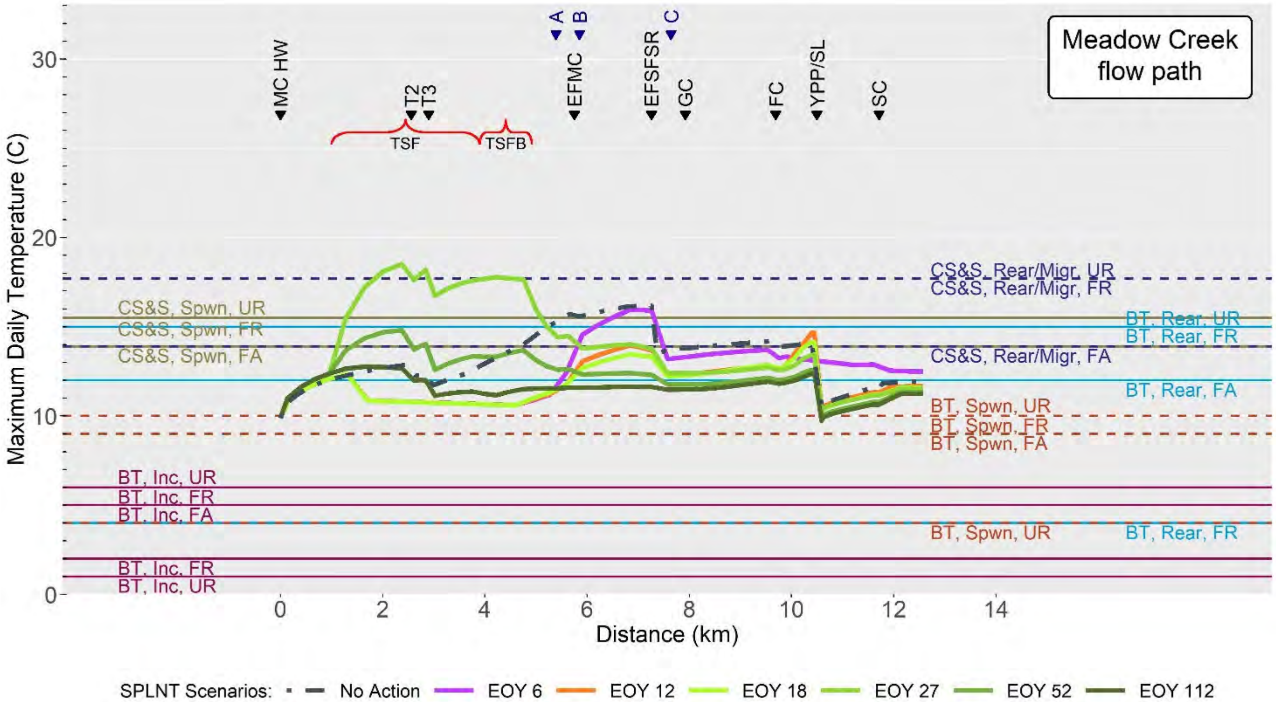


Figure 3-5. Simulated Maximum Temperatures for the Maximum Weekly Fall Condition Compared to IDEQ Criteria for Meadow Creek and EFSFSR Flow Paths



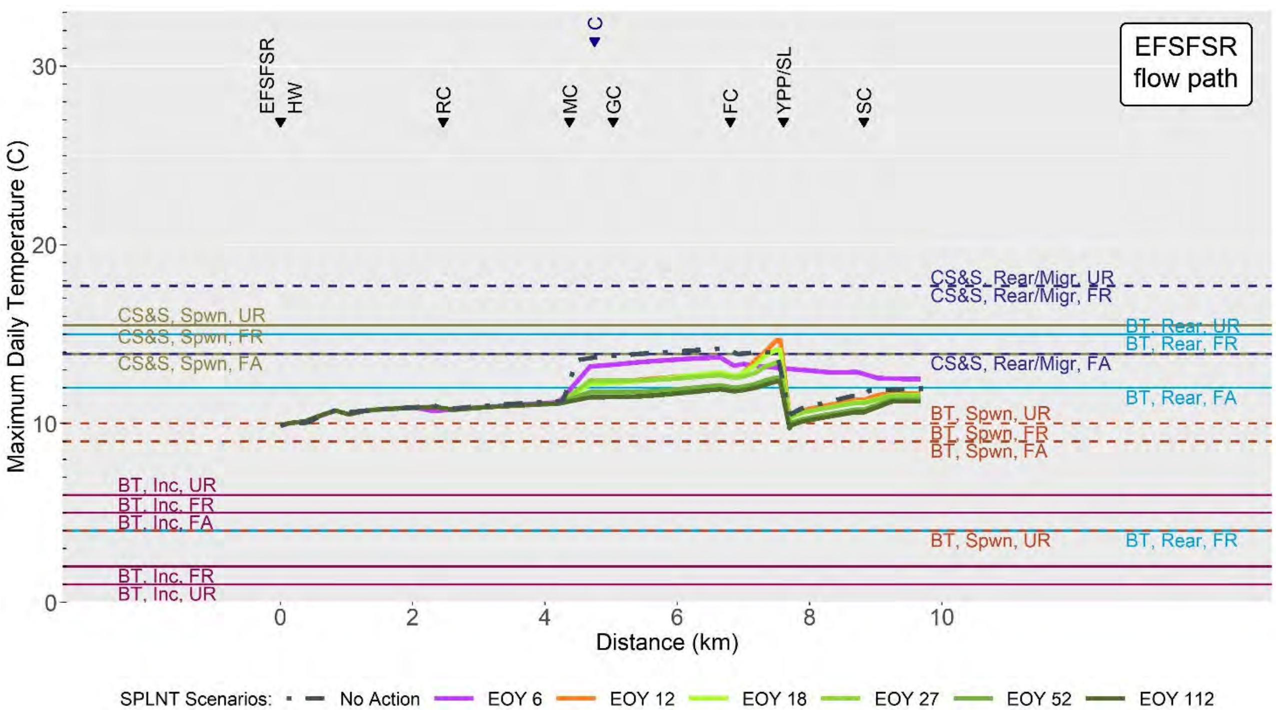
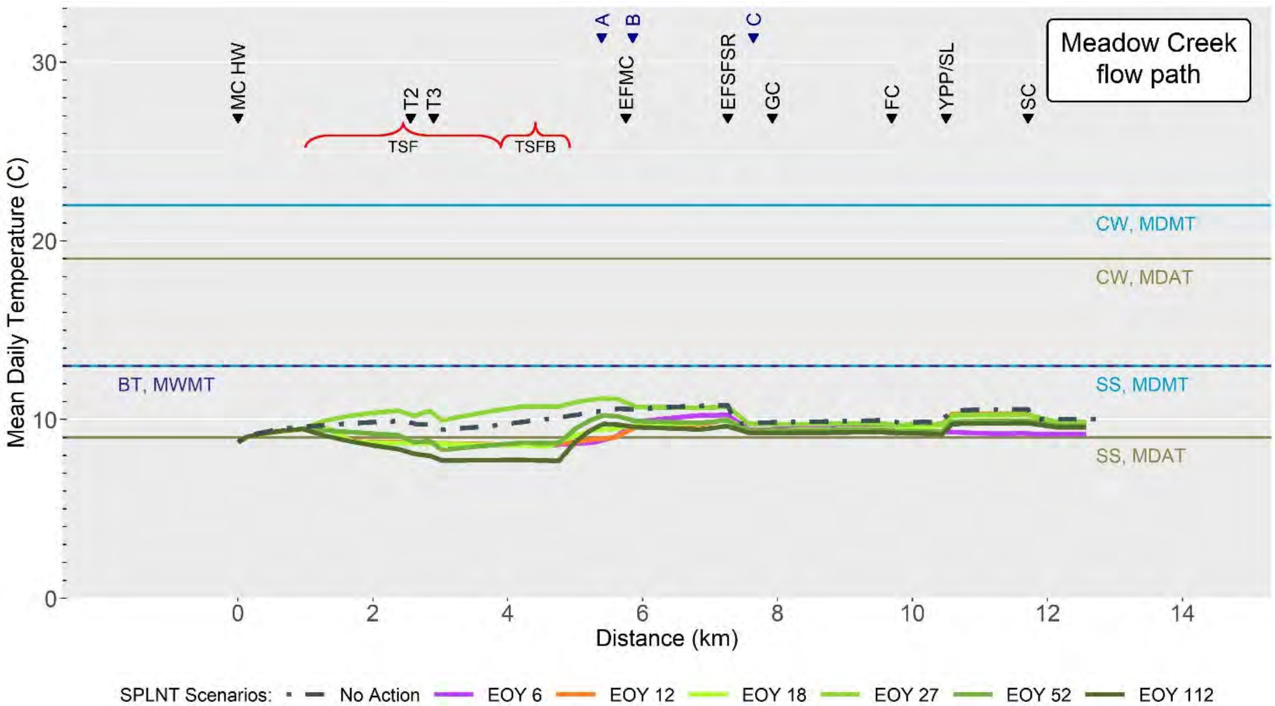


Figure 3-6. Simulated Maximum Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths



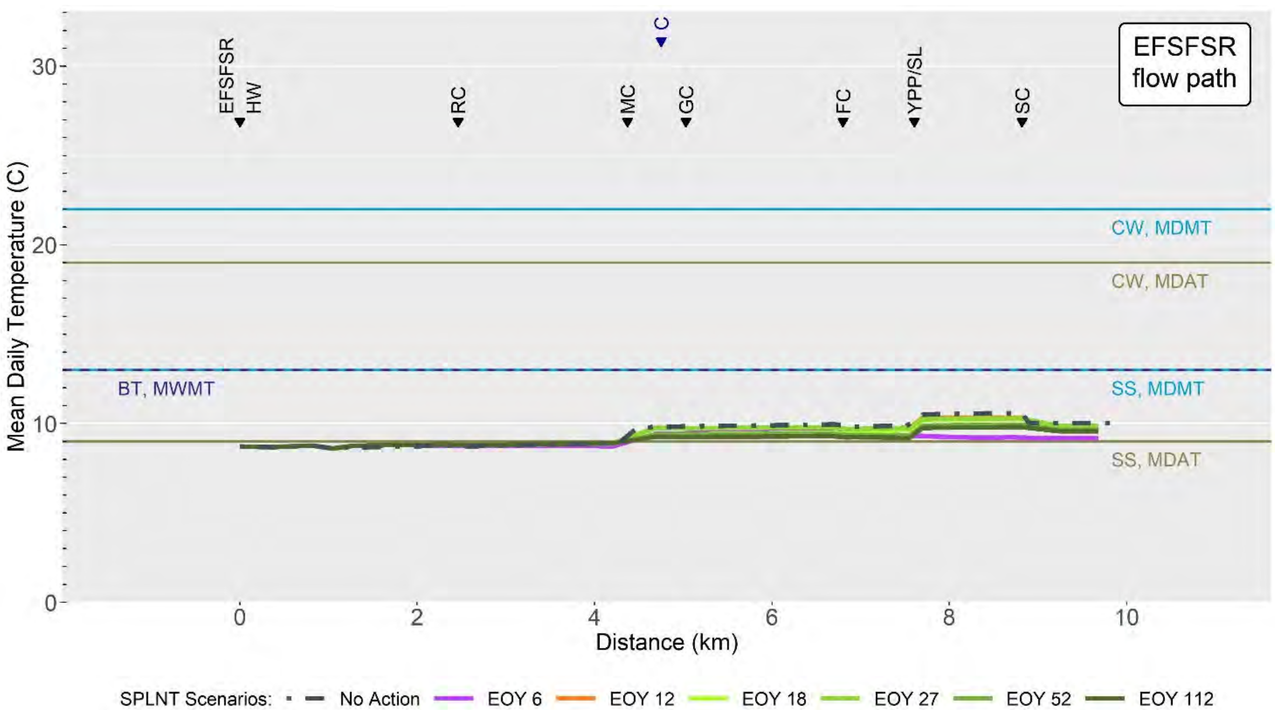
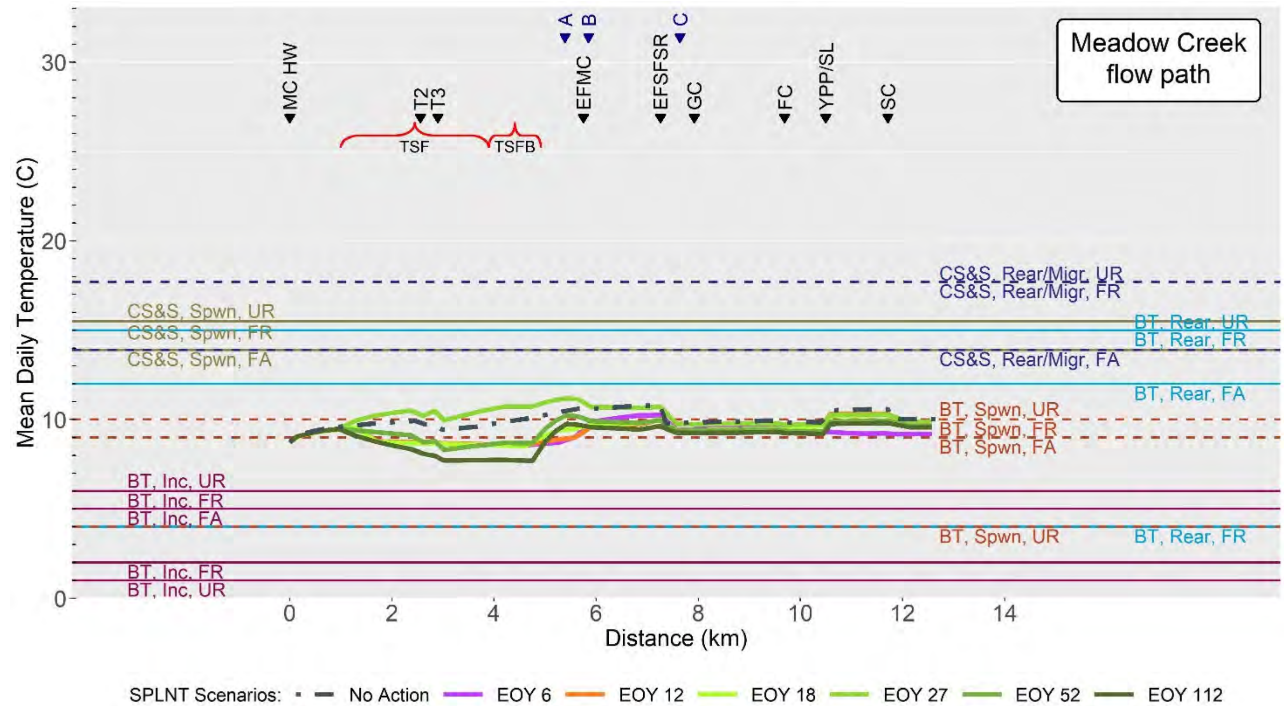


Figure 3-7. Simulated Average Temperatures for the Maximum Weekly Fall Condition Compared to IDEQ Criteria for Meadow Creek and EFSFSR Flow Paths



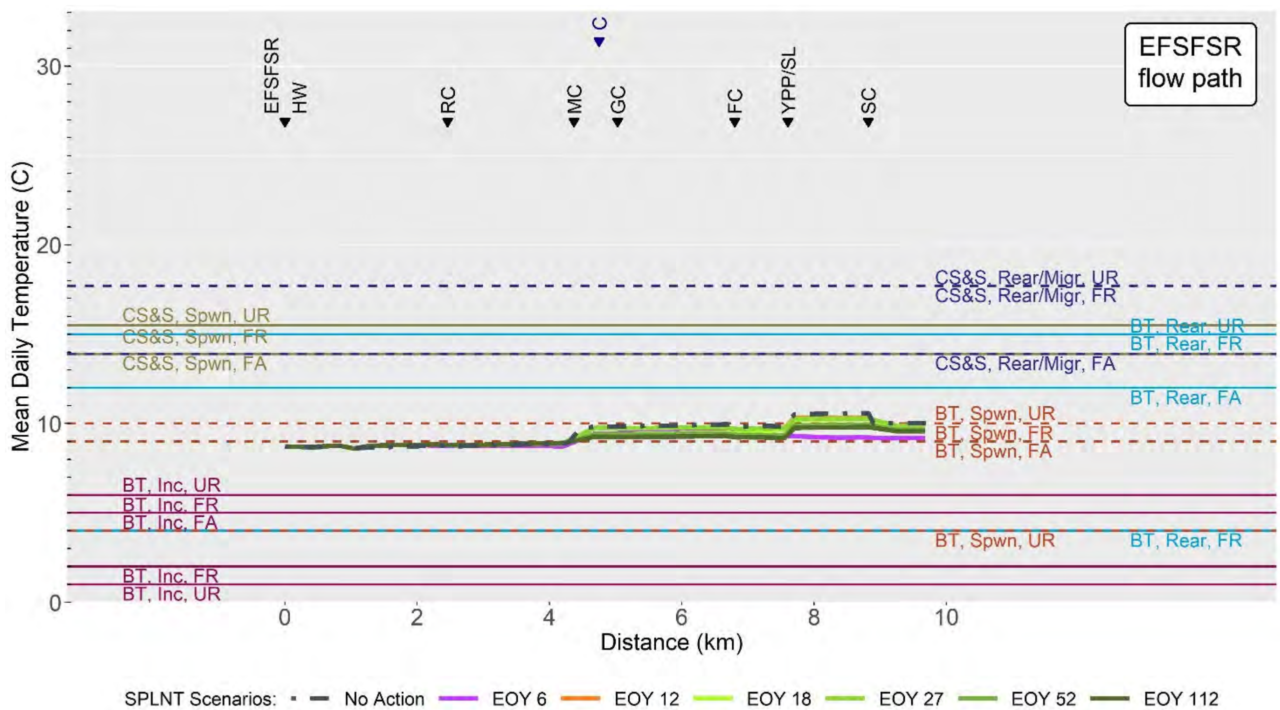
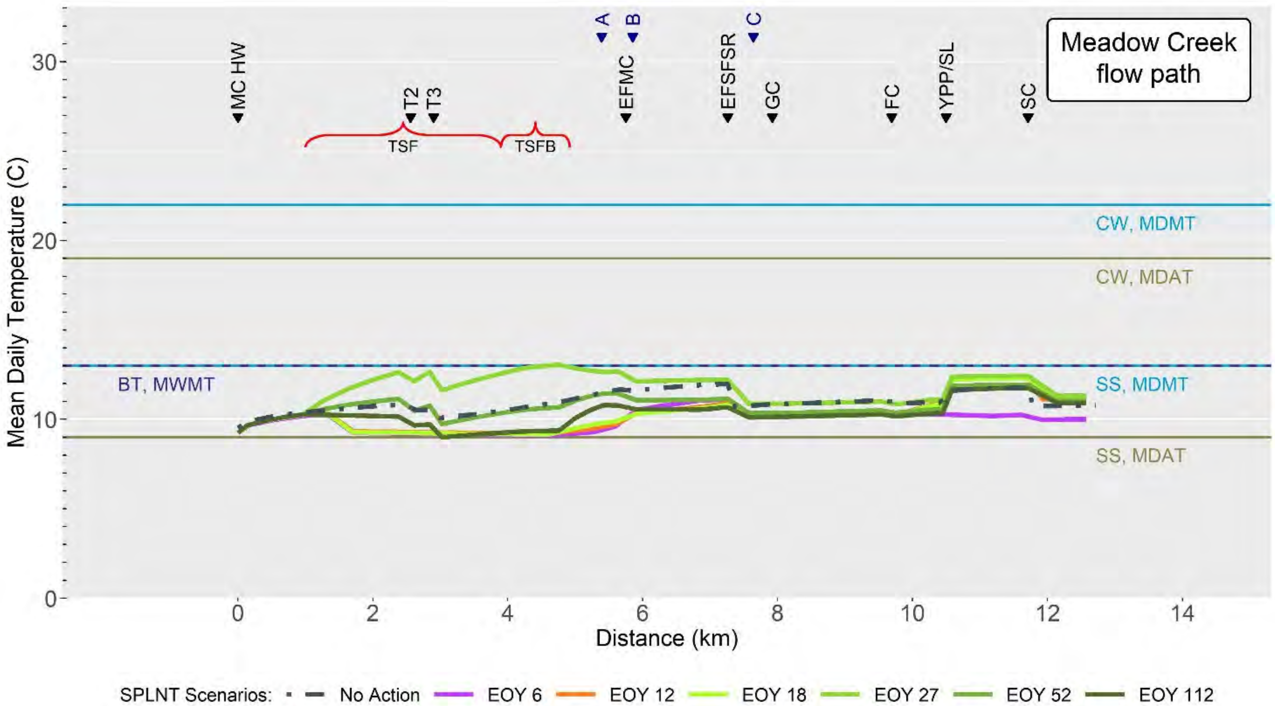


Figure 3-8. Simulated Average Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths



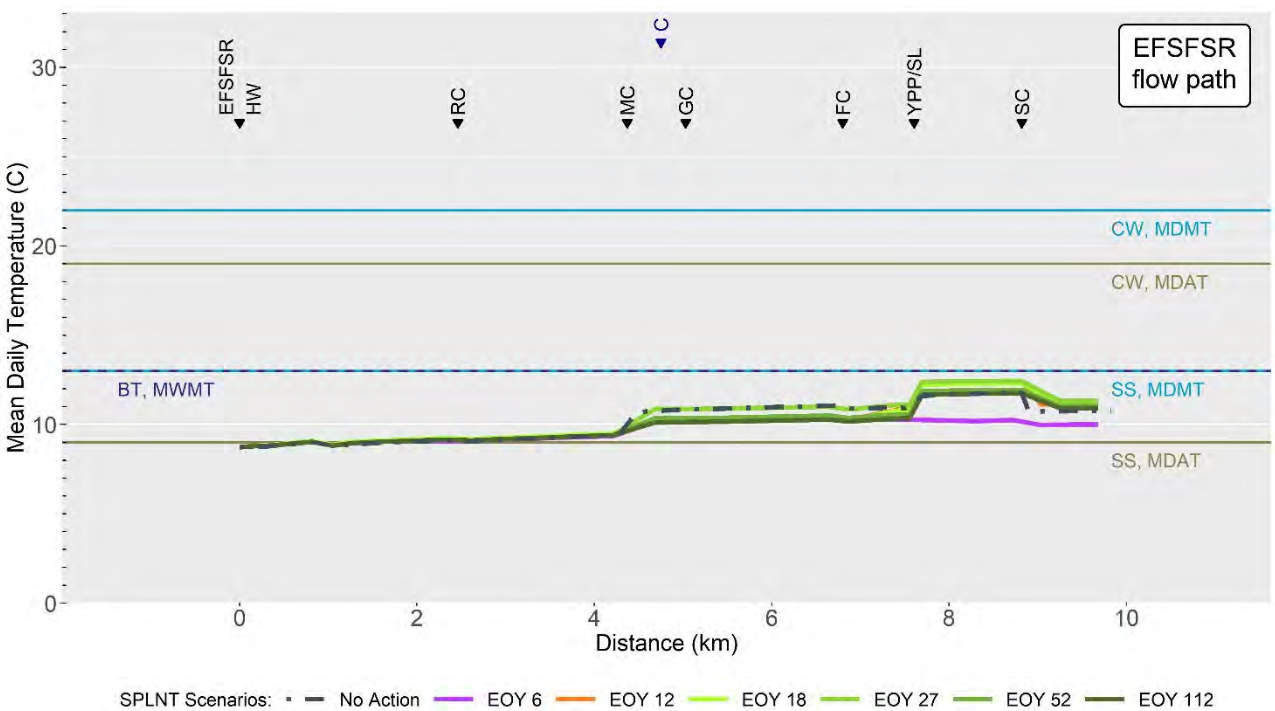


Figure 3-9. Simulated Average Temperatures for the Mean August Condition Compared to IDEQ Criteria for Meadow Creek and EFSFSR Flow Paths

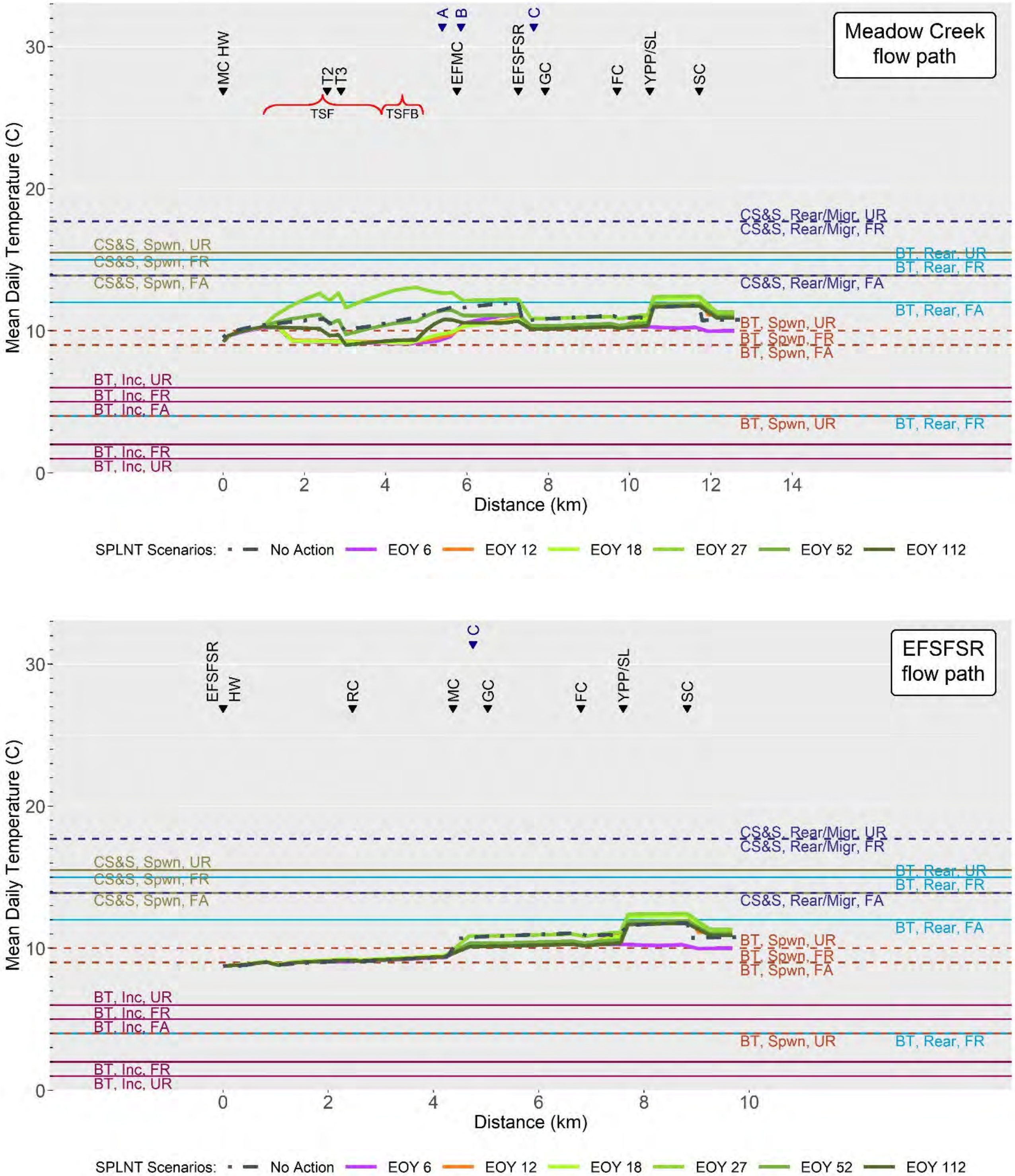


Figure 3-10. Simulated Average Temperatures for the Mean August Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths

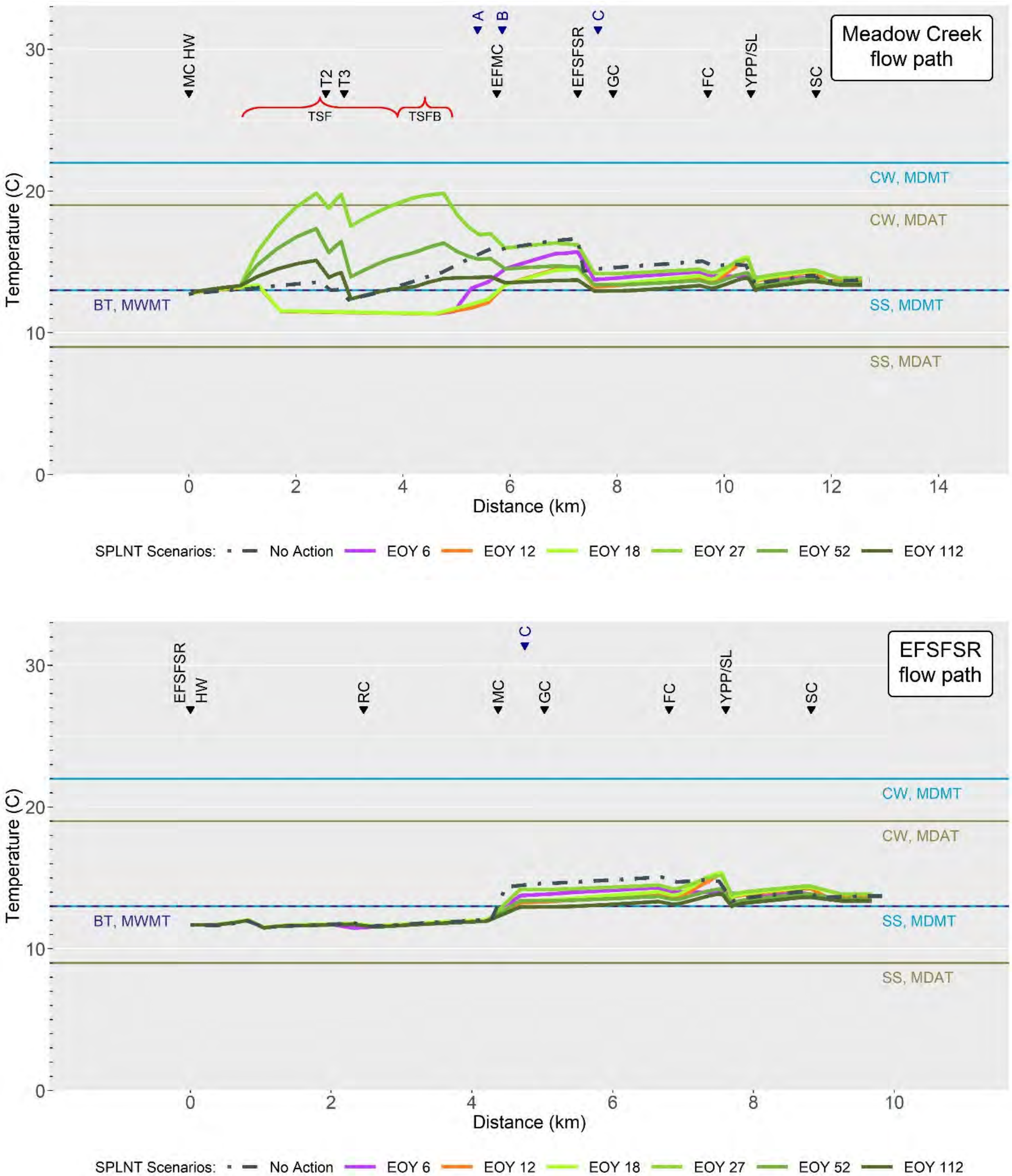


Figure 3-11. Simulated "Constant" Temperatures for the Maximum Weekly Summer Condition Compared to IDEQ Criteria for Meadow Creek and EFSFSR Flow Paths

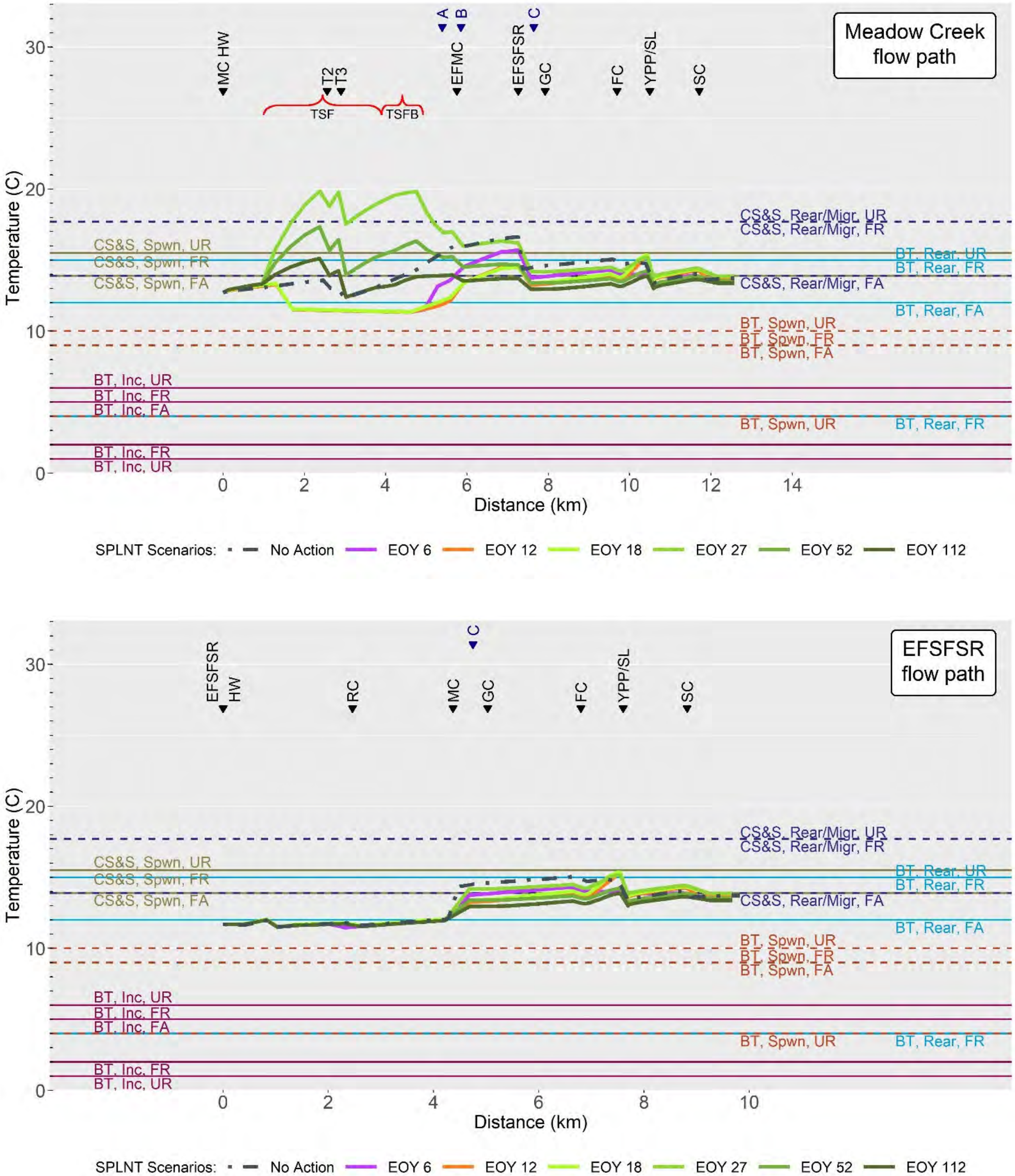


Figure 3-12. Simulated "Constant" Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths

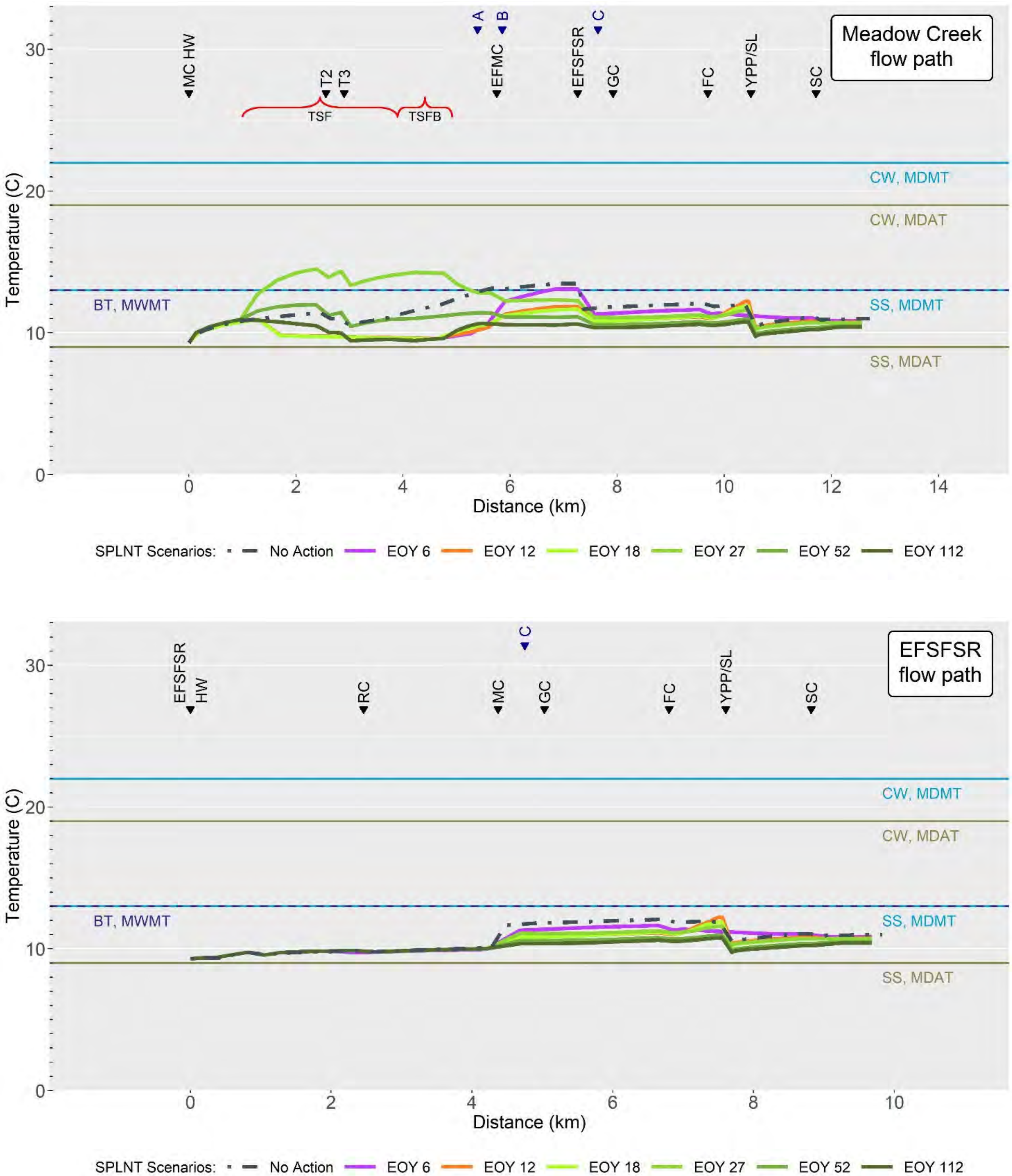


Figure 3-13. Simulated "Constant" Temperatures for the Maximum Weekly Fall Condition Compared to IDEQ Criteria for Meadow Creek and EFSFSR Flow Paths

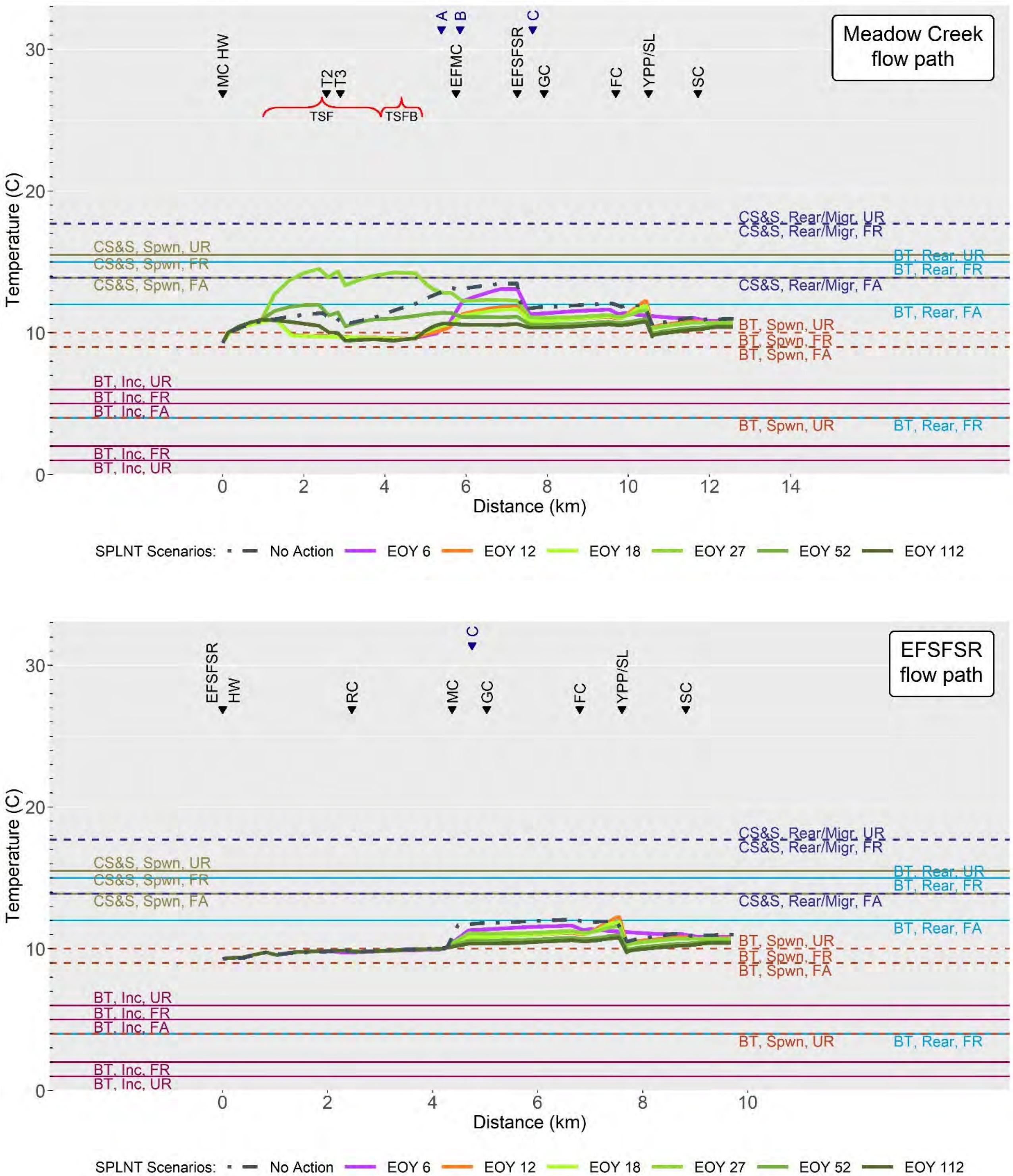


Figure 3-14. Simulated "Constant" Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for Meadow Creek and EFSFSR Flow Paths

3.1.2 West End Creek and Fiddle Creek

The longitudinal profile figures shown in Figure 3-15 through Figure 3-28 compare the ModPRO2 and NA, which is shown for reference on each figure as a dashed navy-blue line. Both the West End and Fiddle Creek flow paths end at the downstream end of the SPLNT model domain just downstream of the Sugar Creek and EFSFSR confluence. One flow path extends to the headwaters of West End Creek and the other extends to the headwaters of Fiddle Creek. These profiles separately display either the simulated average or maximum or “constant” (the average of the mean and maximum) temperature for the maximum weekly summer, maximum weekly fall, and mean August conditions along with the IDEQ and USFS thermal criteria. Simulated maximum temperatures for both the maximum weekly summer and fall conditions are more sensitive than simulated averages, and the relative change in average temperatures is less pronounced. The longitudinal temperature profiles for West End and Fiddle Creek show the following patterns (<u>if no distinction is made between simulated maximums and simulated averages, then the statement applies to both; if distinction is warranted then the text describes these separately</u>):

- West End Creek Flow Path:
  - During operations model runs (EOY6 and EOY12):
    - During mining of West End pit, stream flow upstream of the pit is diverted in an open channel and simulated maximum temperatures are warmer than NA by 6°C to 9°C depending on the season simulated. Daily average temperatures are 1°C to 3°C warmer. West End Creek is too steep and small to support fish now and is unlikely to support fish in the future.
    - Around and downstream of the pit, low flows are diverted in a pipe, and the stream temperatures decrease during operations.
    - In Sugar Creek, simulated maximums and averages are similar to NA for all mine years and seasons simulated. The summary of results for EFSFSR downstream of Sugar Creek is provided in Section 3.1.1.
  - Post-closure model runs (EOY18 and beyond):
    - West End pit lake is not predicted to discharge under the ModPRO2. A small discharge from West End pit lake has been assumed to provide a headwater flow for the model to West End Creek downstream of the pit lake. This assumption results in simulated temperatures that are higher than NA near the pit lake.
    - In Sugar Creek, simulated maximums and averages are similar to NA for all mine years and seasons simulated. The summary of results for EFSFSR downstream of Sugar Creek is provided in Section 3.1.1.
- Fiddle Creek Flow Path:
  - During operations model runs (EOY6 and EOY12) and early post closure model runs (EOY24)
    - The Fiddle Growth Media Stockpile disturbs the lower reaches of Fiddle Creek until EOY24 when the area is restored and planted. Upstream of the Stockpile, Fiddle Creek is simulated using the NA configuration and reach characteristics. At the upper end of the Stockpile, Fiddle Creek is routed underneath, which has the effect of fully shading the water. As both conditions provide abundant shade, the simulated stream temperatures in Fiddle Creek are similar during this period for ModPRO2 and NA.
    - The summary of results for EFSFSR downstream of Fiddle Creek is provided in Section 3.1.1.

- Post-closure model runs (EOY25 and beyond):
  - Simulated maximum temperatures are approximately 0.5°C warmer in the years immediately following restoration and planting of lower Fiddle Creek during the maximum weekly summer condition; temperatures are within 0.2°C of NA by EOY52. Fall maximums are approximately 0.7°C warmer than NA in the years following restoration and planting and are within 0.5°C of NA by EOY52.
  - Simulated average temperatures are approximately 0.5°C warmer in the years immediately following restoration and planting of lower Fiddle Creek during the maximum weekly summer condition; temperatures are within 0.4°C of NA by EOY52. Fall averages are approximately 0.2°C warmer than NA in the years following planting are within 0.1°C of NA by EOY32.
  - The summary of results for EFSFSR downstream of Fiddle Creek is provided in Section 3.1.1.

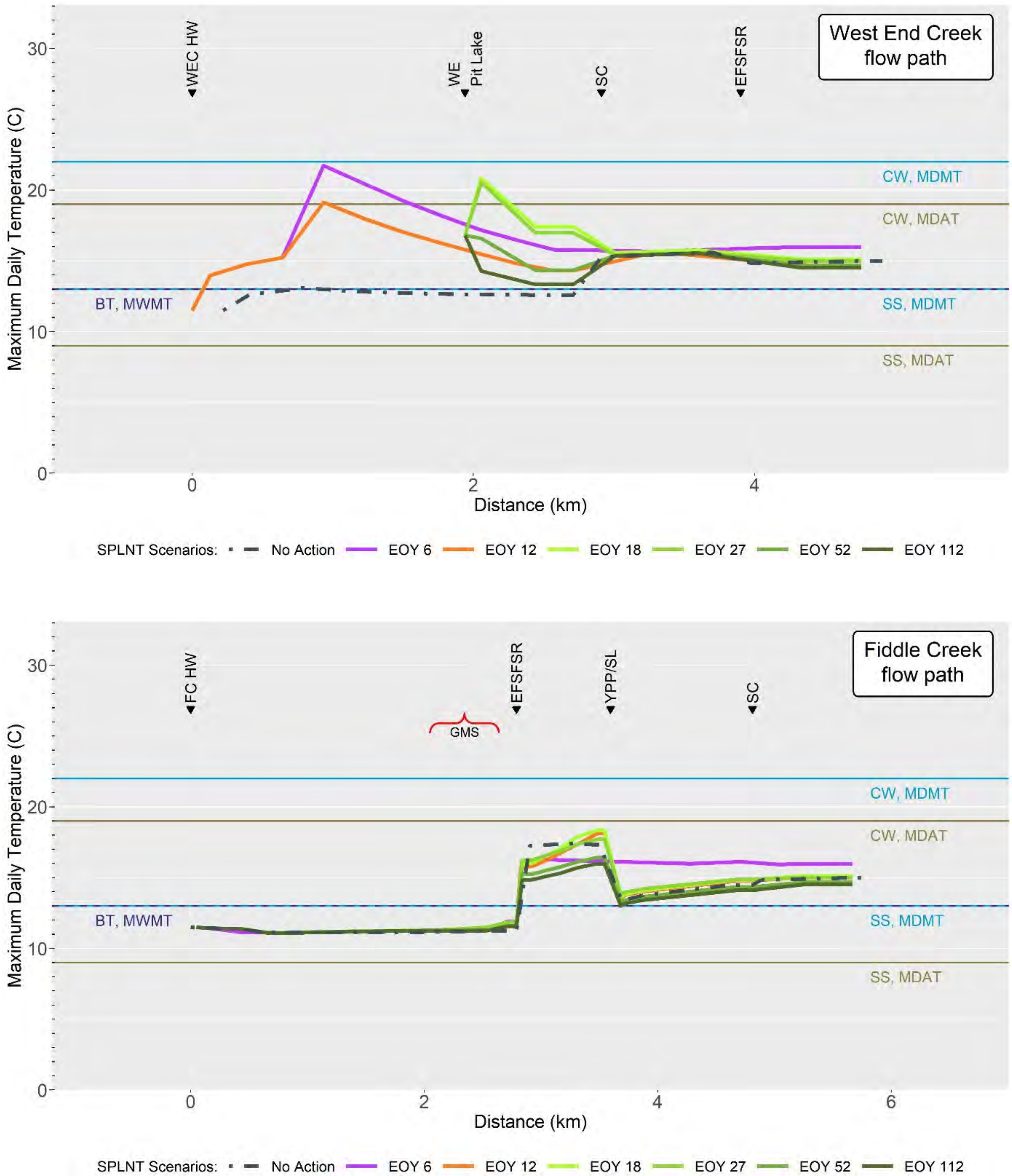
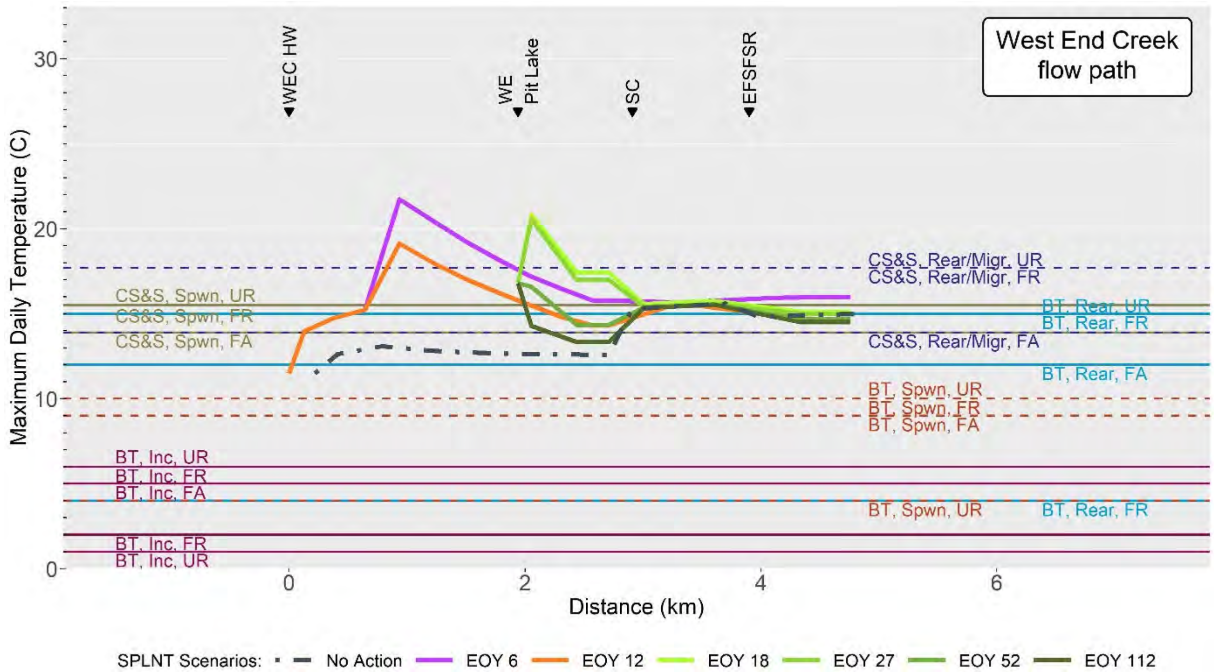


Figure 3-15. Simulated Maximum Temperatures for the Maximum Weekly Summer Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths



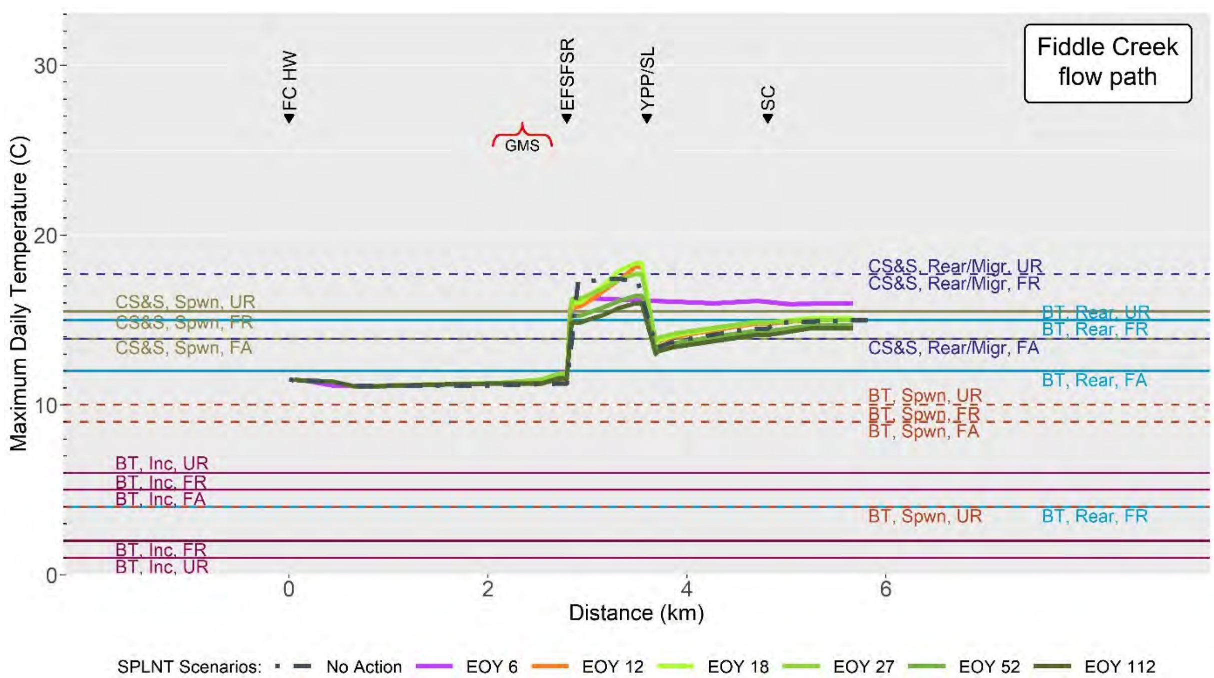


Figure 3-16. Simulated Maximum Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for West End and Fiddle Flow Paths

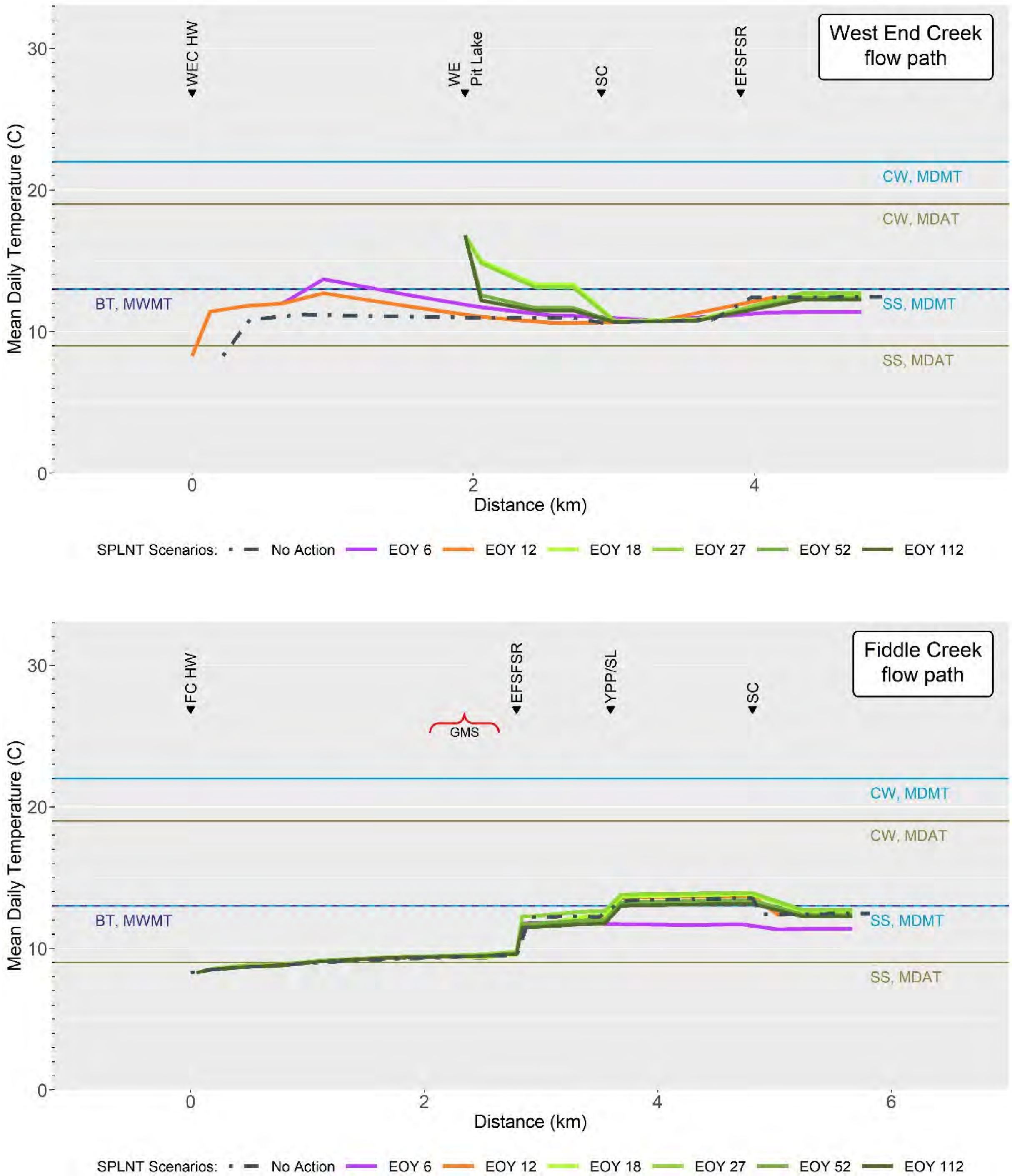


Figure 3-17. Simulated Average Temperatures for the Maximum Weekly Summer Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths

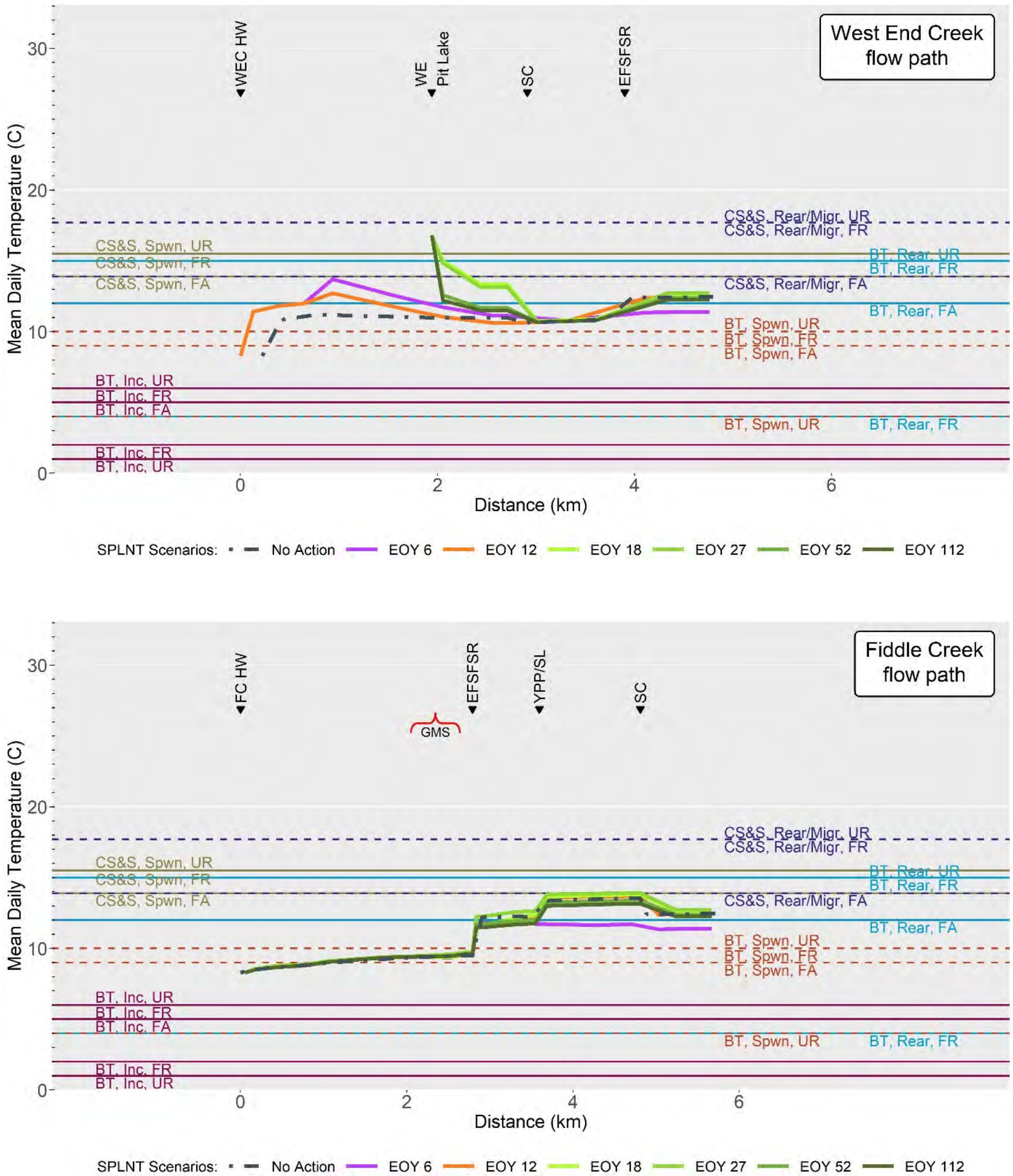


Figure 3-18. Simulated Average Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for West End and Fiddle Flow Paths

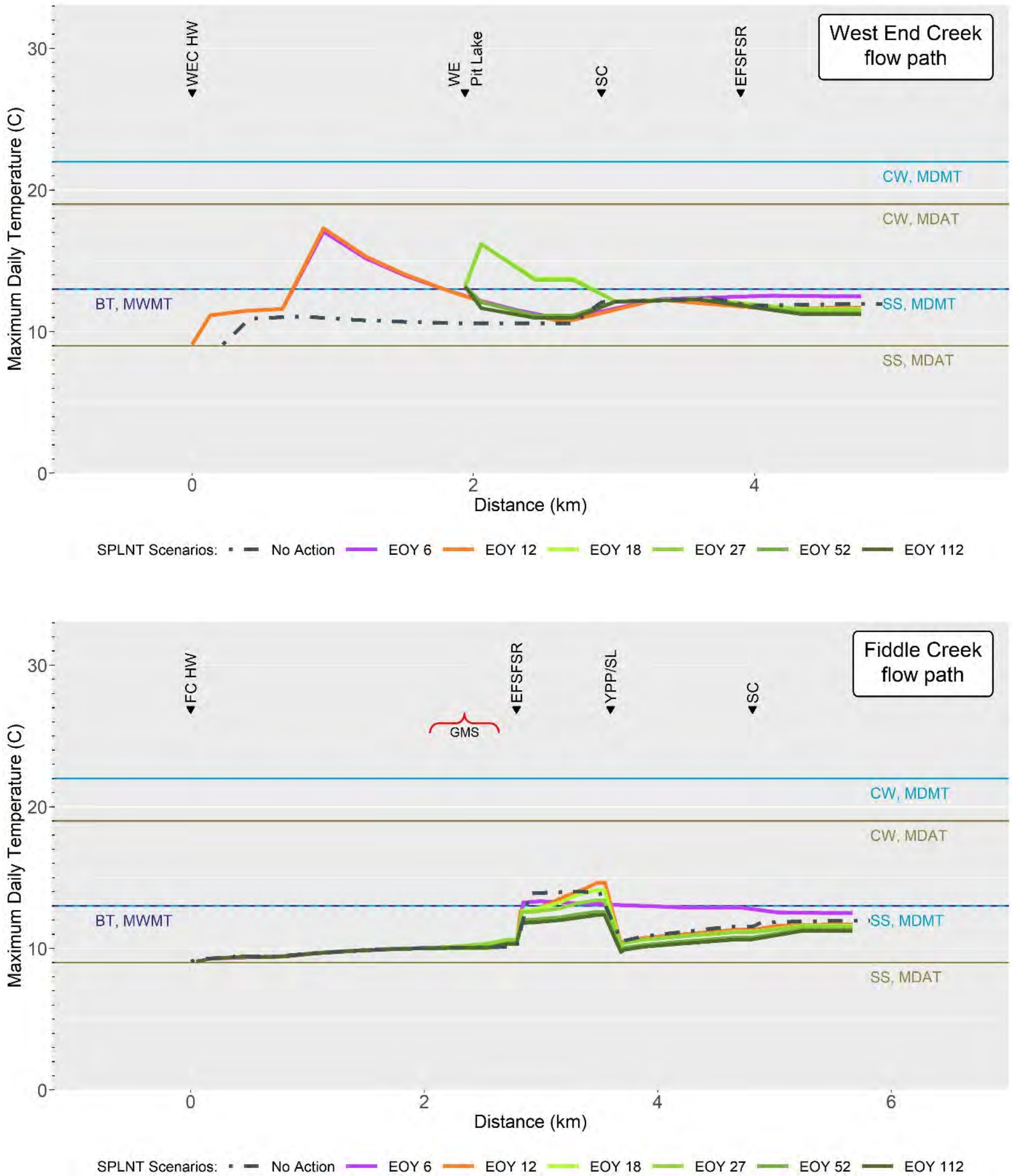


Figure 3-19. Simulated Maximum Temperatures for the Maximum Weekly Fall Condition Comparison to IDEQ Criteria for West End and Fiddle Flow Paths

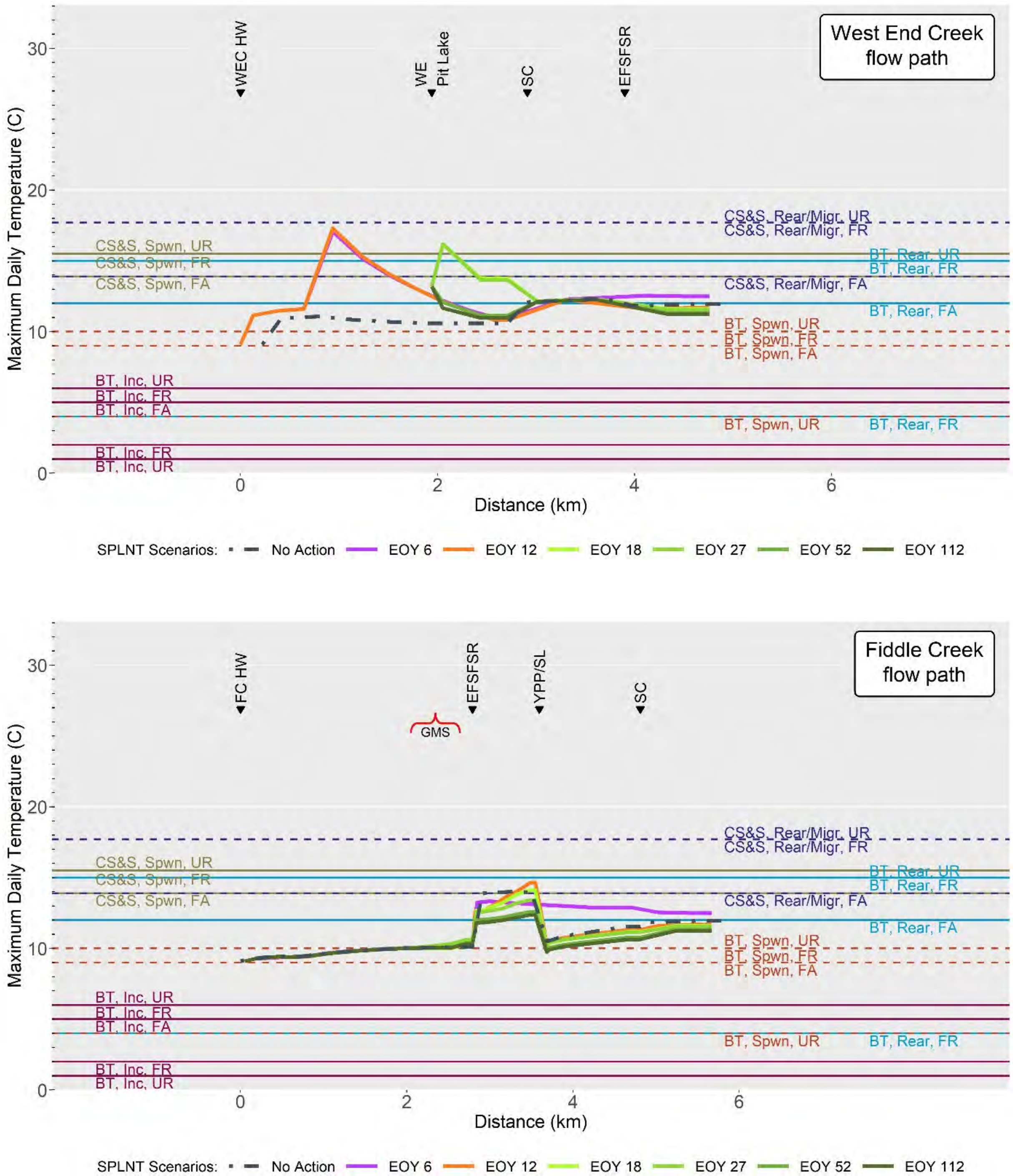
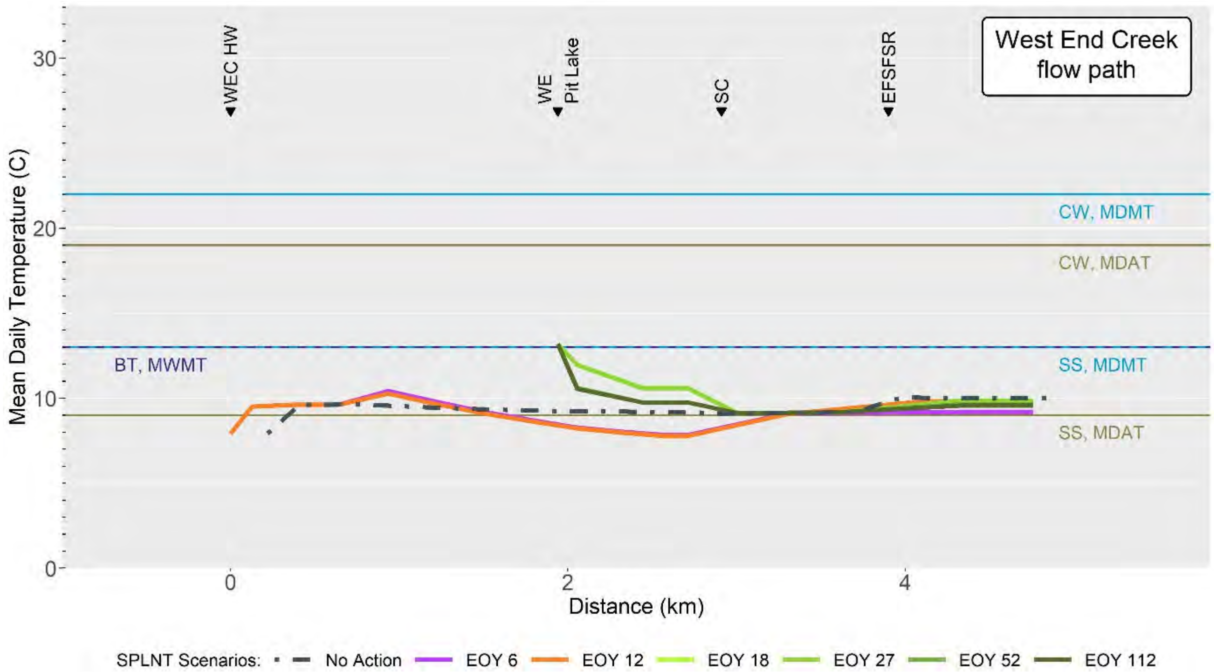


Figure 3-20. Simulated Maximum Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for West End and Fiddle Flow Paths



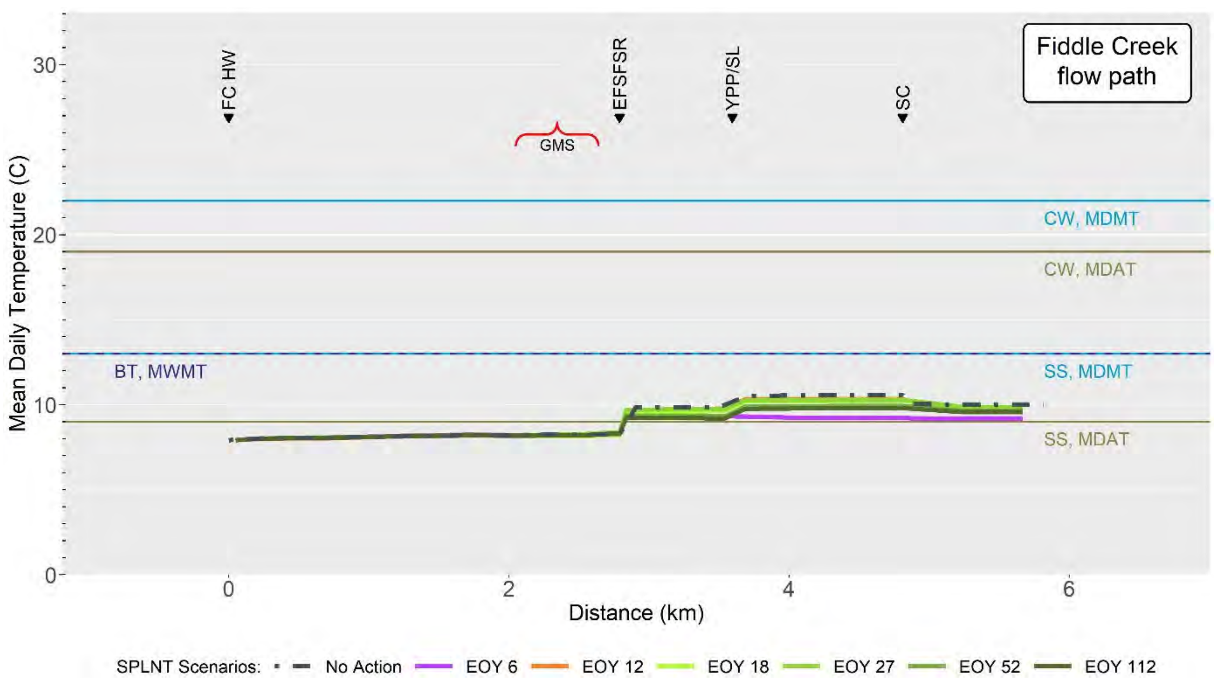
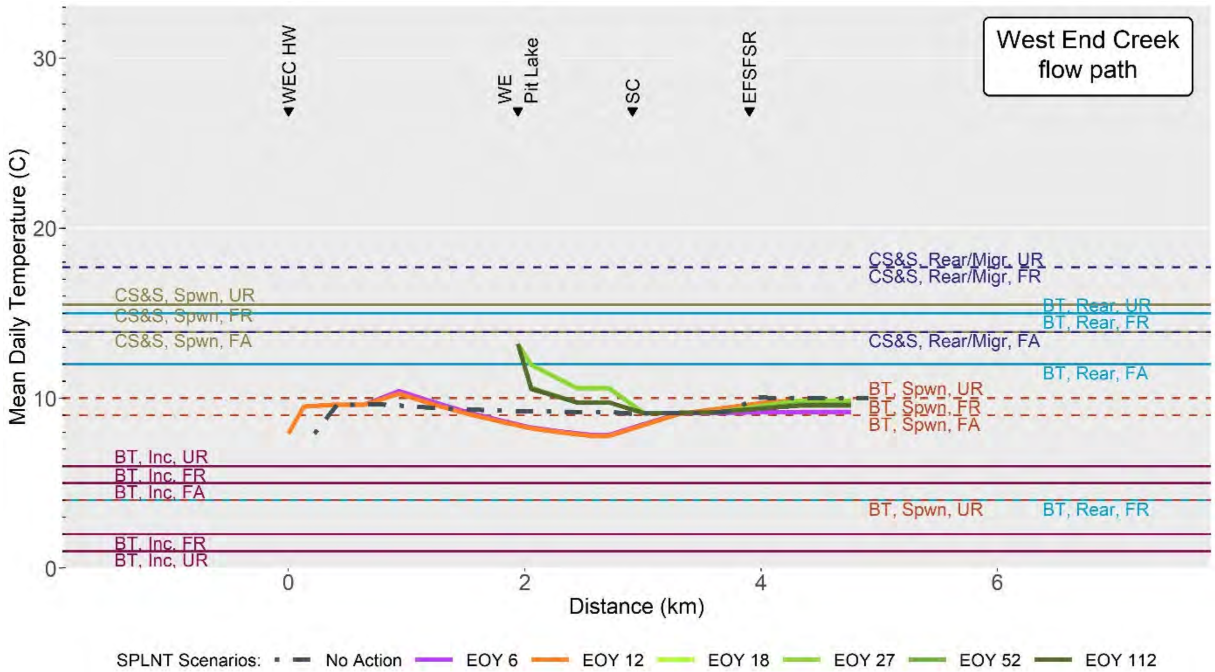


Figure 3-21. Simulated Average Temperatures for the Maximum Weekly Fall Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths



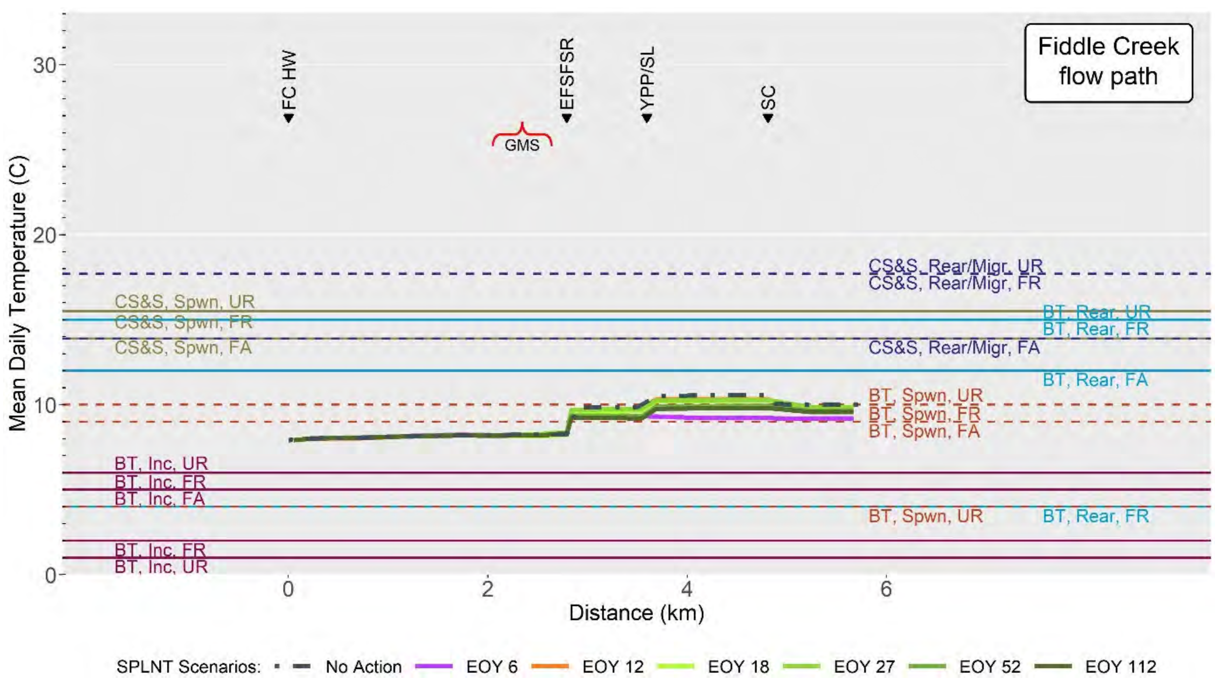
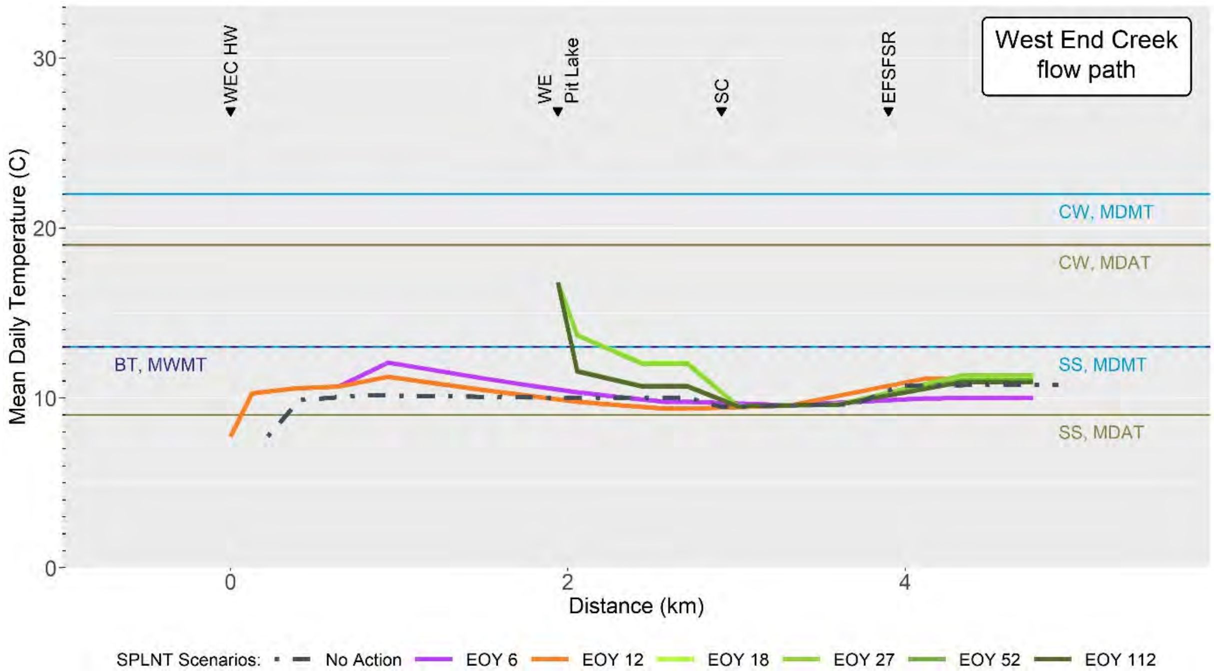


Figure 3-22. Simulated Average Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for West End and Fiddle Flow Paths



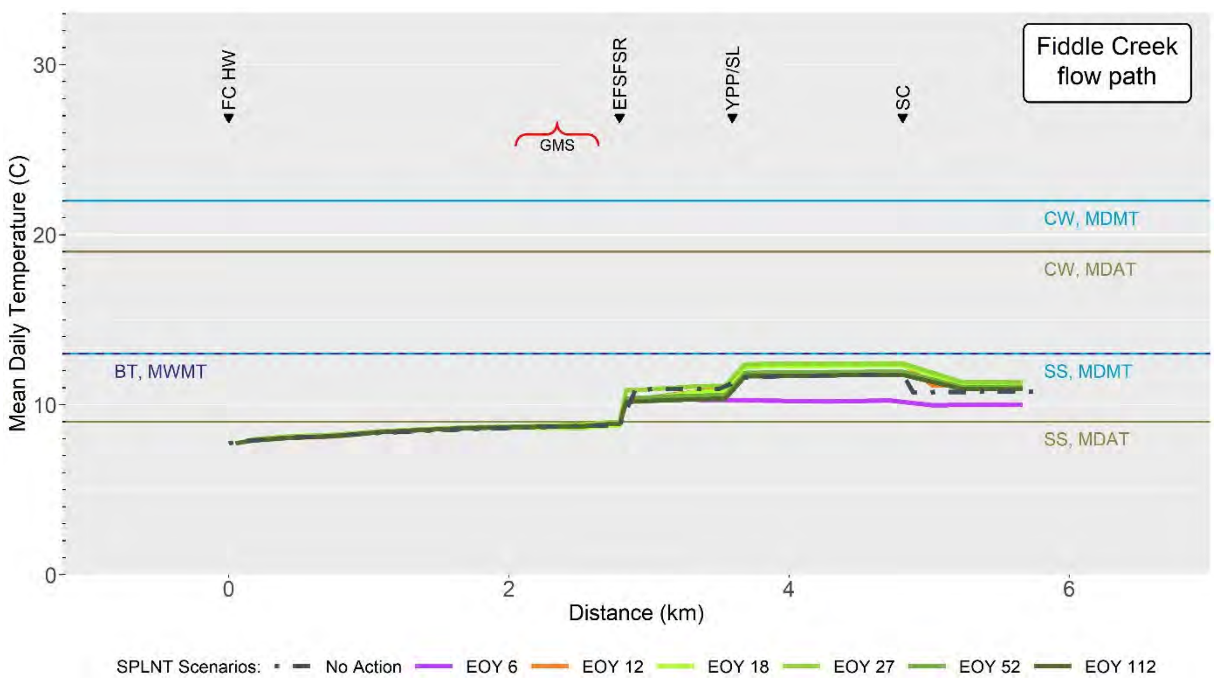
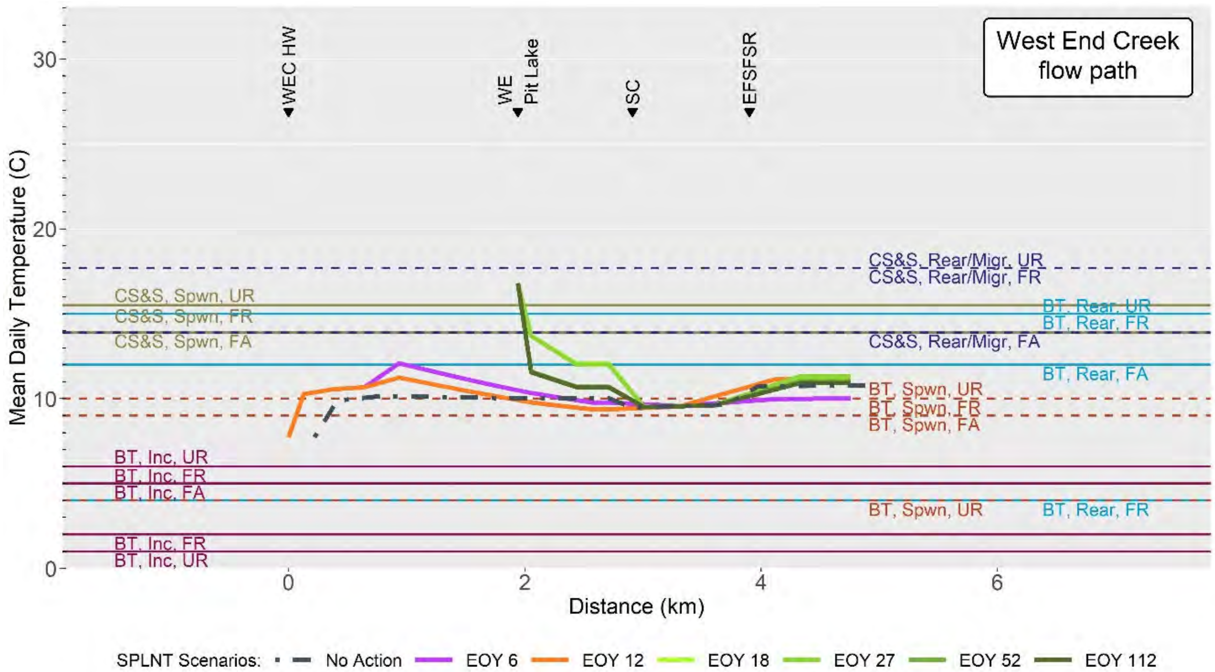


Figure 3-23. Simulated Average Temperatures for the Mean August Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths



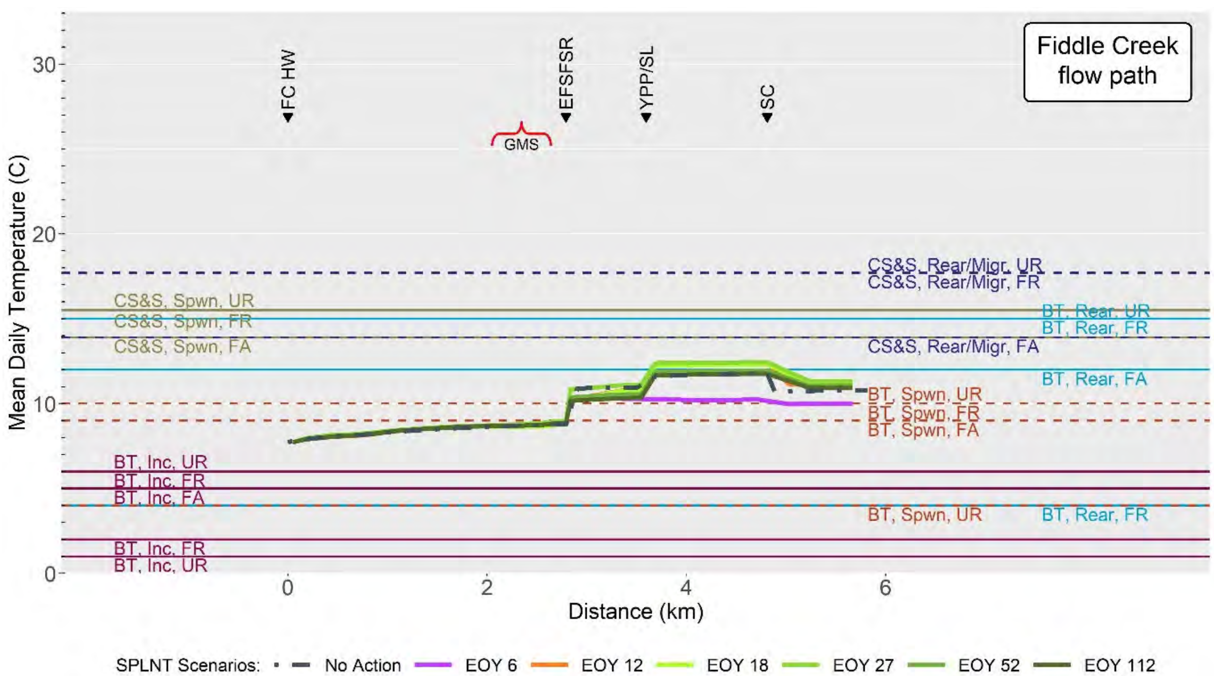


Figure 3-24. Simulated Average Temperatures for the Mean August Condition Comparison to USFS Criteria for West End and Fiddle Flow Paths

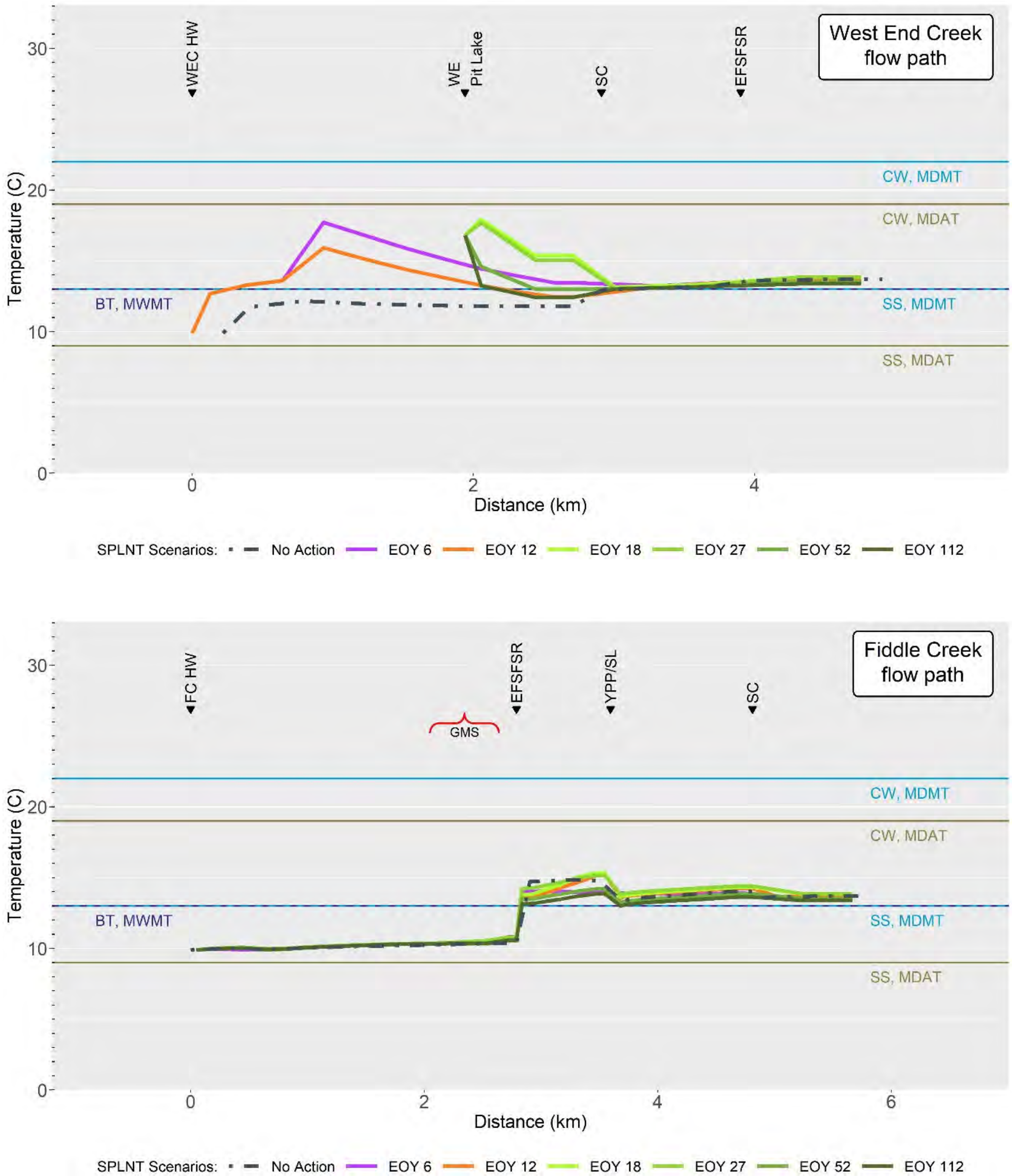
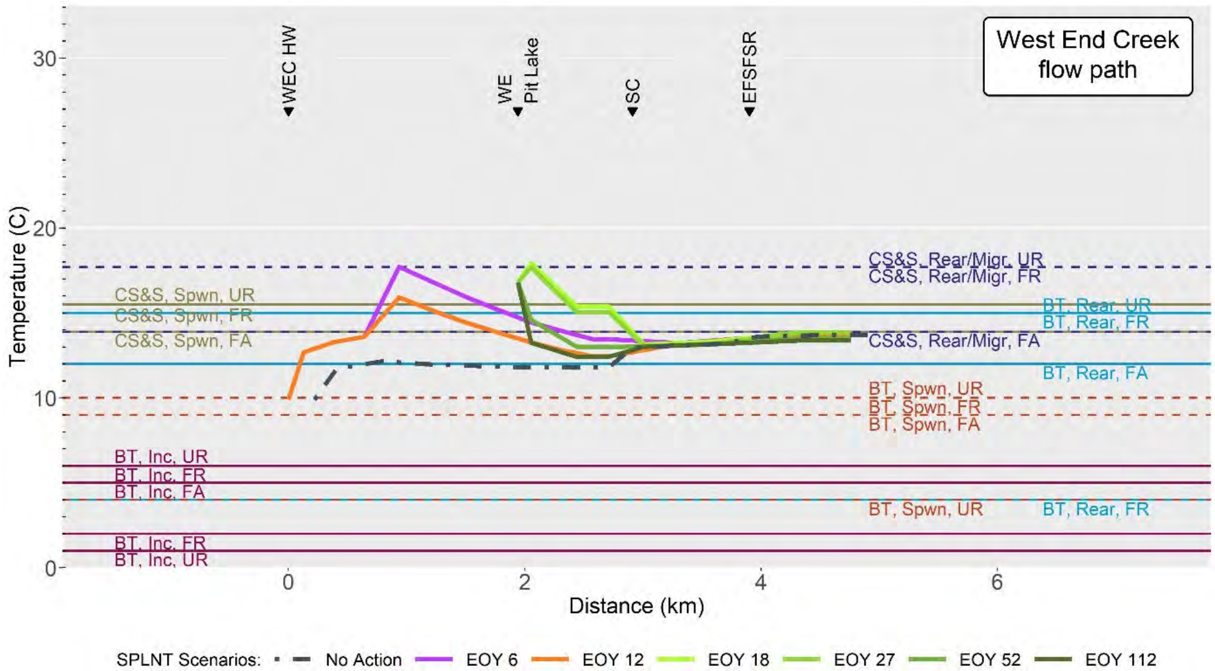


Figure 3-25. Simulated "Constant" Temperatures for the Maximum Weekly Summer Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths



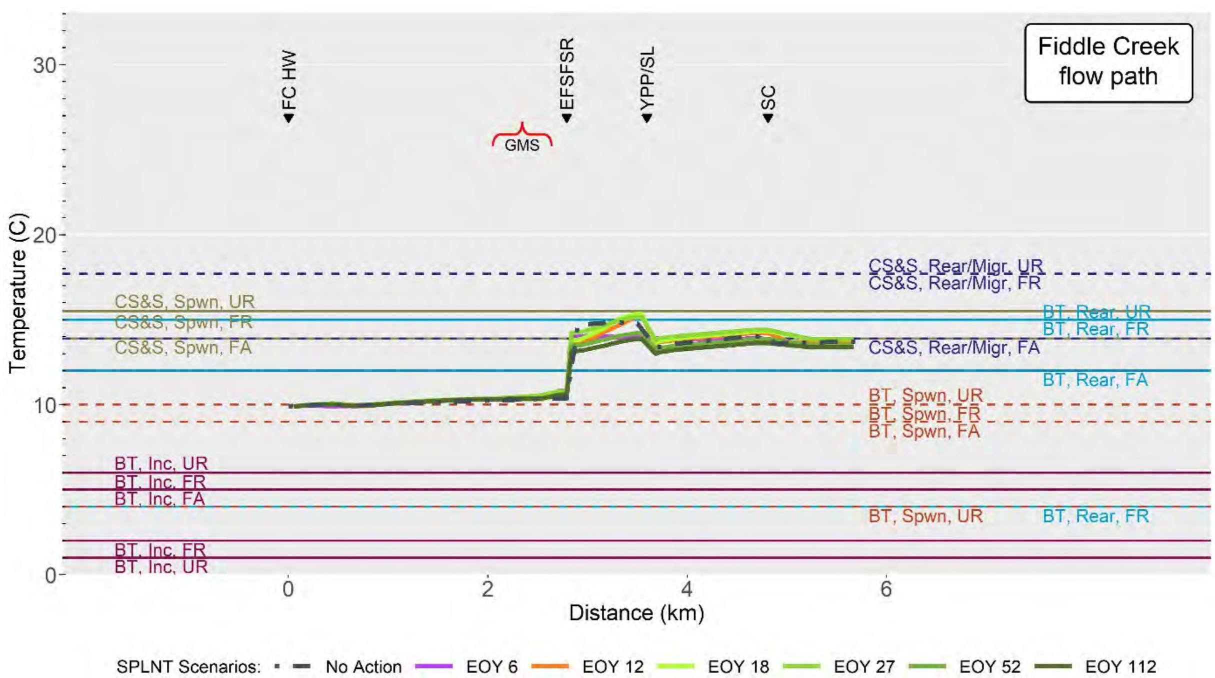


Figure 3-26. Simulated "Constant" Temperatures for the Maximum Weekly Summer Condition Compared to USFS Criteria for West End and Fiddle Flow Paths

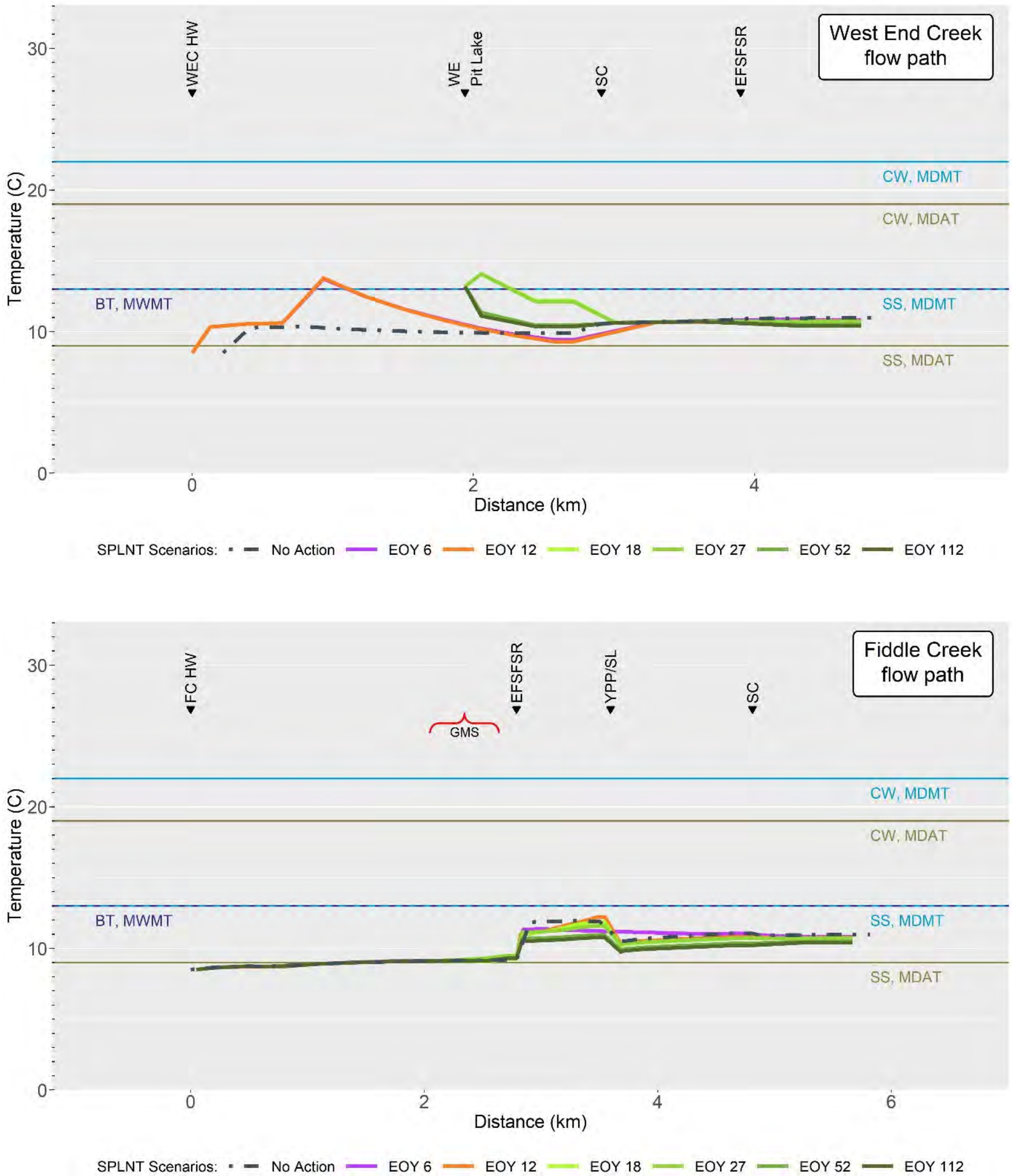
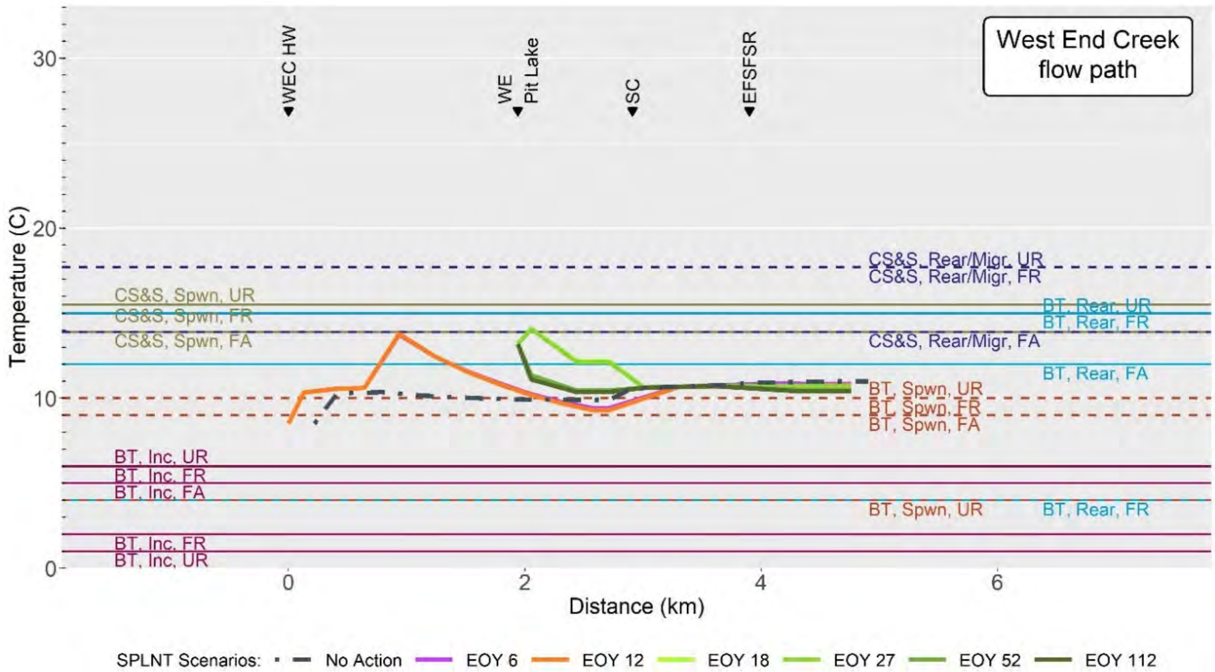


Figure 3-27. Simulated "Constant" Temperatures for the Maximum Weekly Fall Condition Compared to IDEQ Criteria for West End and Fiddle Flow Paths



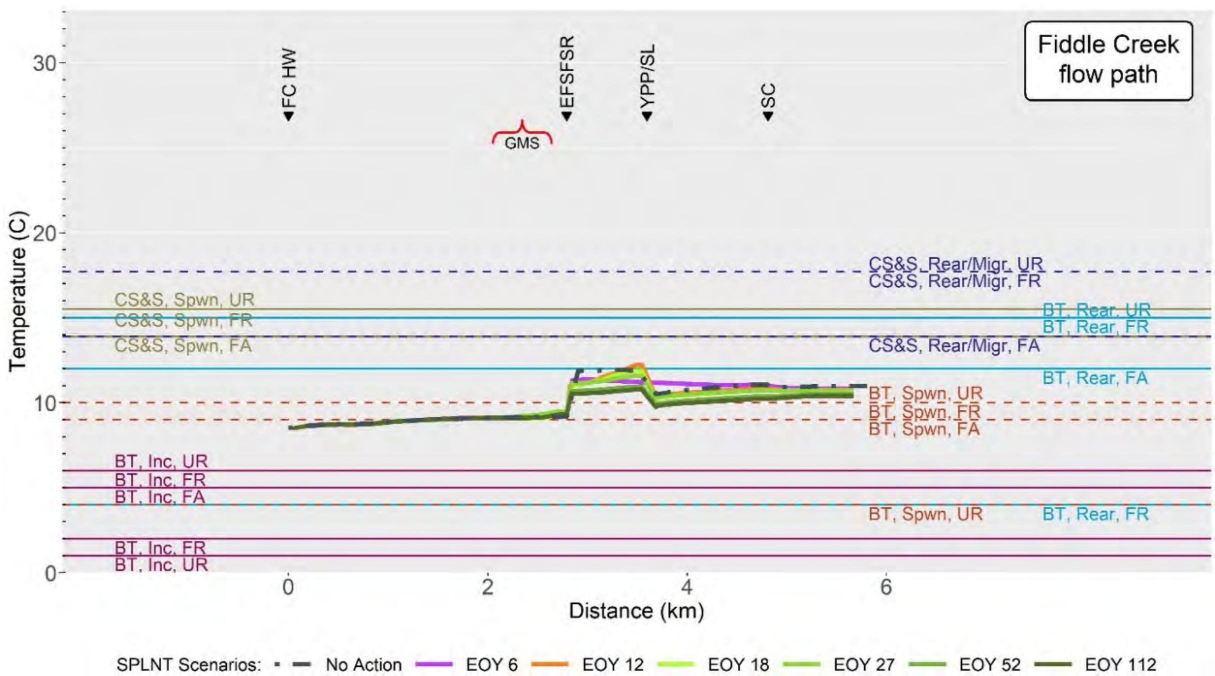


Figure 3-28. Simulated "Constant" Temperatures for the Maximum Weekly Fall Condition Compared to USFS Criteria for West End and Fiddle Flow Paths

3.2 Comparison of ModPRO2 Temperature Improvements to Site Data and Research Studies

ModPRO2 includes several design features that reduce stream temperatures relative to other project alternatives. Many of these features were included to address public comments on the draft EIS and to reduce stream temperatures to NA levels or similar.

Stream-side design features include wider riparian planting zones that are planted as early as possible in the mine life and include a higher percentage of taller species. Floodplain liner in lower Meadow Creek extended into lower East Fork Meadow Creek reduces stream flow losses and helps mitigate temperatures. As a result of these stream-side improvements, daily average temperatures for ModPRO2 upstream of Stibnite Lake are similar to NA. Daily maximum temperatures are within 1°C of NA upstream of Stibnite Lake except on the TSF. While the daily averages are relatively similar across the project alternatives at most locations, the daily maximums tend to be more variable. The increased riparian plantings under ModPRO2 provide a greater reduction of the daily maximums which are most sensitive to direct solar inputs.

The temperature improvements simulated as a result of increased shade are consistent with peer-reviewed studies (Table 3-1). There is general consensus in the literature that 1) direct solar radiation is the major control of stream temperature and 2) shade has a meaningful effect on stream temperatures. Changes in maximum daily temperatures after disturbance or after vegetation has fully grown ranged from 5°C to 10°C for similar sized streams and ranged from 1.9°C to 10°C for all streams in the published studies. Simulated daily maximum stream temperature reduction on the TSF (where the greatest reductions are simulated) is 5°C and is at the low end of the published range. Additionally, the recovery period for the SPLNT simulations to achieve a 5°C decrease on the TSF is 30 years. This is 2 to 3 times longer than published values that document recovery periods for 5 to 15 years and achievement of a 4°C to 7°C decrease in daily maximum temperature for similar sized streams. Thus, the SPLNT model likely overestimates the length of the recovery period associated with vegetation growth and resulting shade. A literature review was provided in BC 2021b.

While the benefits of the increased riparian plantings result in stream temperatures similar to NA upstream of the YPP backfilled area in the ModPRO2, the temperatures entering the area would remain fairly constant passing through the river across the backfilled area and out of the project area. This result is evident under the PA and ModPRO scenarios where YPP lake is replaced with restored stream channels over the backfilled area and temperatures are higher than NA conditions. The only way to replicate the effects that the existing YPP lake has on temperatures is to replace the lake with a similar feature. Stibnite Lake provides these benefits under ModPRO2 by decreasing daily maximum temperatures with only a slight increase in daily average temperatures (similar to YPP lake). The simulations for Stibnite Lake match the patterns of the simulated YPP lake for NA and the data collected onsite by USGS and Perpetua Resources upstream and downstream of YPP lake, as described BC 2021b.

Table 3-1. SPLNT Model and Published Studies Temperature Change Comparison

Study (Author) or SGP Simulation	Change in Maximum Daily Temperature	Time to Recover	Other Notes
Meadow Creek (SPLNT Model)	5°C	30 years	Streamflows are 1.5 to 2 cfs; vegetation has been completely removed prior to planting
Boise RB (Dunham et al. 2007)	2.1-5.2°C	after 10 years	Stream size influences temperature response
Yellowstone (Minshall et al. 1997)	>5°C	not discussed	1st and 2nd order streams

Study (Author) or SGP Simulation	Change in Maximum Daily Temperature	Time to Recover	Other Notes
Oregon Cascades (Johnson 2004)	5°C	not discussed	Response to stream shading on a 150-m reach of 2nd order stream; benefits of shading more pronounced in streams cut off from groundwater (e.g., over bedrock)
Oregon Cascades (Johnson and Jones 2000)	7°C	15 years	Response to forest harvesting
Burns Creek (Woodsmith et al. 2004)	5-6°C	not discussed	Temperatures peaked 3 years after the fire then began to decline; small streams (500 ha catchments)
Bitterroot (Mahlum et al. 2011)	1.9-5.4°C	Study ended 7 years post fire	2nd to 4th order streams
Hayman Fire CO (Rhoades et al. 2011)	10°C	5 years post fire: 4C decrease	Average spring and summer water temperatures were 5 and 6°C higher the year following the fire
Pacific Coast Range (Janisch et al. 2012)	up to 3.6°C	Not discussed	Following harvesting where canopy plus topographic shade density decreased from 95% to 53%

Abbreviations:

°C = degrees Celsius

Cfs = cubic feet per second

SPLNT = stream and pit lake network temperature

3.3 Extent of Thermal Impacts Downstream of Sugar Creek

Temperature changes downstream of the SPLNT study area were estimated with a mass balance approach that was applied for the tributaries entering the system downstream of Sugar Creek. This analysis was included in the SPLNT PA modeling report (BC 2019a) at the request of the review agencies. The removal of the YPP lake as part of the PA and ModPRO results in higher maximum temperatures in the lower part of the SPLNT study area compared to NA. The ModPRO2 proposes to replace YPP lake with a similarly sized Stibnite Lake to replicate the effects of the YPP lake on diurnal temperature variability. Under the NA Alternative, maximum weekly summer condition daily maximums are 14.9°C. This analysis estimates the distance downstream of Sugar Creek that would be required to achieve this maximum.

This analysis focuses on simulated maximum temperatures for the summer because this metric is impacted more than others (i.e., summer averages or fall temperatures), and the extent of returning to the NA summer maximum would encompass the extent for these other metrics. This analysis does not account for diffuse flows entering the system; it only accounts for tributary inputs. Because diffuse flow temperatures are cooler than surface water temperatures, omitting this input from the mass balance results in warmer temperatures and a longer extent of impact than would likely occur. In the summer, the diffuse flow temperatures are assumed 11.9°C across most of the reaches in the study area based on monitoring data. Two reaches in lower Meadow Creek were assigned diffuse flow temperatures of 13.9°C based on observations in that area, and the last reach on Sugar Creek, and most downstream reach on the EFSFSR have assumed diffuse flow temperatures of 14.8°C. Development of assumptions for diffuse flow temperature is documented in the SPLNT Existing Conditions Modeling Report (BC 2018) and are summarized in Appendix A of this report.

This mass balance analysis applies tributary drainage areas generated using United States Geological Survey StreamStats. Tributary flow rates were estimated by scaling the Sugar Creek flow for the summer simulation (12.7 cubic feet per second) relative to the Sugar Creek drainage area

(11,500 acres). Consistent with the methods used by the QUAL2K model for representing tributaries as point sources, the applied temperature for the analysis is an average. The temperatures simulated for lower Sugar Creek under NA were assumed representative of temperatures for the tributaries entering the system downstream of the SPLNT study area. For the summer simulation, a temperature of 10.7°C was applied.

Under the ModPRO2, the period during operations when the tunnel is in use and Stibnite Lake is not online has the highest simulated maximum stream temperatures in the summer (15.9°C) on the EFSFSR downstream of Sugar Creek. The addition of Salt and Pepper Creeks (3,622 acres) brings the maximum stream temperature down to 15.3°C and the addition of Tamarack Creek (11,712 acres), at approximately 3.5 kilometers downstream of Sugar Creek, brings the maximum temperature down to 14°C which is less than the NA temperature on the EFSFSR downstream of Sugar Creek. Once Stibnite Lake is online by EOY12, stream temperatures on EFSFSR downstream of Sugar Creek are similar to No Action.

3.4 Summary and Conclusions

To compare simulated temperatures between the NA and ModPRO2 Alternatives, the warmest reach-averaged temperatures simulated in different parts of the SPLNT study area are listed in Table 3-2 through Table 3-5 and shown on Figure 3-29 through Figure 3-32. Table 3-2 and Figure 3-29 focus on EOY6, Table 3-3 and Figure 3-30 on EOY12, Table 3-4 and Figure 3-31 on EOY18, and Table 3-5 and Figure 3-32 on EOY112. Summary tables for additional simulation years are provided in Appendix B.

The following general observations can made:

- Simulated temperature effects tend to be more pronounced when comparing maximum temperatures for the maximum weekly summer condition followed by either maximum temperatures for the fall condition or average conditions for the summer condition. The simulated averages for the maximum weekly fall condition are the least affected by the Project and are similar to NA across the SPLNT study area.
- Piping low flows in diversion channels results in fully shaded conveyances that result in temperatures that are similar to, and sometimes lower than, NA depending on the degree of shade present for the NA condition.
- Improving the riparian planting plan by planting wider buffers, increasing the percentage of taller tree species, including enhanced reaches, and planting earlier in the mine life increases shade and reduces stream temperatures. The magnitude of simulated changes to daily maximum temperatures is near the low end of the ranges reported in peer-reviewed studies. The SPLNT model estimates that the duration to achieve temperature reductions is 2 to 3 times longer than the periods reported in these studies. The SGP includes adaptive management plans (Tetra Tech 2021a, b, c) that require monitoring and maintenance activities until performance standards have been met and the areas can be transferred to an appropriate steward. Planting areas are designed to become self-sustaining with minimal or no required maintenance after vegetation establishment.
- Including Stibnite Lake on the YPP backfill reduces diurnal temperature variation and maximum temperatures.
- The ModPRO2 results in improved stream temperatures relative to the ModPRO, PA, and EFSFSR TSF Alternatives (BC 2019b and 2019c). Once Stibnite Lake is online, maximum stream temperatures in the summer are at or below NA everywhere in the system except on top of the TSF, just upstream of Stibnite Lake, and the upper reaches of West End Creek and Meadow Creek. While temperatures are significantly higher than NA on the TSF in the early part of post

closure, these reaches are not accessible for spawning by migratory/anadromous fish. Once Meadow Creek mixes with East Fork Meadow Creek, maximum stream temperatures are consistently below NA. Higher temperatures in West End Creek occur in the upper reaches, cool before reaching Sugar Creek and do not impact stream temperatures in Sugar Creek because the flow rate of West End Creek is proportionally small.

- Simulated maximums for the ModPRO2 at the model terminus (EFSFSR below Sugar Creek) are within 1°C of NA for each mine year.
- Under the ModPRO2, temperatures would return to NA when Tamarack Creek enters the system and would not be more than 1°C higher than NA in the EFSFSR downstream of the Project Area.

Results for the mean August condition are not included in the summary results. Reach-by-reach output are available in Appendix B along with the output for the maximum weekly summer and fall conditions.

Table 3-2. Warmest Simulated Reach-Averaged Temperatures (°C) for EOY6 for the ModPRO2 Compared to NA for the Maximum Weekly Summer and Fall Conditions

Area	Simulated Daily Temperature Statistic	NA	ModPRO2
Upper EFSFSR (above Meadow Creek)	Summer Max:	13.7	13.8
	Fall Max:	11.1	11.0
	Summer Avg:	10.3	10.2
	Fall Avg:	8.8	8.8
Meadow Creek above East Fork Meadow Creek	Summer Max:	17.9	14.6
	Fall Max:	15.1	12.2
	Summer Avg:	12.7	11.2
	Fall Avg:	10.4	9.1
Meadow Creek below East Fork Meadow Creek	Summer Max:	19.8	17.2
	Fall Max:	16.2	15.9
	Summer Avg:	13.4	12.4
	Fall Avg:	10.8	10.2
Middle EFSFSR (between Meadow and Fiddle Creeks)	Summer Max:	17.4	16.2
	Fall Max:	14.0	13.6
	Summer Avg:	12.3	11.7
	Fall Avg:	9.9	9.5
Fiddle Creek	Summer Max:	11.5	11.9
	Fall Max:	10.1	10.4
	Summer Avg:	9.5	9.7
	Fall Avg:	8.3	8.3
Lower EFSFSR (between Fiddle and Sugar Creek)	Summer Max:	17.4	16.1
	Fall Max:	14.0	13.3
	Summer Avg:	13.5	11.6
	Fall Avg:	10.6	9.4
West End Creek	Summer Max:	12.9	21.7
	Fall Max:	11.0	17.1
	Summer Avg:	11.1	13.7
	Fall Avg:	9.6	10.4
Lower Sugar Creek	Summer Max:	15.4	15.7
	Fall Max:	12.2	12.3

Area	Simulated Daily Temperature Statistic	NA	ModPRO2
	Summer Avg:	10.7	10.8
	Fall Avg:	9.1	9.1
EFSFSR downstream of Sugar Creek	Summer Max:	14.9	15.9
	Fall Max:	11.9	12.5
	Summer Avg:	13.0	11.3
	Fall Avg:	10.3	9.2

Abbreviations:
°C = degrees Celsius
Avg = average
EFSFSR = East Fork of the South Fork of the Salmon River
EOY = end of year
Max = maximum
NA = No Action

Figure 3-29. Comparison of Warmest Simulated Reach-Averaged Temperatures for EOY6 for ModPRO2 and NA

Table 3-3. Warmest Simulated Reach-Averaged Temperatures (°C) for EOY12 for the ModPRO2 Compared to NA for the Maximum Weekly Summer and Fall Conditions

Area	Simulated Daily Temperature Statistic	NA	ModPRO2
Upper EFSFSR (above Meadow Creek)	Summer Max:	13.7	13.8
	Fall Max:	11.1	11.0
	Summer Avg:	10.3	10.3
	Fall Avg:	8.8	8.9
Meadow Creek above East Fork Meadow Creek	Summer Max:	17.9	14.6
	Fall Max:	15.1	11.5
	Summer Avg:	12.7	11.2
	Fall Avg:	10.4	9.1
Meadow Creek below East Fork Meadow Creek	Summer Max:	19.8	16.8
	Fall Max:	16.2	13.7
	Summer Avg:	13.4	12.1
	Fall Avg:	10.8	9.9
Middle EFSFSR (between Meadow and Fiddle Creeks)	Summer Max:	17.4	15.8
	Fall Max:	14.0	12.7
	Summer Avg:	12.3	11.5
	Fall Avg:	9.9	9.4
Fiddle Creek	Summer Max:	11.5	11.5
	Fall Max:	10.1	10.3
	Summer Avg:	9.5	9.6
	Fall Avg:	8.3	8.3
Lower EFSFSR (between Fiddle and Sugar Creek)	Summer Max:	17.4	18.1
	Fall Max:	14.0	14.7
	Summer Avg:	13.5	13.7
	Fall Avg:	10.6	10.3
West End Creek	Summer Max:	12.9	19.1
	Fall Max:	11.0	17.3
	Summer Avg:	11.1	12.7
	Fall Avg:	9.6	10.3
Lower Sugar Creek	Summer Max:	15.4	15.6
	Fall Max:	12.2	12.3
	Summer Avg:	10.7	10.7
	Fall Avg:	9.1	9.1
EFSFSR downstream of Sugar Creek	Summer Max:	14.9	15.0
	Fall Max:	11.9	11.6
	Summer Avg:	13.0	13.1
	Fall Avg:	10.3	10.1

Abbreviations:

°C = degrees Celsius

Avg = average

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

Max = maximum

NA = No Action

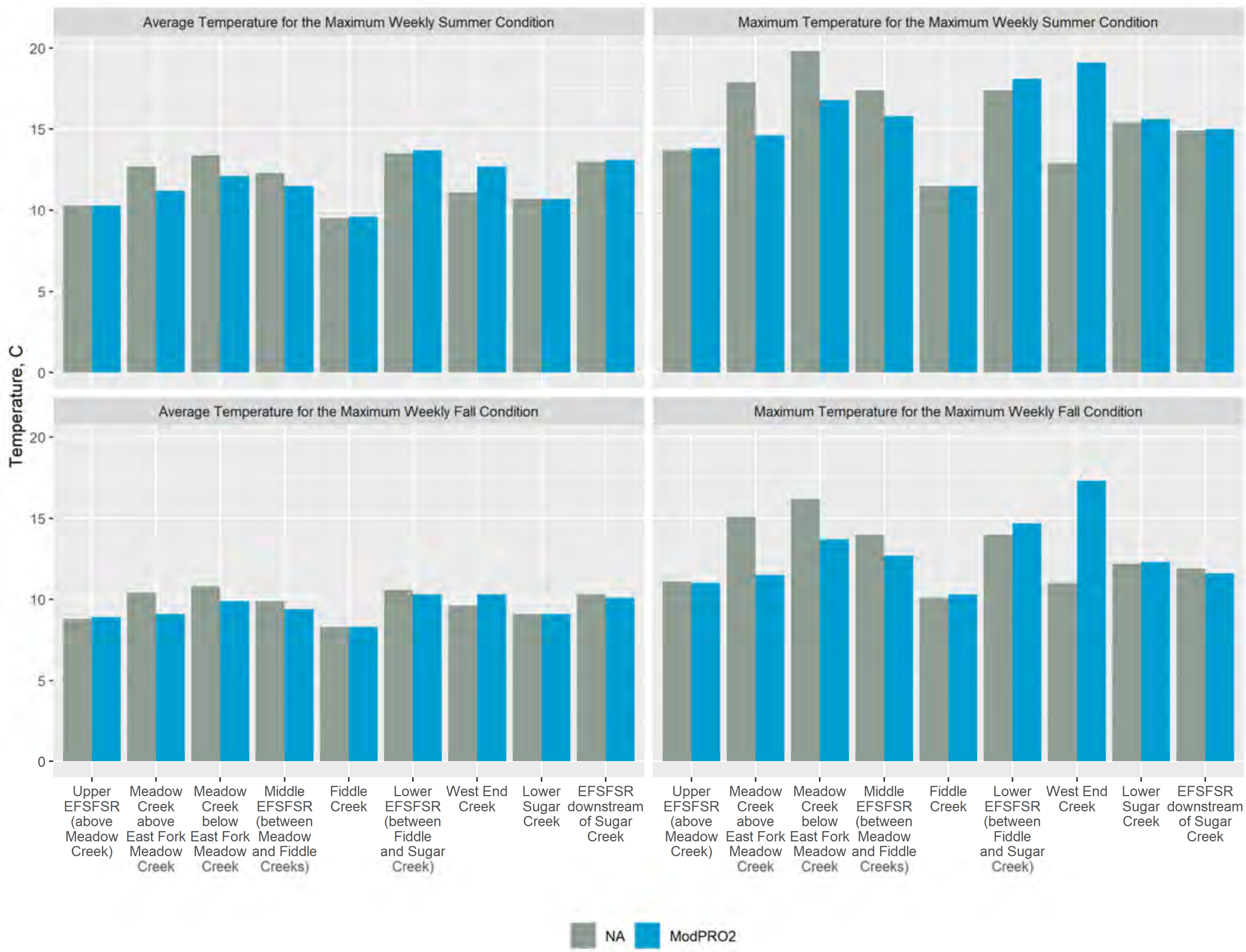


Figure 3-30. Comparison of Warmest Simulated Reach-Averaged Temperatures for EOY12 for ModPRO2 and NA

Table 3-4. Warmest Simulated Reach-Averaged Temperatures (°C) for EOY18 for the ModPRO2 Compared to NA for the Maximum Weekly Summer and Fall Conditions

Area	Simulated Daily Temperature Statistic	NA	ModPRO2
Upper EFSFSR (above Meadow Creek)	Summer Max:	13.7	13.8
	Fall Max:	11.1	11.0
	Summer Avg:	10.3	10.3
	Fall Avg:	8.8	8.8
Meadow Creek above East Fork Meadow Creek	Summer Max:	17.9	14.6
	Fall Max:	15.1	11.5
	Summer Avg:	12.7	11.2
	Fall Avg:	10.4	9.4
Meadow Creek below East Fork Meadow Creek	Summer Max:	19.8	16.7
	Fall Max:	16.2	13.3
	Summer Avg:	13.4	12.1
	Fall Avg:	10.8	10.0
Middle EFSFSR (between Meadow and Fiddle Creeks)	Summer Max:	17.4	16.0
	Fall Max:	14.0	12.7
	Summer Avg:	12.3	11.6
	Fall Avg:	9.9	9.5
Fiddle Creek	Summer Max:	11.5	11.6
	Fall Max:	10.1	10.3
	Summer Avg:	9.5	9.5
	Fall Avg:	8.3	8.2
Lower EFSFSR (between Fiddle and Sugar Creek)	Summer Max:	17.4	18.3
	Fall Max:	14.0	14.1
	Summer Avg:	13.5	13.8
	Fall Avg:	10.6	10.2
West End Creek	Summer Max:	12.9	20.9
	Fall Max:	11.0	16.2
	Summer Avg:	11.1	16.8
	Fall Avg:	9.6	13.2
Lower Sugar Creek	Summer Max:	15.4	15.7
	Fall Max:	12.2	12.2
	Summer Avg:	10.7	10.8
	Fall Avg:	9.1	9.1
EFSFSR downstream of Sugar Creek	Summer Max:	14.9	15.1
	Fall Max:	11.9	11.6
	Summer Avg:	13.0	13.2
	Fall Avg:	10.3	10.0

Abbreviations:

°C = degrees Celsius

Avg = average

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

Max = maximum

NA = No Action

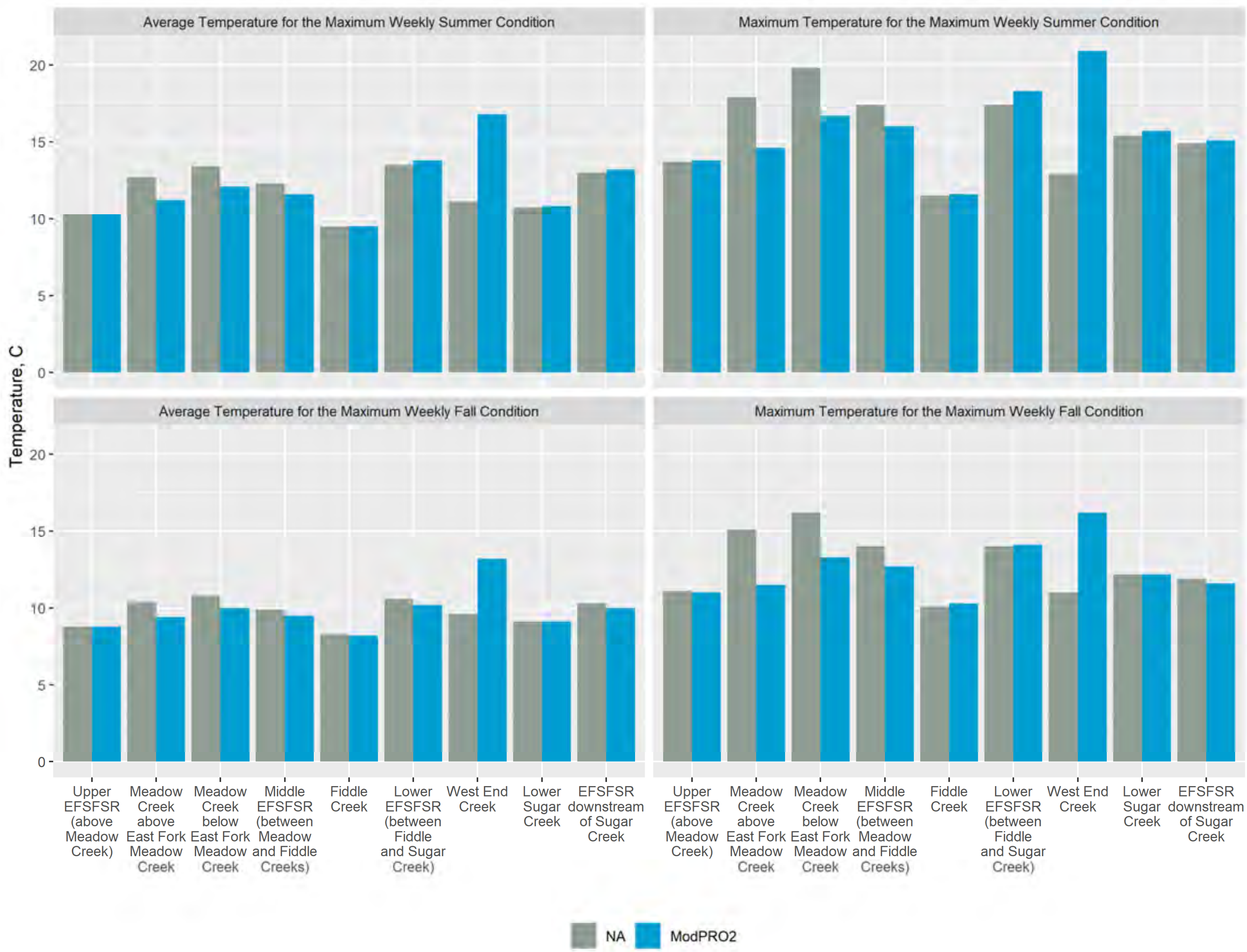


Figure 3-31. Comparison of Warmest Simulated Reach-Averaged Temperatures for EOY18 for ModPRO2 and NA

Table 3-5. Warmest Simulated Reach-Averaged Temperatures (°C) for EOY112 for the ModPRO2 Compared to NA for the Maximum Weekly Summer and Fall Conditions

Area	Simulated Daily Temperature Statistic	NA	ModPRO2
Upper EFSFSR (above Meadow Creek)	Summer Max:	13.7	13.8
	Fall Max:	11.1	11.0
	Summer Avg:	10.3	10.3
	Fall Avg:	8.8	8.9
Meadow Creek above East Fork Meadow Creek	Summer Max:	17.9	16.9
	Fall Max:	15.1	12.4
	Summer Avg:	12.7	12.4
	Fall Avg:	10.4	9.7
Meadow Creek below East Fork Meadow Creek	Summer Max:	19.8	15.3
	Fall Max:	16.2	11.6
	Summer Avg:	13.4	12.2
	Fall Avg:	10.8	9.6
Middle EFSFSR (between Meadow and Fiddle Creeks)	Summer Max:	17.4	14.8
	Fall Max:	14.0	11.8
	Summer Avg:	12.3	11.5
	Fall Avg:	9.9	9.3
Fiddle Creek	Summer Max:	11.5	11.6
	Fall Max:	10.1	10.3
	Summer Avg:	9.5	9.6
	Fall Avg:	8.3	8.3
Lower EFSFSR (between Fiddle and Sugar Creek)	Summer Max:	17.4	16.0
	Fall Max:	14.0	12.4
	Summer Avg:	13.5	13.1
	Fall Avg:	10.6	9.8
West End Creek	Summer Max:	12.9	16.8
	Fall Max:	11.0	13.2
	Summer Avg:	11.1	16.8
	Fall Avg:	9.6	13.2
Lower Sugar Creek	Summer Max:	15.4	15.4
	Fall Max:	12.2	12.2
	Summer Avg:	10.7	10.7
	Fall Avg:	9.1	9.1
EFSFSR downstream of Sugar Creek	Summer Max:	14.9	14.5
	Fall Max:	11.9	11.3
	Summer Avg:	13.0	12.7
	Fall Avg:	10.3	9.7

Notes:

°C = degrees Celsius

Avg = average

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

Max = maximum

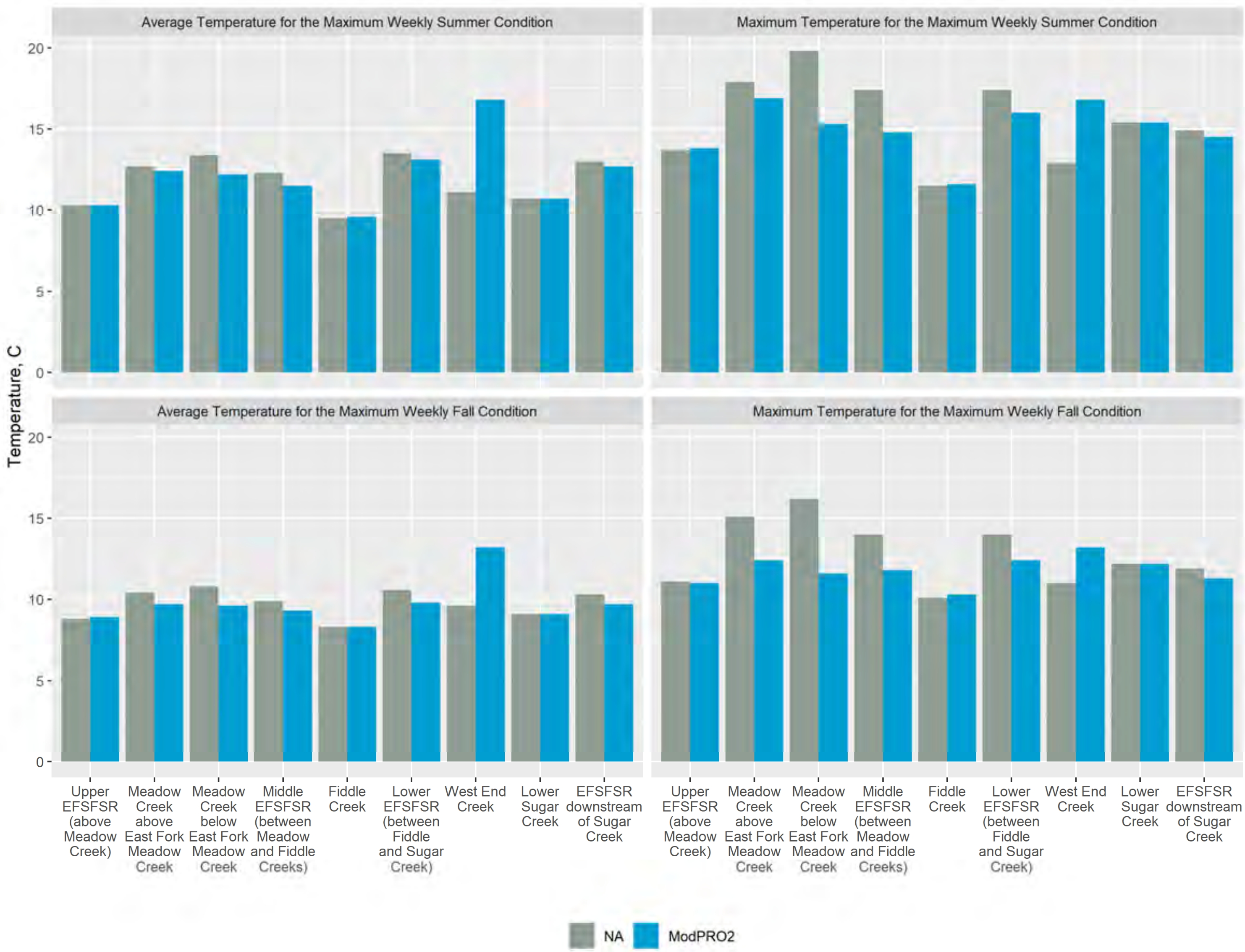


Figure 3-32. Comparison of Simulated Temperatures for EOY112 for ModPRO2 and NA

Section 4

Limitations

This document was prepared solely for Perpetua Resources in accordance with professional standards at the time the services were performed and in accordance with the contract between Perpetua Resources and Brown and Caldwell dated January 1, 2021. This document is governed by the specific scope of work authorized by Perpetua Resources; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Perpetua Resources and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 5

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Appendix A: SPLNT Existing Conditions and No Action Modeling Summary

Stibnite Gold Project
Stream and Pit Lake Network Temperature Model
Summary of Existing Conditions and No Action Modeling

Prepared for

Perpetua Resources Idaho, Inc.

Valley County, Idaho

July 2021

Brown AND Caldwell

950 West Bannock Street, Suite 350

Boise, ID 83702

Table of Contents

List of Tables

List of Graphs

List of Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
AME	absolute mean error
BC	Brown and Caldwell
CFR	Code of Federal Regulations
Cfs	cubic feet per second
Cm	centimeter
cm^2/s	square centimeter per second
cms	cubic meter per second
DO	dissolved oxygen
DYRESM	Dynamic Reservoir Simulation Model
EFSFSR	East Fork of the South Fork of the Salmon River
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
FC	Fiddle Creek
FS	Feasibility Study
Ft	foot
GLM	General Lake Model
HDR	HDR Engineering, Inc.
IDEQ	Idaho Department of Environmental Quality
km	kilometer
LiDAR	light detection and ranging
m	meter
M	monthly
MC	Meadow Creek
ME	mean error
m/s	meter per second
MDAT	maximum daily average temperature
MDMT	maximum daily maximum temperature
mg/L	milligram per liter
Midas Gold	Midas Gold Idaho, Inc.
ModPRO	Modified Proposed Action
ModPRO2	Refined Modified Proposed Action
MWH	MWH Americas, Inc.
MWMT	maximum weekly (7-day average) maximum temperature
NED	National Elevation Dataset
NPDES	National Pollutant Discharge Elimination System
N/A	not applicable
O	observations

ODEQ	Oregon Department of Environmental Quality
P	prediction
Perpetua Resources	Perpetua Resources Idaho, Inc.
PRO	Plan of Restoration and Operations
Project	Stibnite Gold Project
Q	quarterly
Rio ASE	Rio Applied Science and Engineering
SC	Sugar Creek
SFSR	South Fork of the Salmon River
SGP	Stibnite Gold Project
Sim-Obs	Simulated minus Observed
SPLNT	Stream and Pit Lake Network Temperature
Sq. mi.	square mile
SWWC	site-wide water chemistry
USFS	United States Forest Service
USGS	United States Geological Survey
YPP	Yellow Pine pit

Section 1

Background and Purpose

Perpetua Resources Idaho, Inc. (Perpetua Resources, formerly Midas Gold Idaho, Inc.) proposes to redevelop portions of the Stibnite Mining District in the headwaters of the East Fork of the South Fork of the Salmon River (EFSFSR), Valley County, central Idaho. The original proposal was outlined in the Plan of Restoration and Operations (PRO) (Midas Gold 2016) for the Stibnite Gold Project (SGP or Project). The PRO was submitted to the United States Forest Service (USFS) and the Idaho Department of Lands in September 2016 and deemed complete by the USFS in December 2016.

The USFS then began to evaluate whether to approve the PRO as submitted by Perpetua Resources, or to require changes or additions to meet the requirements for environmental protection and reclamation set forth at 36 Code of Federal Regulations (CFR) 228 Subpart A before approving a final plan. Consistent with their responsibility under the National Environmental Policy Act, this included USFS development and review of a range of alternatives and design features that could be determined reasonable and necessary to meet USFS regulations for locatable minerals set forth at 36 CFR 228 Subpart A, and that could require changes and/or additions to the Project as proposed. The development of alternatives was informed by Agency and public scoping comments and included evaluation by Perpetua Resources to assess the technical and economic feasibility of proposed alternative components, and whether they fulfilled the Project purpose and need.

While the USFS was in the process of evaluating alternatives, Perpetua Resources continued to refine and clarify the PRO. This included completing more detailed feasibility analyses and re-evaluating components of the Project to further avoid and minimize environmental impacts while meeting the Project purpose and need. Perpetua Resources' own studies of the Project footprint and potential effects on key resources such as wetlands and streams, water quality, federally listed species, public use, and other environmental considerations pointed to areas that the Project's environmental performance might be improved through modifications of the PRO. The combination of incremental improvements to the PRO was submitted to the USFS in May 2019 as a Modified Proposed Action (Modified PRO or ModPRO) (Brown and Caldwell [BC] 2019c) and represented Perpetua Resources' refined proposal to be evaluated in the Environmental Impact Statement (EIS).

Stream and Pit Lake Network Temperature (SPLNT) modeling in support of the PRO and Draft EIS Alternatives is documented in the SGP SPLNT Model Existing Conditions Report (Brown and Caldwell [BC], 2018b), the SGP SPLNT Proposed Action Report (BC, 2019a), the SGP East Fork South Fork Salmon River TSF/DRSF Alternative Modeling Report (BC, 2019b), and the SGP Modified PRO Alternative Modeling Report (BC, 2019c).

Concurrent to the preparation of the Draft EIS, Perpetua Resources has continued to study alternatives that reduce the overall Project footprint, reduce associated wetland impacts, improve surface water and groundwater quality, reduce temperature impacts to surface water, reduce air emissions, improve fisheries and wildlife habitat, and improve upon reclamation and restoration design in accordance with Perpetua Resources' values, principles and goals. These considerations guided the preparation of the PRO and the ModPRO and were equally influential in preparation of Perpetua Resources' Feasibility Study (FS) (M3 Engineering and Technology, 2020).

Some Project elements have changed in the FS to reduce environmental impact relative to the PRO and ModPRO as designs have proceeded and additional information has been learned. These modifications form, in part, the refined ModPRO, referred to as the ModPRO2 (Midas Gold 2020).

This SPLNT ModPRO2 Modeling Report is a part of Perpetua Resources' description of the ModPRO2 Alternative environmental analysis necessary for USFS inclusion of this alternative in the Final EIS. This appendix is included here to provide background on the SPLNT Existing Conditions model and No Action Alternative necessary for appropriate interpretation of the SPLNT modeling results presented in the main report.

This appendix is an abridged version of the Existing Conditions model report (BC 2018b) and No Action Alternative documented in the SPLNT Proposed Action modeling report (BC 2019b). An update to the Existing Conditions model and No Action model for the ModPRO2 Alternative was not necessary because the SPLNT model methodology, assumptions, and configuration for these scenarios has not changed. The Existing Conditions modeling is calibrated to observed field data and is therefore independent of alternative modeling. The No Action model is based on Existing Conditions with modifications as described in Section 2.3 of this Appendix. Stream temperature predictions for Project Alternatives are based on streamflow estimates using a percent difference calculated from the Project's hydrologic modeling for No Action and an Alternative. The updated Stibnite Hydrologic Site Model Existing Conditions is not directly applied to generate SPLNT model predictions. Additional discussion of hydrologic inputs is provided in Section 3.5 of this appendix and a comprehensive discussion of the No Action model is included in BC 2019b.

1.1 Purpose and Scope

The SPLNT model was designed to provide important inputs to the environmental consequences analyses being completed for the EIS and preparation of the biological assessment for the Section 7 consultation under the Endangered Species Act for Snake River spring/summer Chinook salmon (Chinook salmon; *Oncorhynchus tshawytscha*), Snake River Basin steelhead (steelhead; *O. mykiss*), and Columbia River bull trout (bull trout; *Salvelinus confluentus*).

Because the SGP has the potential to affect instream conditions such as stream flows, groundwater interaction, and stream shading, the stream water temperature regime may also be altered. Brown and Caldwell developed a SPLNT model for the Project to evaluate the potential changes that may occur as a result of the proposed mining and subsequent reclamation.

In the first phase of SPLNT modeling, the Existing Conditions model was built and calibrated to observed data to demonstrate the model's suitability for predictive simulations of dissolved oxygen (DO) (pit lakes only) and temperature (streams and pit lakes) (BC 2018b). This report documents the model fit using statistical and graphical summaries. The approach and methods were then used to complete the second phase of modeling to simulate changes that would occur as a result of the Proposed Action. A No Action model based on the Existing Conditions model was also developed to address agency comments on the modeling and provide a comparison to the Project Alternatives. This appendix to the ModPRO2 Modeling Report summarizes the Existing Conditions and No Action SPLNT models.

Water temperature affects biological activity of aquatic organisms such as fish. For example, higher temperatures increase metabolic rates and decrease the solubility of DO, reducing its availability to aquatic organisms (Forney et al. 2013). Because of this effect, a stream's peak temperature in the summer is often a critical characteristic of habitat quality for various aquatic life (Forney et al. 2013). Water temperature studies in the Pacific Northwest have specifically focused on analyzing flow and temperature data observed during summer months (David Duncan and Associates 2002; Tetra Tech 2014).

Previously collected temperature data from the region have shown that stream temperatures may exceed temperature criteria during the late spring spawning period for salmonids (April through June), peak summer (July and August), and early fall spawning (September) (Shumar and de Varona

2009). Outside these periods, stream temperatures are rarely a problem for spawning and migration activities and may not be the dominant temperature impairment impacting salmonid life stages (Scranton et al. 2015).

Simulated water temperatures derived from the SPLNT models for the Project Alternatives including No Action are compared to thermal criteria based on indicators for Chinook salmon, steelhead, and bull trout. Specifically, the SPLNT model output was used to evaluate the following:

- Achievement of USFS stream temperature criteria
- Achievement of Idaho Department of Environmental Quality (IDEQ) stream temperature criteria
- Depth-dependent temperature and DO concentration in the Hangar Flats, West End, and Midnight pit lakes to provide the following:
  - Stream flow and temperature inputs for simulation of downstream reaches
  - Input to the site-wide water chemistry (SWWC) model being developed by SRK Consulting, Inc.
- Effects of discharges permitted under the National Pollutant Discharge Elimination System (NPDES)
- Provide temperature data for the bull trout and Westslope cutthroat trout occupancy models being developed by Ecosystem Sciences for their proposed application of the Isaak et al. (2017) methods for the SGP.

1.2 Thermal Criteria for Evaluation

Thermal criteria describe the temperature thresholds and frequencies that aquatic species can tolerate without suffering adverse effects and are often specified for different seasons and life stages. Published literature, USFS criteria, and IDEQ water temperature standards have been used to develop the thermal criteria for this evaluation.

The IDEQ's water quality standards (Idaho Administrative Procedures Act 58.01.02) include relatively complex criteria for temperature, based in part upon seasonal spawning and rearing requirements for salmonids. Idaho first adopted bull trout temperature criteria in 1998. These criteria were revised in 2001 and submitted to the United States Environmental Protection Agency (EPA) for approval. The EPA has not acted, so the bull trout temperature criterion effective for Clean Water Act purposes is the 1997 federally promulgated temperature criterion of 10 degrees Celsius (°C) for 7-day average maximum daily temperatures from June through September for waters specified in the federal rule (40 CFR 131.33).

The modeling approach developed for the SGP is similar to other temperature evaluations in the Pacific Northwest. For example, in 2011, Tetra Tech used the QUAL2K model to evaluate the effects of different management practices for Nemote Creek in Montana (Tetra Tech 2014). The scenarios they evaluated included baseline conditions (i.e., low flow and warm weather), improved riparian vegetation conditions, and conditions of reduced surface water withdrawals (Tetra Tech 2014). In QUAL2K (Chapra et al. 2008), the heat budget and water temperatures are simulated as a function of meteorology, point and non-point source pollutant loads, and withdrawals from a stream network. The model provides minimum, maximum, and average daily water temperature outputs.

Other studies in the Pacific Northwest have combined empirical data with spatial analyses to model water temperatures under various climate and flow conditions using a linear regression approach (David Duncan and Associates 2002; Forney et al. 2013). For example, a study initiated by the Columbia River Federal Caucus was conducted in the John Day River Basin in Oregon to evaluate the resiliency of salmon habitat to climate change and used a regional database to support development of a summer stream temperature model called NorWeST (Scranton et al. 2015). The NorWeST model database contains stream temperature data and model output for different climate scenarios for various streams and rivers in the western United States.

To evaluate stream temperatures for a given site, the following metrics are commonly used (Scranton et al. 2015):

- **Maximum weekly high temperature** identifies abnormal baseline temperatures for a given site and habitats susceptible to extreme temperatures.
- **Maximum weekly maximum temperature** (MWMT; 7-day average of daily maximums) quantifies weekly maximum stream temperature while limiting the influence of an individual measurement from a single day.
- **Average weekly high temperature** identifies the expected normal baseline temperatures for a given stream network.
- **Modeled mean August temperature reported by NorWeST database** can be used to convert NorWeST database to MWMT.

Thermal criteria can also be established to describe the temperature thresholds and frequencies that aquatic life can tolerate without suffering adverse effects during different life stages. Specific thermal criteria are often established for different seasons and life stages. Previous stream temperature studies recommend prioritizing life stages in selected streams for a month or period of concern. For example, for small tributary streams of the upper Salmon River Basin, Maret et al. (2005) recommended a priority ranking (from high to low) of passage → spawning → adult → juvenile. Therefore, the months of April through September (when migration and spawning activities most often occur) would represent a critical period within the Salmon River Basin.

Table 1-1 summarizes the temperature criteria from the Watershed Indicators and Pathways in the Payette National Forest Land and Resource Management Plan (USFS 2003). For the bull trout criteria, not all temperature values are represented in the published criteria, which are only listed using whole numbers. Some values not represented as whole numbers required interpretation. The values listed in Table 1-2 reflect an interpretation of the USFS criteria for the bull trout life stages. Thermal criteria applied by IDEQ for salmonids are listed in Table 1-3. Both USFS and IDEQ criteria were used to assess the temperature impacts to streams under the Proposed Action with pipes (Section 5 and Appendix D) and without pipes (Appendix C).

The USFS and IDEQ thermal criteria assessments are relevant to specific fish species (Chinook salmon, steelhead, bull trout), their life stages (spawning, incubation, rearing, migration), and their associated times of year. In the results reported herein, the thermal criteria in each reach of the SPLNT model were evaluated with respect to all of the temperature criteria. However, not every reach currently supports or is accessible to all of these species/life stages or has suitable habitat for these species/life stages. When these SPLNT model results are further analyzed and interpreted, such as in the evaluation of changes in water temperature for the different species/life stages, or when the results are incorporated into the updated Stream Functional Assessment, temperature criteria should be applied for only those species/life stages appropriate on a reach-by-reach basis.

Table 1-1. USFS Thermal Criteria Based on the MWMT

Species/Life Stage	Months	Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Chinook Salmon				
Spawning	Mid-August–September	≤13.9	>13.9–15.5	>15.5
Rearing/Migration	Year-Round	≤13.9	>13.9–17.7	>17.7

Species/Life Stage	Months	Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Steelhead				
Spawning	March–May	≤13.9	>13.9–15.5	>15.5
Rearing/Migration	Year-Round	≤13.9	>13.9–17.7	>17.7
Bull Trout				
Incubation*	Mid-August–Early February	2.0–5.0	<2.0, 6.0	<1.0, >6.0
Rearing*	Year-Round	4.0–12.0	<4.0, 13.0–15.0	>15.0
Spawning*	Mid-August–September	4.0–9.0	<4.0, 10.0	<4.0, >10.0

Notes:

Source: USFS 2003

**See Table 1-2 for interpretations of this guidance.*

Abbreviations:

°C = degrees Celsius

MWMT = maximum weekly (7-day average) maximum temperature

USFS = United States Forest Service

Table 1-2. Interpretation of USFS Temperature Scoring Guidance for Bull Trout

Bull Trout Life Stage Guidance and Interpretation		Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning at Unacceptable Risk (°C)
Incubation	Guidance	2.0–5.0	<2.0 or 6.0	<1.0 or >6.0
	Interpretation	2.0–5.0	≥1.0 to <2.0 or >5.0 to ≤6.0	<1.0 or >6.0
Rearing	Guidance	4.0–12.0	<4.0 or 13.0 to 15.0	>15.0
	Interpretation	4.0–12.0	<4.0 or >12.0 to ≤15.0	> 15.0
Spawning	Guidance	4.0–9.0	<4.0 or 10.0	<4.0 or >10.0
	Interpretation	4.0–9.0	>9.0 to ≤10.0	<4.0 or >10.0

Notes:

Sources: USFS 2003; Interim Draft Stream Functional Assessment Ledger (Rio ASE 2018); Stream Functional Assessment Temperature Scoring (Great Ecology 2018).

Abbreviations:

°C = degrees Celsius

Rio ASE = Rio Applied Science and Engineering

USFS = United States Forest Service

Table 1-3. Idaho Thermal Criteria

Criteria	Warm Water	Seasonal Cold	Cold Water	Salmonid Spawning	Bull Trout
MDMT	33°C (91°F)	26°C (79°F)	22°C (79°F)	13°C (55°F)	N/A

Criteria	Warm Water	Seasonal Cold	Cold Water	Salmonid Spawning	Bull Trout
MWMT	N/A	N/A	N/A	N/A	13°C (55°F)
MDAT	29°C (84°F)	23°C (73°F)	19°C (66°F)	9°C (48°F)	N/A

Notes:

Source: http://www.deq.idaho.gov/water-quality/surface-water/temperature/.

Abbreviations:
°C = degrees Celsius

°F = degrees Fahrenheit

MDAT = maximum daily average temperature

MDMT = maximum daily maximum temperature

MWMT = maximum weekly (7-day average) maximum temperature

N/A = not applicable

1.3 Appendix Organization

This appendix describes the development of the SPLNT Existing Condition and No Action models as reference to the reviewer of the ModPRO2 Modeling Report. For brevity, this appendix references figures contained in the SPLNT Existing Conditions Report (BC 2018b) and the SPLNT Proposed Action Report (BC 2019).

Section 2 of this appendix describes the SPLNT modeling approach. Section 2 reviews the types and sources of data used to develop the SPLNT models. Section 4 summarizes the methods and generation of model input and Section 5 summarizes the model output. Section 6 provides a summary of the Existing Conditions and No Action models.

Section 2

SPLNT Model Approach

The final SPLNT Model Work Plan (BC 2018a) and final SPLNT Existing Conditions Report (BC 2018b) describe the approach and extensive data and studies that were used to build the SPLNT model for the SGP. The SPLNT Existing Conditions Report also provides statistical and graphical comparisons of simulated to observed stream temperatures. A No Action model was also developed to incorporate modeling recommendations from the agencies that were used to develop the Proposed Action models. These improvements were incorporated into the No Action models to provide a direct comparison to the Project Alternatives. The models were not recalibrated for No Action, but comparisons to observed temperatures were provided. The No Action modeling and comparison to observed stream temperatures were provided in Appendix B of the SPLNT Proposed Action Modeling Report (BC 2019). Existing Conditions modeling and No Action modeling are not impacted by updates to the SGP hydrologic model nor the ModPRO2 Alternative, so updating these models is not necessary. This appendix summarizes the SPLNT Existing Conditions and No Action modeling.

The SPLNT model domain represents the existing perennial stream network of the upper EFSFSR and tributaries downstream to the confluence with the first perennial tributary downstream of the study area (unnamed tributary with confluence at latitude 44.94121, longitude 115.3457), including the existing Yellow Pine pit (YPP) lake. Figure 3 of the SPLNT Existing Conditions Report (BC 2018b) shows the extent of the SPLNT model domain and which streams are explicitly simulated. The SPLNT modeling extent has not changed since the development of the Existing Conditions models, and the main report shows the model extent along with the reach configuration for the ModPRO2.

Pit lakes including YPP are simulated using a dynamic model that predicts a daily time series of temperature and DO profiles and outlet water temperatures reflective of the full time series of modeled scenarios. Outputs from the pit lake models serve as inputs to downstream reaches for stream temperature modeling.

The SPLNT model was developed using two separate software packages: QUAL2K for stream temperature modeling and the General Lake Model (GLM) for simulating pit lakes. QUAL2K simulates stream temperature upstream and downstream of the pit lakes, using GLM-simulated pit lake temperature as an input for the segment downstream of the lake.

Two SPLNT models are summarized in this appendix:

- The existing conditions model was developed to confirm that the approach resulted in models capable of reproducing observed conditions, and through calibration/validation, demonstrated the models' suitability to perform predictive simulations of temperature and DO. Existing Conditions included simulations for the YPP using the GLM. Details on the development of the existing conditions model and goodness of fit are provided in the SPLNT Existing Conditions Report (BC 2018b).
- No Action models were developed to simulate conditions that would be expected if the Proposed Action is not implemented. No Action models are based on existing conditions models with a few exceptions. Based on discussions with review agencies during development of the Proposed Action models and after review of the initial draft SPLNT report (BC 2018c), some changes to the modeling methods and assumptions were altered for the Proposed Action models. The No Action

models incorporate these same changes for consistency. **The reach configurations, meteorological, and hydrologic inputs are the same for No Action and Existing Conditions models; these models are independent of Alternative modeling, and do not directly use streamflow output from the SGP hydrologic model.**

General model specifications for the SPLNT models and scenarios are provided in Table 2-1.

Table 2-1. SPLNT Model Specifications

Model Area	Active stream domain (linear miles): Existing Conditions and No Action: 25.5 miles
Modeling Software	QUAL2K (streams) GLM (pit lakes)
Supplemental Modeling Tools	Shade.xls (stream shade inputs to QUAL2K) TTools (spatial analyses for inputs to Shade.xls)
Units	QUAL2K: metric GLM: metric
Model Type	QUAL2K: Steady-state flow model with diurnal temperature simulations GLM (Pit Lakes): Time series model, one-dimensional vertical lake profile
Time Step	QUAL2K: Hourly inputs over a 24-hour period to simulate daily output GLM: Daily time steps for model inputs and outputs
Simulation Timelines and Approach[a]	**Existing Conditions:** QUAL2K: Two 24-hour periods representing maximum weekly temperature conditions for July–August (Summer) and September–October (Fall). GLM: Daily simulation period from January 1, 2014, to December 31, 2016, for YPP lake **No Action:** QUAL2K: Three 24-hour periods representing maximum weekly temperature conditions for July–August (Summer) and September–October (Fall) and mean August temperature conditions to support occupancy modeling GLM: Daily simulation period from January 1, 2014, to December 31, 2016, for YPP lake
Boundaries	QUAL2K (Streams): Node-based model; upstream inputs for each stream segment represent headwater flow entering the model domain GLM (Pit Lakes): Surface water and groundwater nodes representing water entering the model domain

Notes:

[a] The specific periods selected for simulation with the QUAL2K model were low-flow, maximum weekly temperature, summer conditions observed on July 29, 2016, and low-flow, maximum weekly temperature, fall conditions observed on September 24, 2014. These maximum weekly summer and fall conditions are used for the No Action models as described in the SPLNT Proposed Action Modeling Report (BC 2019) and the model calibration presented in the SPLNT Existing Conditions Modeling Report (BC 2018b). A subsequent request by the agencies for mean August temperature modeling was also conducted for the Proposed Action and No Action conditions. The period selected for simulation with the GLM for No Action was January 1, 2014, through December 31, 2016, to bracket the periods simulated with QUAL2K.

Abbreviations:

BC = Brown and Caldwell

GLM = General Lake Model

SPLNT = stream and pit lake network temperature

YPP = Yellow Pine pit

2.1 Modeling Software

2.1.1 Stream Network Temperature Model

QUAL2K is a one-dimensional river and stream water quality model that simulates water temperature over a 24-hour period under steady-state flow conditions. This model has been widely applied to temperature evaluations in the Pacific Northwest and is used by the EPA (Montana Department of Environmental Quality and EPA Region 8 2014; Tetra Tech 2013, 2014). The modeled stream network can consist of a mainstem river and branched tributaries. The streams are represented by a series of reaches, each of which is represented using constant hydraulic characteristics (e.g., slope, width). The heat budget and water temperatures are simulated as a function of meteorology, headwater conditions, point and non-point loads, and withdrawals from each reach. QUAL2K is a freely available update to the older QUAL2E model. Both versions use Fortran for numerical computations, but QUAL2K has an enhanced user interface implemented within a Microsoft Excel spreadsheet. The latest version of the model is maintained and distributed by Tufts University and is available for download at http://www.qual2k.com/. The model outputs minimum, maximum, and average daily temperature for each reach. Inputs that were applied to all model configurations and scenarios in QUAL2K are provided in Appendix A which includes the heat balance equations applied and the meteorological and headwater inputs for the summer and fall model periods.

A key input for the QUAL2K model is hourly stream shading, which is specified for each modeling reach. The Washington State Department of Ecology developed a spreadsheet-based model called Shade.xls to predict stream shading by reach at an hourly time step as needed for QUAL2K. The Shade.xls model accounts for latitude, longitude, topography, vegetation (height, density, and overhang), and solar radiation in its calculations. The Shade.xls model and documentation are available at http://www.ecy.wa.gov/programs/eap/models.html. The Shade.xls model was adapted from a Fortran-based program called HeatSource, developed by the Oregon Department of Environmental Quality (ODEQ 2001 and 2009). The ODEQ also developed an ArcGIS extension called TTools (Boyd and Kasper 2003) to process geospatial data for input into these models. TTools was applied to process the spatial data for the Study Area and generate inputs for the Shade.xls model. The TTools extension and supporting documentation are available at http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Tools.aspx.

2.1.2 Pit Lake Model

The GLM is a one-dimensional lake model which dynamically simulates water balance and vertical stratification (Hipsey et al. 2014). The model produces a time series of temperature profiles that account for surface water and groundwater inflows and outflows, surface heating and cooling (using local weather conditions), and subsequent vertical mixing within the lake. The GLM provides a modernized code structure around the same underlying equations of the older Dynamic Reservoir Simulation Model (DYRESM) (Imberger and Patterson 1981; Antenucci and Imerito 2001), which has a long history of use for mining applications (Castendyk 2009). Both programs were developed at the University of Western Australia and are based on the same underlying models and equations, but GLM was updated to produce greater computational efficiency and ease of use. Like DYRESM, GLM can be paired with modules for simulating water quality, including a module capable of simulating DO dynamics. The model can be run as a standalone executable (programmed using C++) or through an R-project interface that was developed by the United States Geological Survey (USGS) (glmtools). GLM is open-source and freely available under the GNU General Public License (GPLv3, https://www.gnu.org/licenses/gpl.html).

2.2 Existing Conditions Model

The purpose of simulating existing conditions with the SPLNT model was to confirm that the approach resulted in models capable of reproducing observed conditions, and through calibration/validation, demonstrated the models' suitability to perform predictive simulations of temperature and DO. Details on the development and calibration of the existing conditions model are provided in the SPLNT Existing Conditions Report (BC 2018b) including reach-level characteristics. This appendix provides a summary of the inputs for the Existing Conditions model.

QUAL2K. The steady-state QUAL2K component of the SPLNT model was designed to simulate: (1) low-flow, maximum weekly temperature summer conditions (July through August) and (2) low-flow, maximum weekly temperature fall conditions (September through October) to allow for an assessment of mining impacts based on thermal criteria applicable to these conditions. To select time periods representative of these two conditions, a review of historical observed flows and temperatures was performed. Observed conditions on July 29, 2016, represent recurring flows/temperatures observed over a 2-week period; steady-state simulations of July 29, 2016, therefore represent low-flow, maximum weekly temperature, summer conditions. Similarly, the date selected to represent consistently low-flow, maximum weekly temperatures during the fall was September 24, 2014. The SPLNT Existing Conditions Report (BC 2018b) presents the observed flows and temperatures for the two-week periods centering around these representative dates. The meteorology and stream hydrology measured on these specific days provide the inputs to the SPLNT model. For Existing Conditions and No Action models, the inputs are the same. To evaluate Project Alternatives, the stream baseflows are adjusted based on a percent difference calculated by comparing SGP hydrologic model simulations of No Action to a Project Alternative, but the meteorology for the evaluation is not altered.

General Lake Model. The GLM simulation period of the YPP lake temperature and DO was January 1, 2014, through December 31, 2016. This period was selected to coincide with the extent of concurrent flow, temperature, and meteorology data collected in the Study Area and to bracket the representative periods simulated with QUAL2K. The series of daily simulated pit lake and DO temperature profiles over the 3-year period were compared to stream flows and temperatures observed by the USGS at the gage downstream as described below.

2.3 No Action Model

The No Action models are based on the Existing Conditions models but incorporate changes discussed with the agencies following review of the preliminary draft Proposed Action models (BC 2018c). These changes were incorporated to address agency concerns regarding the estimate of shade along the model reaches. These changes included the following relative to the existing conditions model:

- Used 10-meter elevation data published by USGS rather than Light Detection and Ranging (LiDAR)-based elevation data
- Applied the smallest potential shading from streambanks rather than an average based on left and right bank elevations
- Assigned stream elevations based on single grid cell rather than adjacent grid cells
- Sampled vegetation data along the stream every 10 meters rather than every 60 meters
- Adjusted the Shade.xls model riparian zone configuration to accommodate a 7-foot restoration planting zone in alignment with the post-closure vegetation analysis (BC 2019b, Section 4.2.2).
- Accounted for the presence of rock drains in the shade modeling rather than averaging in characteristics for the QUAL2K model

The No Action models were developed to provide a comparison to the Proposed Action models using a consistent set of methods. Reach-level QUAL2K model inputs and outputs for the No Action models are provided in Appendix B of the SPLNT Proposed Action Modeling Report (BC 2019b) including rating curves, hourly shade values, diffuse flow rates and temperatures, and point source inputs representing small tributaries to the system.

Section 3

Data Types and Sources

This section describes the raw data that was used to develop the SPLNT model. Data processing to generate model inputs is described in Section 4.

3.1 Topographic Data

Topographic data describes the changes in elevation, aspect angles, and the direction of stream flows. There are two main sources of topographic data for the study area. Perpetua Resources collected LiDAR data for most of the study area. Contours created from the LiDAR data are shown in Figure 4 of the SPLNT Existing Conditions Report (BC 2018b). The USGS National Elevation Dataset (NED) are available to fill holes in LiDAR coverage or extent beyond the study area as required by TTools.

3.2 Meteorological Data

The QUAL2K model requires the user to input hourly values for air temperature, dew point temperature, wind speed, and cloud cover. The GLM requires times series inputs for solar radiation, air temperature, relative humidity, wind speed, rainfall, and snowfall.

Available data were compiled for the MesoWest Perpetua Resources station, which is located in Meadow Creek valley. Figure 5 of the SPLNT Existing Conditions Report (BC 2018b) shows the raw data available for 2014 through 2017 for this site.

3.3 Stream Hydraulic Data

Cross section data were collected along 15 reaches in the study area for the aquatic resource baseline study (MWH Americas Inc. [MWH] 2017) and for field studies completed by Rio Applied Science and Engineering (Rio ASE) for stream restoration design (Rio ASE 2019). Figure 6 of the SPLNT Existing Conditions Report (BC 2018b) shows the location of the 12 cross sections measured as part of the PACFISH/INFISH Biological Opinion surveys by MWH (2017). The location of the nine cross section surveys by Rio ASE to support restoration design are shown in Figure 7 of the SPLNT Existing Conditions Report (BC 2018b). The cross section data were used along with stream flow and hydraulic data collected by the USGS at the five gages in the study area (also shown on Figure 6 and Figure 7 of the SPLNT Existing Conditions Report (BC 2018b) and discussed in Section 3.5 of the SPLNT Existing Conditions Report (BC 2018b) to develop the rating curves described in Section 4.3 of this appendix.

3.4 Pit Lake Bathymetry Data

Bathymetry for the YPP (Figure 8 of the SPLNT Existing Conditions Report [BC 2018b]) is available from Quadrant Consulting, Inc. (2016) and was used to define the morphological characteristics for the GLM existing conditions modeling.

3.5 Stream Flow and Water Temperature Data

Water temperature and stream flow measurements are used to set initial conditions and develop and calibrate the SPLNT model. Because the SPLNT model simulates a 24-hr period (selected based on observations of low flow, steady state, warm temperature conditions), the SGP hydrologic model does not provide direct inputs of stream base flows (i.e., diffuse flows) to the SPLNT model. The hydrologic model runs on a monthly time step, and the SPLNT model was calibrated and validated to specific days that represent weeks that would be comparable to maximum weekly summer and maximum weekly fall conditions. When the SPLNT model is used to assess potential impacts due to Project Alternatives, the percent change in simulated stream base flows from the SGP hydrologic models for No Action and an Alternative are applied to the SPLNT No Action model and the diffuse flows are adjusted accordingly. For example, a stream reach in the SPLNT No Action model may have a baseflow (i.e., diffuse flow) input of 0.10 cubic feet per second (cfs). This input was set during model development based on a mass balance approach such that the simulated stream flows at USGS stream flow gages matched those observed on the representative day. The SGP hydrologic model may have predicted a No Action monthly average baseflow over that reach of 0.12 cfs; this value would not have been used to develop the SPLNT No Action models. Under a Project Alternative, the SGP Hydrologic Model may have predicted a monthly average diffuse flow to that reach of 0.9 cfs, or a 25 percent reduction from the monthly average under No Action. The SPLNT Model for the Project Alternative would then apply a 25 percent reduction to the diffuse flow in that reach, and the input value would decrease from 0.10 cfs under No Action to 0.075 cfs under the Project Alternative.

Because of the way that the SGP hydrologic model is applied to the SPLNT models, the changes made to the hydrologic model Existing Conditions or for the ModPRO2 Alternative do not require the SPLNT No Action or Existing Conditions models to be rerun: these models are developed using daily stream flow observations on specific days. When the SGP hydrologic model was revised for the ModPRO2, a No Action hydrologic model was also developed. Stream baseflows from both revised hydrologic models were used to calculate the percent change in stream baseflows, and this change was applied to the SPLNT model inputs to evaluate the ModPRO2.

There are five active USGS stations in the watershed that measure flow and water temperature (https://waterdata.usgs.gov/nwisl). In addition, Perpetua Resources measured water temperature during the summer period between 2013 and 2016 for the surface water quality baseline study (HDR Engineering, Inc. [HDR] 2017) and the aquatic resources baseline study (MWH 2017). These data were used to develop the SPLNT Existing Conditions models. Figure 9 of the SPLNT Existing Conditions Report (BC 2018b) shows the locations of the USGS gages and HDR monitoring stations (32 of these stations monitor streams). Figure 6 of the SPLNT Existing Conditions Report (BC 2018b) shows the location of the MWH stations where temperature was monitored (denoted by a “T” in the center of the station label). Table 3-1 through Table 3-3 summarize the flow and the temperature data available in the study area to develop the SPLNT Existing Conditions models. Figure 10 through Figure 13 of the SPLNT Existing Conditions Report (BC 2018b) display the data available from these gages and monitoring stations.

Table 3-1. USGS 15-Minute Streamflow and Temperature Monitoring Gages in the Study Area

Gage Number	Tributary Name and Location	Drainage Area (sq. mi.)	Period of Record Available to Develop Existing SPLNT Conditions Model	Count of Measurements				
				Discharge	Water Temperature	Velocity (at point in stream)	Width	Gage Height
13310800	EFSFSR above Meadow Creek	9	2011-09-19 to 2017-08-23	2,208	2,238	25	32	103

13310850	Meadow Creek near Stibnite	5.6	2011-09-19 to 2017-08-23	2,209	2,197	26	33	76
13311000	EFSFSR at Stibnite	19.3	1983-01-25 to 2017-08-24	11,361	2,384	26	32	136
13311250	EFSFSR above Sugar Creek	25	2011-09-19 to 2017-08-24	2,246	2,052	26	33	136
13311450	Sugar Creek near Stibnite	18	2011-09-21 to 2017-08-24	2,244	2,052	26	33	137

Abbreviations:

EFSFSR = East Fork of the South Fork of the Salmon River

SPLNT = stream and pit lake network temperature

sq. mi. = square mile

USGS = United States Geological Survey

Table 3-2. Perpetua Resources Temperature Monitoring Stations (15-Minute Data)

Station Number	Tributary Name and Location	Period of Record Available to Develop Existing SPLNT Conditions Model *
MWH-001	Headwaters—EFSFSR	2013–2016
MWH-003	Headwaters—EFSFSR	2013–2016
MWH-004	Headwaters—EFSFSR	2014–2016
MWH-005	Deadman Creek—EFSFSR	2013–2016
MWH-006	Headwaters—EFSFSR	2013–2016
MWH-007	Headwaters—EFSFSR	2013–2016
MWH-008	Sugar Creek	2013–2016
MWH-021	Sugar Creek	2014–2016
MWH-033	No Mans Creek—EFSFSR	N/A
MWH-034	Headwaters—EFSFSR	2013–2016
MWH-051	Burntlog Creek	2014–2016
MWH-054	Trapper Creek—Johnson Creek	2014–2016
MWH-055	Riordan Creek	2016
MWH-056	Fourmile Creek—SFSR	2014–2016
MWH-057	Goat Creek—SFSR	2014–2016

Notes:

**Records have various gaps due to equipment failures.*

Source: Aquatic Resources Baseline Report (MWH 2017).

See Figure 6 of the SPLNT Existing Conditions Report (BC 2018b) for map of locations.

Abbreviations:

BC = Brown and Caldwell

EFSFSR = East Fork of the South Fork of the Salmon River

MWH = MWH Americas, Inc.

N/A = Not available

SFSR = South Fork of the Salmon River

SPLNT = stream and pit lake network temperature

Table 3-3. Perpetua Resources Stream, Seep, and Adit Temperature Monitoring Stations

Station Number	Station Name	Drainage	Sample Count	Frequency Type
4	YP-AS-1	Sugar Creek	29	M, Q
5	YP-AS-2	Sugar Creek	37	M, Q
6	YP-AS-3	EFSFSR	35	M, Q
7	YP-AS-4	EFSFSR	36	M, Q
8	YP-AS-5	EFSFSR	1	Q
9	YP-AS-6	EFSFSR	34	M, Q
10	YP-AS-7	Meadow Creek	17	M, Q
11	YP-S-1	Sugar Creek	27	M, Q
12	YP-S-2	Meadow Creek	17	M, Q
13	YP-S-3	EFSFSR	24	M, Q
14	YP-S-5	Meadow Creek	16	M, Q
15	YP-S-6	Meadow Creek	34	M, Q
16	YP-S-7	Meadow Creek	33	M, Q
17	YP-S-8	Meadow Creek	34	M, Q
18	YP-S-9	EFSFSR	23	M, Q
19	YP-S-10	Meadow Creek	37	M, Q
20	YP-SEBS-1	EFSFSR	24	M, Q
21	YP-SEBS-2	EFSFSR	24	M, Q
22	YP-SR-2	EFSFSR	38	M, Q
23	YP-SR-4	EFSFSR	38	M, Q
24	YP-SR-6	EFSFSR	38	M, Q
25	YP-SR-8	EFSFSR	38	M, Q
26	YP-SR-10	EFSFSR	38	M, Q
27	YP-SR-11	EFSFSR	38	M, Q
28	YP-SR-13	EFSFSR	38	M, Q
29	YP-T-1	Sugar Creek	38	M, Q
30	YP-T-6	Sugar Creek	37	M, Q
31	YP-T-7	Sugar Creek	38	M, Q
32	YP-T-8A	Sugar Creek	31	M, Q
33	YP-T-10	EFSFSR	37	M, Q
34	YP-T-11	EFSFSR	38	M, Q
35	YP-T-12	EFSFSR	27	M, Q

Station Number	Station Name	Drainage	Sample Count	Frequency Type
36	YP-T-17	EFSFSR	37	M, Q
37	YP-T-21	EFSFSR	38	M, Q
38	YP-T-22	Meadow Creek	38	M, Q
39	YP-T-23A	Meadow Creek	23	M, Q
40	YP-T-27	Meadow Creek	38	M, Q
41	YP-T-29	Meadow Creek	38	M, Q
42	YP-T-33	Meadow Creek	38	M, Q
43	YP-T-35	EFSFSR	34	M, Q
44	YP-T-37	Sugar Creek	21	M, Q
45	YP-T-40	EFSFSR	38	M, Q
46	YP-T-41	EFSFSR	38	M, Q
47	YP-T-42	EFSFSR	23	M, Q
48	YP-T-43	Meadow Creek	35	M, Q
49	YP-M-3	Meadow Creek	35	M, Q
50	YP-HP-S1	Sugar Creek	30	M, Q
51	YP-T-15	EFSFSR	38	M, Q
52	Keyway Input	Meadow Creek	4	Q
53	YP-M-4	EFSFSR	24	M, Q
54	GM-MN-192	EFSFSR	1	Q
55	GM-GC-56	EFSFSR	1	Q
56	GM-GC-60	EFSFSR	1	Q
57	Rabbit Adit	EFSFSR	1	Q
58	GM-RC-220	EFSFSR	1	Q
59	GM-RC-216	EFSFSR	1	Q
60	YP-T-44	EFSFSR	23	M, Q
61	YP-SR-14	EFSFSR	26	M, Q
62	YP-T-45	Meadow Creek	17	M, Q
63	YP-T-46	Meadow Creek	10	M, Q
64	YP-T-47	EFSFSR	1	Q
65	YP-T-48	EFSFSR	19	M, Q
136	YP-HD-BLDG2-2014	EFSFSR	1	Q
138	YP-T-49	Sugar Creek	5	Q

Notes:

Source: Surface Water Quality Baseline Report (HDR 2017).

See Figure 9 of the SPLNT Existing Conditions Report (BC 2018b) for map of locations.

Abbreviations:

BC = Brown and Caldwell

EFSFSR = East fork of the South Fork of the Salmon River

HDR = HDR Engineering, Inc.

M = monthly

Q = quarterly

SPLNT = stream and pit lake network temperature

3.6 Pit Lake Temperature Data

BC measured water temperature and DO in the YPP lake on October 3, 2017, between 12:11 p.m. and 12:36 p.m. This pit lake is shallow (35 feet [ft] maximum depth at normal pool) relative to the proposed West End and Hangar Flats pit lakes. Data were collected by boat at the center of the lake (0631346E, 4976250N UTM). Temperature and DO profile data were collected approximately every 1.5 ft from the surface to 6.5 ft and every 3.2 ft from 6.5 ft to 33 ft using a YSI 556 Meter. The DO meter was calibrated to the 100 percent saturation concentration before sampling, and a post-sampling drift check was conducted to verify that the meter was operating within 10 percent of the known calibration values. Secchi depth, a measure of water clarity, was also measured and was found to be 21 ft.

The lake appeared to be well mixed and nearly isothermal through most of the water column (Table 3-4, Graph 3-1). There was a thin layer of ice on the northeast corner of the lake at the time of sampling.

Historical temperature data for the YPP lake (URS Corporation 2000) are also available (Table 3-5). Differences between surface and deep water temperatures collected in July, August, and September 1999 suggest stratification may have been relatively weak over the summer, but by September, temperatures at the deepest (central) location are indicative of stable thermal stratification (URS 2000). Historical and recent monitoring station locations for the YPP are shown on Figure 14 of the SPLNT Existing Conditions Report (BC 2018b).

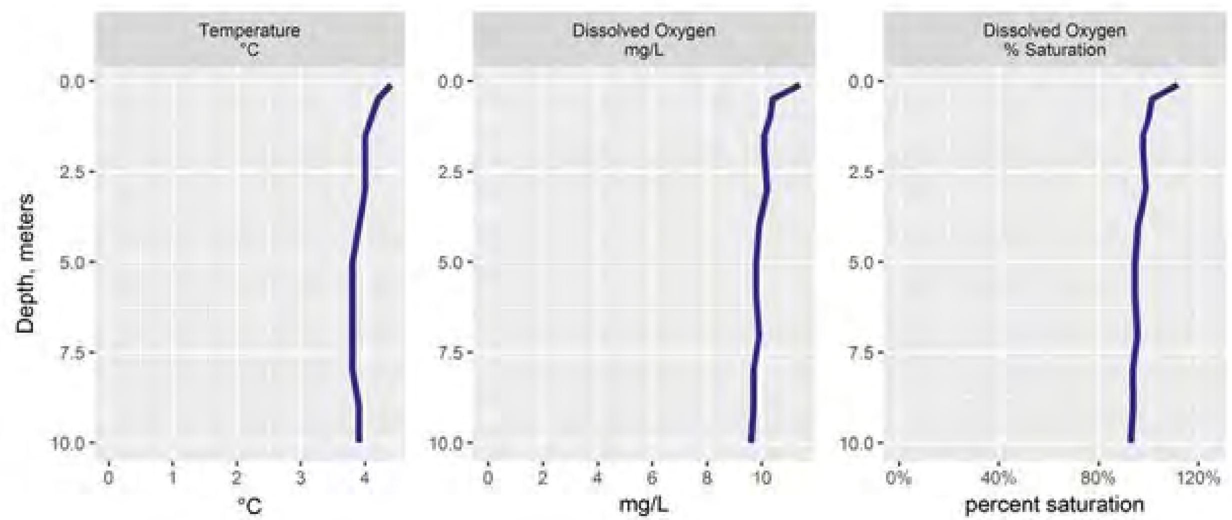
Table 3-4. YPP Lake Measurements (October 3, 2017)

Water Depth (ft)	Temp (°C)	DO (mg/l)	DO Percent Saturation[a]
0.33	4.4	11.34	108.6
0.66	4.2	10.4	99.1
3.3	4.1	10.3	98.3
4.9	4.0	10.1	95.4
6.6	4.0	10.1	95.9
9.8	4.0	10.12	96.3
13.1	3.9	9.9	93.9
16.4	3.8	9.8	92.8
19.7	3.8	9.8	92.7
23.0	3.8	9.9	93.7
26.2	3.8	9.7	91.6
29.5	3.9	9.7	92.0
32.8	3.9	9.6	91.1

Notes:

[a] *Estimated assuming a barometric pressure of 613.0 mm Hg as specified on the field sheet (Appendix A).*

Abbreviations:
°C = degree Celsius
DO = dissolved oxygen
ft = foot/feet
mg/l = milligram per liter
YPP = Yellow Pine pit



Graph 3-1. YPP Lake Temperature and DO Depth Profiles (October 3, 2017)

Table 3-5. 1999 YPP Lake Profile Data

Station	Temp (°C)			DO (mg/l)		
	7/15/1999	8/31/1999	9/14/1999	7/15/1999	8/31/1999	9/14/1999
GH-1						
Surface	9.7	12.0	21.3	9.8	7.6	8.1
Mid	8.7	9.6	18.6	11.5	7.4	5.8
Bottom	8.5	9.4	17.9	11.7	6.2	4.9
GH-2						
Surface	8.7	11.9	20.1	9.3	8.0	7.0
Mid	7.9	9.4	15.7	9.4	7.2	5.3
Bottom	7.8	8.6	12.6	8.8	0.3	4.7
GH-3						
Surface	8.5	10.5	28.6	9.6	7.9	6.7
Mid	8.1	10.0	19.4	9.0	8.0	4.9
Bottom	8.1	9.5	18.2	9.0	7.5	4.9

Notes:
Source: URS 2000
Abbreviations:
°C = degree Celsius
DO = dissolved oxygen
mg/l = milligram per liter
YPP = Yellow Pine pit

Section 4

Methods and Generation of Model Input

This section describes the methods and procedures used to generate model input for the SPLNT model and the underlying models including TTools, Shade, QUAL2K, and GLM.

4.1 Development of Seamless Topographic Coverage

Topographic shading can be created by both near-field and far-field features, and the degree of shading changes with the position of the sun. The Shade.xls model uses the maximum of the near-field (banks, local hills) and far-field (ridgelines) topographic angles in each of the east, south, and west directions to drive topographic shading. The TTools ArcGIS extension described by Boyd and Kasper (2003) uses high resolution topographic data to identify shade angles in the near-field. This high-resolution dataset is derived from LiDAR data everywhere LiDAR data have been collected (the majority of the study area).

For the Existing Conditions models, far-field topographic shading (from distant ridge lines) was evaluated using TTools and the 30-meter NED from the USGS. Figure 15 of the SPLNT Existing Conditions Report (BC 2018b) shows the seamless topographic coverage generated from the LiDAR and NED data. For the No Action models, the 10-meter NED from USGS was used.

4.2 Delineation of Subbasins

The SPLNT model explicitly simulates perennial streams and pit lakes that may be affected by the PRO or alternatives. Areas upstream of this model domain are represented as headwater inputs to the model. To estimate the flows entering as headwaters, the drainage area upstream of each modeled reach is required. BC delineated the drainage areas to each model reach using the seamless topographic coverage described in Section 4.1. Estimates of flows based on these drainage areas vary for the calibration and validation period as described in Section 4.6.2.

BC also delineated drainage areas to locations in the study area where stream cross sections were measured. These drainage areas were used to characterize channel dimensions as described in Section 4.3.

BC delineated the drainage areas to USGS gages with reported drainage areas for comparison to provide a quality assurance check. The drainage areas reported for four USGS gages (13310800 EFSFSR above Meadow Creek, 13311000 EFSFSR at Stibnite, 13311250 EFSFSR above Sugar Creek, and 13311450 Sugar Creek near Stibnite) were within 0.8 percent of those delineated by BC. One USGS gage (13310850 Meadow Creek near Stibnite) had a reported drainage area within 2.1 percent of that delineated by BC. This exercise demonstrates the accuracy of the methods used and provides confidence that using drainage areas delineated by BC and applied in several steps in the development of the SPLNT model does not introduce a noticeable level of uncertainty in the modeling.

4.3 Characterization of Channel Dimensions

Separate components of the SPLNT model require characterization of stream channel dimensions including bankfull width and wetted depth, velocity, and width. The characterization of channel dimensions supports modeling in TTools and QUAL2K. Units in this section are presented as metric units consistent with the input requirements for these tools and to facilitate review by the USFS and cooperating agencies.

Bankfull width is associated with channel forming flows and is often correlated with drainage area (Emmett 1975; Lawlor 2004). Rating curves for bankfull width provided by Emmett and Lawlor were evaluated for the study area and compared to data collected by MWH at 16 sites. Lawlor (2004) provided rating curves for varying amounts of annual average precipitation. The rating curves for regions with 30 to 45 inches of annual precipitation provided a better fit to the data compared to Emmett and were selected to predict bankfull width for streams in the study area:

$$W_B = 1.84 * (DA^{0.441})$$

where

W_B = bankfull width in meters

DA = drainage area in square miles

Graph 4-1 of the SPLNT Existing Conditions Report (BC 2018b) compares the predicted and observed bankfull widths using the Lawlor (2004) rating curves. A trendline with a slope of 1 would indicate a near perfect fit. Given the varying conditions observed within a reach (typically comprising riffles, runs, and pools), and the nature of the observations (a limited number of transects were collected within each reach), a trendline slope of 0.81 and an R^2 of 0.79 are sufficiently accurate for this application. TTools requires bankfull width in its determination of topographic and vegetative shading. TTools uses bankfull width to indicate the width across which rooted vegetation would not occur (canopy overhang is accounted for separately). Predicted bankfull widths were assigned to streamlines for this analysis.

Characteristics describing wetted conditions (velocity, depth, and wetted width) vary with stream flow, and rating curve equations can be developed relating each of the three variables to flow. Laws of continuity summarized by Emmett require that the sum of the rating curve equation exponents equals 1, and the product of the coefficients equals 1. Thus, specification of two of the three curves dictates the third curve. Rating curves were developed using data collected by USGS, MWH, and Rio ASE. For this study area, the following rating curves were developed based on the available data:

$$V_W = 0.75 * (Q^{0.32})$$

$$D_W = 0.35 * (Q^{0.25})$$

$$W_W = 3.81 * (Q^{0.43})$$

where

V_W = Velocity in meters per second

D_W = Wetted depth in meters

W_W = Wetted width in meters

Q = Flow in cubic meters per second

Graph 4-2 through Graph 4-4 of the SPLNT Existing Conditions Report (BC 2018b) show the predicted (i.e., computed from flow using the rating curve equations above; y-axis) versus observed data (i.e., measured in the field by USGS, MWH, and Rio ASE; x-axis) for these three parameters (V_W,

D_w, and W_w). Coefficients and exponents were adjusted to achieve the best fit across all three parameters (the closest slopes to 1 for the dotted line and best R^2 values). For these data, slopes of the regression line of 0.73 to 0.74 were achieved across the three parameters. R^2 values ranged from 0.44 (for width) to 0.92 (for velocity). The lower R^2 for width indicates it is less strongly correlated to flow compared to the other parameters. Fitting a rating curve solely to the width data without the constraints of continuity did not result in higher R^2 values.

These "global" rating curves were entered into QUAL2K to describe the hydraulic conditions associated with simulated stream flow. During model calibration (described in Section 5.1), rating curves for some segments were revised to better simulate water temperatures. Revisions to rating curves were based on velocity, wetted depth, and wetted width measurements collected by MWH and Rio ASE near the reach being calibrated. Table 4-1 summarizes the rating curve coefficients and exponents for streams in the study area for the calibrated model. The coefficients and exponents for each set of equations maintain the laws of continuity for flow.

Table 4-1. Rating Curves for Streams in the Study Area

Reach Description (Number)	Velocity (m/s)	Depth (m)	Width (m)
Model Reaches Upstream of YPP			
EFSFSR above Meadow Creek (1–6)	$0.75 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$6.06 * (Q^{0.43})$
Lower Meadow Creek above East Fork Meadow Creek (15 and 16)	$0.48 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$9.47 * (Q^{0.43})$
East Fork Meadow Creek (17)	$1.60 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$1.78 * (Q^{0.43})$
EFSFSR below Meadow Creek (21)	$0.48 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$9.47 * (Q^{0.43})$
Model Reaches Downstream of YPP			
Upper Sugar Creek and unnamed tributaries to upper Sugar Creek (1–7)	$0.48 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$5.95 * (Q^{0.43})$
Model Reaches Upstream and Downstream of YPP			
All other streams in the study area	$0.75 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$3.81 * (Q^{0.43})$

Abbreviations:

EFSFSR = East Fork of the South Fork of the Salmon River

m = meter

m/s = meter per second

YPP = Yellow Pine pit

4.4 Selection of Calibration and Validation Dates

QUAL2K is a steady state model that predicts diurnal temperature variability. To evaluate potential impacts of mining and restoration, simulation dates representative of thermal criteria (maximum weekly summer and fall conditions) were selected as the calibration and validation periods. Late July and late September were selected as the target periods for calibration and validation, respectively. The calibration period was selected as a low-flow, high-temperature condition for comparison to the

USFS MWMT and the IDEQ maximum daily maximum temperature, MWMT, and maximum daily average temperature described in Section 1.2. The validation period was selected for comparison to spawning season conditions for bull trout and Chinook salmon (the spawning period for steelhead is in the spring when flows due to snowmelt runoff are relatively high and mining operations would be less likely to impact water temperatures).

Evaluating 15-minute flow data available at multiple USGS gages in the study area during these months led to the selection of July 29, 2016, for calibration and September 24, 2014, for validation. Both dates represent steady-state flow conditions as shown in Figure 16 and Figure 17 of the SPLNT Existing Conditions Report (BC 2018b). Fifteen-minute temperature data around this time is shown on Figure 18 and Figure 19 of the SPLNT Existing Conditions Report (BC 2018b).

4.5 TTools and Shade Model Configuration

QUAL2K requires hourly estimates of stream shading caused by topography and surrounding vegetation. Estimation of hourly shade values for reaches simulated in QUAL2K have been developed using TTools and Shade.xls. TTools is an ArcMap script that processes spatial coverages of topographic and vegetative data and outputs aspect, topographic angles, canopy height, and canopy density. TTools processes input data in several increments out from the stream channel over a distance of 9 kilometers. Outputs from TTools are entered into the Shade.xls model along with estimates of canopy overhang. Output from the Shade.xls model is entered into QUAL2K as hourly shade estimates by reach. This section of the report describes how TTools and Shade.xls model were used to support development of the SPLNT model.

4.5.1 TTools for Existing Conditions Models

The ArcGIS Extension TTools (Boyd and Kasper 2003) was applied to process the spatial data for the study area and generate inputs for the Shade.xls model. The topographic data processed with TTools is described in Section 4.1 and shown in Figure 15of the SPLNT Existing Conditions Report (BC 2018b).

Shading from riparian vegetation is influenced by canopy height, density, overhang, and distance from the stream. The LiDAR data collected by Perpetua Resources was used to develop coverages of canopy height and density using methods similar to those described by the USGS (2013) for the data in the vicinity of the streams. Vegetation height was determined as the difference in elevation between returns classified as vegetation and a normalized ground-surface layer based on ground-classified returns. A 10-foot-by-10-foot raster layer of canopy height was created for the region using the top of the vegetative layer in each cell. Vegetation density was estimated as the ratio of LiDAR returns classified as vegetation to the total number of returns classified as vegetation or ground. These height and density coverages were sampled for each stream reach using the TTools extension to provide inputs to the Shade.xls model. Figure 20 through Figure 22 of the SPLNT Existing Conditions Report (BC 2018b) show the vegetation characteristics provided by the USFS or derived from the LiDAR data.

4.5.2 Shade Model for Existing Conditions Models

The Washington State Department of Ecology developed the Shade.xls model to facilitate the generation of hourly shade estimates based on previous modeling by the ODEQ (Models for Total Maximum Daily Load Studies; http://www.ecy.wa.gov/programs/eap/models.html). The Shade.xls model accounts for geographic position, topography, and vegetation characteristics to estimate the hourly percent shading by stream reach. Topographic shading can be created by both near-field and far-field features, and the degree of shading changes with the position of the sun.

The Shade.xls model relies on output from TTools (Section 4.5.1) in the determination of hourly shade values for QUAL2K (Section 4.6.5). In addition, the user must also assign canopy overhang estimates. Average overhang was estimated as a percent of height for trees (10 percent) and shrubs (25 percent) based on studies by Stuart (2012) and Shumar and de Varona (2009). The methods from these studies were also used to estimate overhang for the Nemote Creek, Montana, temperature total maximum daily load (TMDL) approved by EPA (Tetra Tech 2014).

The Shade.xls model was used to evaluate shade conditions every 200 feet along the stream network. Substantial changes in hourly shade estimates along the reaches were used to inform reach breaks for QUAL2K. Once the QUAL2K reaches were determined (based on the tributary network and changes in shade estimates), the Shade.xls model was rerun to provide inputs to QUAL2K (hourly shade estimates by reach). Figure 23 of the SPLNT Existing Conditions Report (BC 2018b) shows the hourly Shade.xls model output every 200 feet along the streams. The length shown on the y-axis for each panel is held constant.

4.5.3 No Action Shade Modeling

For the No Action models, shade values were estimated using mostly the same methods employed for the existing conditions model, i.e., by analyzing LiDAR data collected by Perpetua Resources. Canopy density and height were determined on a 6-meter-square grid.[1] Figure 4-4 of the SPLNT Proposed Action Modeling Report (BC 2019) shows the canopy density for the Existing Conditions and No Action models. Changes to the methods between the Existing Conditions and No Action models are listed in Section 2.3 of this appendix.

4.6 QUAL2K Model Configuration

This section describes the configuration and initialization of the QUAL2K model to represent Existing Conditions and No Action for the study area. While Perpetua Resources typically reports English units for reports, the QUAL2K model inputs are in metric units. These sections provide inputs in metric units consistent with the QUAL2K model to facilitate review by the USFS and cooperating agencies.

4.6.1 Stream Network and Reach Characterization

QUAL2K defines a model reach as one where average conditions are similar over the length of the reach. Stream reaches were split into separate modeling reaches at tributary confluences, distinct changes in shade, and the upper extent of proposed mine features. Stream reaches are the same for the Existing Conditions and No Action models. Figure 24 of the SPLNT Existing Conditions Report (BC 2018b) shows the mean hourly shade from 05:00 to 20:00 based on output from the Shade.xls model and conditions representative of early August (solar angles, etc.).

Two separate QUAL2K models have been developed to represent the Existing Conditions and No Action for the study area. Because the YPP is in the model domain and is being simulated dynamically using the GLM (Section 4.7), it was necessary to simulate the existing conditions upstream and downstream of the YPP using two separate QUAL2K models. Table 4-2 summarizes the reach configuration including the reach number, description, and length for each model.

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[1] Canopy density was calculated by dividing the number of vegetation-classified returns by the total number of returns classified as either vegetation or ground surface within each 6-meter grid cell. For canopy height, each 6-meter-square cell was subdivided into nine 2-meter-square cells and a canopy height model (CHM) was developed using the LiDAR package (version 1.6.0) in R (version 3.5.1). The CHM provided the highest vegetation returns for each of the nine 2-meter-square sub-cells within each 6-meter-square grid which were averaged to obtain the mean canopy height for each 6-meter grid cell. The LiDAR data were analyzed on 10-ft-square pixels to develop spatial coverages of canopy height and canopy density.

Table 4-2. Reach Characteristics for the QUAL2K Existing Conditions and No Action Models Upstream and Downstream of YPP

Reach Number	Reach Description[a]	Reach Length (km)
Model Reaches Upstream of YPP		
1	EFSFSR, Headwater to reach break	0.50
2	EFSFSR, reach break to EFSFSR Tributary 4	0.43
3	EFSFSR Tributary 4 Headwater	0.63
4	EFSFSR, EFSFSR Tributary 4 to reach break	0.67
5	EFSFSR, reach break to Rabbit Creek	0.86
6	EFSFSR, Rabbit Creek to MC	1.91
7	MC, Headwater to reach break	1.40
8	MC, reach break to MC Tributary 2	1.16
9	MC Tributary 2, Headwater to reach break	0.76
10	MC Tributary 2, reach break to MC	0.60
11	Meadow Creek, MC Tributary 2 to MC Tributary 3	0.34
12	MC Tributary 3, Headwater to reach break	0.76
13	MC Tributary 3, reach break to MC	0.83
14	MC, MC Tributary 3 to reach break	0.90
15	MC, reach break to reach break	1.02
16	MC, shadebreak to East Fork MC	0.93
17	East Fork MC, Headwater to shadebreak	2.76
18	East Fork MC, shadebreak to MC	1.65
19	MC, East Fork MC to shadebreak	1.15
20	MC, shadebreak to EFSFSR	0.36
21	EFSFSR, MC to Garnet Creek	0.66
22	Garnet Creek, Headwater to shadebreak	1.10
23	Garnet Creek, shadebreak to EFSFSR	0.74
24	EFSFSR, Garnet Creek to FC	1.77
25	FC, Headwater to FC Tributary 3	0.52
26	FC, FC Tributary 3 to shadebreak	0.33
27	FC, shadebreak to EFSFSR	1.94
28	EFSFSR, FC to shadebreak	0.23
29	EFSFSR, shadebreak to Midnight Creek	0.36
30	Midnight Creek Headwater	2.99
31	EFSFSR, Midnight Creek to YPP Lake	0.12

Reach Number	Reach Description[a]	Reach Length (km)
Model Reaches Downstream of YPP		
1	(SC, Headwater to shadebreak	0.55
2	SC, shadebreak to SC Tributary 4	0.58
3	SC Tributary 4 Headwater	0.26
4	SC, SC Tributary 4 to SC Tributary 5	0.17
5	SC Tributary 5 Headwater	0.24
6	SSC, SC Tributary 5 to shadebreak	0.71
7	SC, shadebreak to West End Creek	0.92
8	West End Creek, Headwater to shadebreak	0.76
9	West End Creek, shadebreak to shadebreak	1.13
10	West End Creek, shadebreak to SC	1.60
11	SC, West End Creek to EFSFSR	1.19
12	EFSFSR, YPP Lake to SC	1.12
13	EFSFSR, SC to Hennessy Ditch	0.15[b]
14	Hennessy Creek, Headwater to shadebreak	1.49
15	Hennessy Ditch, shadebreak to shadebreak	0.92
16	Hennessy Ditch, shadebreak to EFSFSR	0.53
17	EFSFSR, Hennessy Ditch to Model End	0.86

Notes:

[a] Shadebreaks are locations where a distinct change in shade was determined from the shade modeling and a new reach was assigned.

[b] Actual distance is 0.04 kilometer. However, the QUAL2K model would not compile and complete the Fortran calculations with the actual distance. Increased distance was necessary for the model to complete calculations for concentrated area of confluence between EFSFSR, Sugar Creek, and Hennessy Ditch (upper reaches are referred to as Hennessy Creek due to more natural condition). This resulted in moving the Hennessy Ditch input downstream approximately 360 feet in the model.

Abbreviations:

EFSFSR = East Fork of the South Fork of the Salmon River

FC = Fiddle Creek

km = kilometer

MC = Meadow Creek

SC = Sugar Creek

YPP = Yellow Pine pit

4.6.2 Headwater Flows and Temperatures

The model domain for the QUAL2K model is illustrated in Figure 3 of the SPLNT Existing Conditions Report (BC 2018b). Drainage areas upstream of the model domain are represented in the model as headwater inputs. Table 4-3 and Table 4-4 summarize the flow and temperatures specified for these headwaters for the calibration and validation models used to evaluate maximum weekly summer and fall conditions, respectively. Flows were based on the drainage areas delineated to each point using the methods described in Section 4.2. Water temperatures were based on observations recorded at nearby, similar temperature monitoring sites. Changes in water temperature relative to stream length (to inform assumptions on headwater temperatures) were estimated based on the difference in measurements at MWH-034 and MWH-003 (Figure 6 of the SPLNT Existing Conditions Report [BC 2018b]). These stations were selected because they are the most upstream stations in the headwaters of the study area that are close enough together to not be influenced substantially by diffuse flow inputs or tributaries. Simulated diurnal variability at the headwaters was exaggerated slightly relative to temperatures observed downstream (while the daily averages were maintained). Headwaters have lower stream flows and are subject to greater fluctuations in water temperature. This pattern was observed by comparing upstream and downstream temperature monitoring data.

Table 4-3. Daily Average Stream Flows Specified for Headwaters for the Calibration and Validation Periods Used to Evaluate the Maximum Weekly Summer and Fall Conditions, Respectively

Tributary (see Figure 3, BC 2018b)	Drainage Area at Headwater Input (sq. mi.)	Average Daily Flow (cms) for Calibration Date (July 29, 2016)	Average Daily Flow (cms) for Validation Date (September 24, 2014)
Sugar	14.810	0.307	0.200
SugarTrib_4	0.250	0.005	0.003
SugarTrib_5	0.470	0.010	0.006
West End	0.024	0.0005	0.0003
Hennessy	0.250	0.005	0.003
Midnight	0.034	0.001	0.0005
Fiddle	0.960	0.019	0.014
Fiddle_Trib3*	0.078	0.002	0.001
Garnet	0.048	0.0009	0.0007
East Fork Meadow	0.740	0.016	0.010
Meadow_Trib3	1.020	0.022	0.013
Meadow_Trib2	0.310	0.007	0.004
Meadow	0.640	0.014	0.008
Rabbit[a]	0.630	0.015	0.012
EFSFSR_Trib4	1.910	0.044	0.036
EFSFSR_US	4.040	0.093	0.076

Notes:

[a]Fiddle_Trib3 and Rabbit are simulated as point source inputs rather than tributaries.

Abbreviations:

BC = Brown and Caldwell

cms = cubic meter per second

sq. mi. = square mile

Table 4-4. Range of Hourly Water Temperatures Specified for Headwaters for the Calibration and Validation Periods Used to Evaluate the Maximum Weekly Summer and Fall Conditions, Respectively

Tributary (see Figure 3, BC 2018b)	Minimum, Average, and Maximum Hourly Temperatures (°C) for Calibration Date (July 29, 2016)	Minimum, Average, and Maximum Hourly Temperatures (°C) for Validation Date (September 24, 2014)
Sugar	6.7, 9.8, 13.7	7.5, 8.7, 9.9
West End	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Hennessy	5.6, 8.3, 11.5	6.7, 7.9, 9.1
EFSFSR Below YPP[a]	13.4	10.5
Midnight	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Fiddle	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Fiddle_Trib3[b]	8.3	7.9
Garnet	5.6, 8.3, 11.5	6.7, 7.9, 9.1
East Fork Meadow	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow_Trib3	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow_Trib2	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow	7.8, 10.9, 14.6	7.5, 8.7, 9.9
Rabbit[b]	8.3	7.9
EFSFSR_Trib6	5.6, 8.3, 11.5	6.7, 7.9, 9.1
EFSFSR_US	6.7, 9.8, 13.7	7.5, 8.7, 9.9

Notes:

[a] Headwater inputs for EFSFSR below the YPP are derived from the GLM described in Section 4.7.

[b] Tributaries simulated as point sources are only assigned a mean daily temperature as model input.

Abbreviations:

BC = Brown and Caldwell

°C = degree Celsius

EFSFSR = East Fork of the South Fork of the Salmon River

YPP = Yellow Pine pit

4.6.3 Diffuse Flow Inputs and Temperatures

Groundwater inputs are simulated by QUAL2K as diffuse flows that are constant inputs over the length of a reach. Assignment of diffuse flows maintains the flow balance throughout the system. Diffuse flows were assigned based on the observed differences at upstream and downstream USGS flow gages. Daily average water temperatures must also be defined for diffuse flows.

Table 4-5 summarizes the diffuse flow inputs and water temperatures assigned to each QUAL2K model reach. Diffuse source temperature was estimated as the average of (1) mean ambient air temperature for the preceding month of the calibration/validation period and (2) the average of seep/adit water temperature data collected by HDR between 2012 and 2016. Seep/adit temperatures were sorted spatially to apply to specific reaches and temporally to apply to the specific calibration and validation periods. This approach allowed for the use of site-specific data and consistency with approaches used for EPA-approved TMDLs (Montana DEQ and EPA Region 8 2014; Tetra Tech 2013, 2014).

Table 4-5. Diffuse Flows and Associated Water Temperature for the QUAL2K Models Upstream and Downstream of YPP

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
Model Reaches Upstream of YPP					
1	EFSFSR, Headwater to reach break	0.0060	11.90	0.0050	10.60
2	EFSFSR, reach break to EFSFSR Tributary 4	0.0050	11.90	0.0040	10.60
3	EFSFSR Tributary 4 Headwater	0.0070	11.90	0.0060	10.60
4	EFSFSR, EFSFSR Tributary 4 to reach break	0.0070	11.90	0.0060	10.60
5	EFSFSR, reach break to Rabbit Creek	0.0100	11.90	0.0080	10.60
6	EFSFSR, Rabbit Creek to MC	0.0210	13.90	0.0170	11.60
7	MC, Headwater to reach break	0.0180	11.90	0.0110	10.60
8	MC, reach break to MC Tributary 2	0.0150	11.90	0.0090	10.60
9	MC Tributary 2, Headwater to reach break	0.0100	11.90	0.0060	10.60
10	MC Tributary 2, reach break to Meadow Creek	0.0080	11.90	0.0050	10.60
11	MC, MC Tributary 2 to MC Tributary 3	0.0040	11.90	0.0030	10.60
12	MC Tributary 3, Headwater to reach break	0.0100	11.90	0.0060	10.60
13	MC Tributary 3, reach break to MC	0.0100	11.90	0.0060	10.60
14	MC, MC Tributary 3 to reach break	0.0090	13.90	0.0060	11.60
15	MC, reach break to reach break	0.0070	13.90	0.0060	11.60
16	MC, shadebreak to East Fork MC	0.0060	13.90	0.0060	11.60
17	East Fork MC, Headwater to shadebreak	0.0180	11.90	0.0160	10.60
18	East Fork MC, shadebreak to MC	0.0110	11.90	0.0100	10.60

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
19	MC, East Fork MC to shadebreak	0.0080	13.90	0.0070	11.60
20	MC, shadebreak to EFSFSR	0.0020	13.90	0.0020	11.60
21	EFSFSR, MC to Garnet Creek	0.0040	13.90	0.0020	11.60
22	Garnet Creek, Headwater to shadebreak	0.0070	11.90	0.0040	10.60
23	Garnet Creek, shadebreak to EFSFSR	0.0050	11.90	0.0030	10.60
24	EFSFSR, Garnet Creek to FC	0.0110	11.90	0.0060	10.60
25	FC, Headwater to FC Tributary 3	0.0030	11.90	0.0020	10.60
26	FC, FC Tributary 3 to shadebreak	0.0020	11.90	0.0010	10.60
27	FC, shadebreak to EFSFSR	0.0120	11.90	0.0070	10.60
28	EFSFSR, FC to shadebreak	0.0010	11.90	0.0010	10.60
29	EFSFSR, shadebreak to Midnight Creek	0.0020	11.90	0.0010	10.60
30	Midnight Creek Headwater	0.0190	11.90	0.0100	10.60
31	EFSFSR, Midnight Creek to YPP Lake	0.0010	11.90	0.0004	10.60
Model Reaches Downstream of YPP					
1	SC, Headwater to shadebreak	0.0040	11.90	0.0030	10.60
2	SC, shadebreak to SC Tributary 4	0.0040	11.90	0.0030	10.60
3	SC Tributary 4 Headwater	0.0020	11.90	0.0010	10.60
4	SC, SC Tributary 4 to SC Tributary 5	0.0010	11.90	0.0010	10.60
5	SC Tributary 5 Headwater	0.0020	11.90	0.0010	10.60
6	SC, SC Tributary 5 to shadebreak	0.0050	11.90	0.0030	10.60

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
7	SC, shadebreak to West End Creek	0.0070	11.90	0.0040	10.60
8	West End Creek, Headwater to shadebreak	0.0050	11.90	0.0040	10.60
9	West End Creek, shadebreak to shadebreak	0.0080	11.90	0.0050	10.60
10	West End Creek, shadebreak to SC	0.0050	11.90	0.0030	10.60
11	SC, West End Creek to EFSFSR	0.0080	14.80	0.0060	12.00
12	EFSFSR, YPP Lake to SC	0.0070	11.90	0.0040	10.60
13	EFSFSR, SC to Hennessy Creek	0.0003	14.80	0.0001	12.00
14	Hennessy Creek, Headwater to shadebreak	0.0090	11.90	0.0050	10.60
15	Hennessy Ditch, shadebreak to shadebreak	0.0060	11.90	0.0030	10.60
16	Hennessy Ditch, shadebreak to EFSFSR	0.0030	11.90	0.0020	10.60
17	EFSFSR, Hennessy Ditch to Model End	0.0050	14.80	0.0030	12.00

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

FC = Fiddle Creek

MC = Meadow Creek

SC = Sugar Creek

YPP = Yellow Pine pit

4.6.4 Meteorological Inputs

For the QUAL2K modeling of existing conditions, observed conditions for the calibration and validation dates were input to the model. QUAL2K calculates the heat balance based on the geographical position, hours of daylight, short- and long-wave radiation, atmospheric attenuation, reflection, conductance, convection, thermal exchange with the sediments, cloud cover, and shade. Cloud cover and shade are input by the user on an hourly basis. QUAL2K provides user-selected calculations for the other required terms of the heat balance. Meteorological data from the MesoWest station in the study area were used to develop the hourly meteorological inputs for the QUAL2K model for the calibration date (July 29, 2016) and the validation date (September 24, 2014) as shown in Figure 25 of the SPLNT Existing Conditions Report (BC 2018b). Hourly air temperature, dew point temperature, and wind speed are directly input to QUAL2K. Solar radiation is used to estimate cloud cover. For the calibration and validation dates selected, the solar radiation observations generate a smooth curve with values expected for this time of year when no cloud cover is present. Thus, for these dates, percent cloud cover was set to zero each hour. This assumption also results in conservative assumptions for evaluating model scenarios because the maximum amount of solar radiation would reach the streams under this condition.

In subsequent reports, these scenarios will represent the Proposed Action and alternatives by altering the channel configurations, stream flows, and shading values as appropriate (i.e., increased shading due to riparian vegetation restoration or decreased shading due to removal of vegetation). Meteorological conditions will not be varied when evaluating potential changes to water temperature caused by mining operations. Some meteorological inputs were varied during model sensitivity analyses (BC 2018b, Section 5.3)

4.6.5 Shade Inputs

Section 4.5.2 describes how the Shade.xls model was used to evaluate the fraction of shade each hour of the day along the tributaries evaluated. Mean hourly shade values were used to inform reach breaks for QUAL2K. Once the reaches were defined, the incremental output (every 60 meters for the Existing Conditions Models and every 10 meters for the No Action Models) from Shade.xls was averaged to provide inputs to the QUAL2K model. Reach level hourly shade values are provided in the SPLNT Existing Conditions Report (BC 2018b) and Appendix B of the SPLNT Proposed Action Report (BC 2019) for Existing Conditions and No Action, respectively.

4.6.6 QUAL2K Inputs for the Light and Heat Budget

QUAL2K simulates the heat balance with a series of equations describing short- and long-wave radiation, thermal exchange with the air and sediments, and evaporation. The various methods and assumptions are described in the *QUAL2K User Manual* (Chapra et al. 2008). Table 4-6 lists the inputs specified for the calibration and validation runs for the SGP. Default model parameters were applied. The model was not sensitive to altering the default values (BC 2018b, Section 5.3).

Table 4-6. Specifications for the QUAL2K Heat Balance Described by Chapra et al. (2008) Parameter

	Value	Units
Solar shortwave radiation model		
Atmospheric attenuation model for solar	Ryan-Stolzenbach	–
Atmospheric turbidity coefficient (2 = clear, 5 = smoggy, default = 2)	2.0	–
Atmospheric transmission coefficient (0.70–0.91, default 0.80)	0.8	–
Atmospheric longwave emissivity model	Brunt	–
Evaporation and air convection/conduction		
Wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer	–
Sediment heat parameters		
Sediment thermal thickness	10.0	cm
Sediment thermal diffusivity	0.0064	cm^2/s
Sediment density	1.6	g/cm^3
Water density	1.0	g/cm^3
Sediment heat capacity	0.4	cal/(g ^oC)
Water heat capacity	1.0	cal/(g ^oC)

Abbreviations:
cm = centimeter
cm^2/s = square centimeter per second
g/cm^3 = gram per centimeter cubed

4.7 GLM Configuration for Existing Conditions

The GLM dynamically simulates the heat and water balance of the YPP lake over depth and through time and therefore requires time series inputs of model drivers and boundary conditions. This section describes the model configuration, assumptions, and data sources for simulating the existing temperature conditions as water enters and passes through the YPP.

4.7.1 Bathymetry

Existing bathymetric data (Figure 8 of the SPLNT Existing Conditions Report [BC 2018b], Quadrant Consulting, Inc. 2016) were used to quantify the relationship between water depth, surface area, and water volume. Because the model uses a 1-dimensional approximation of the lake, the structure in the horizontal direction is simplified to a simple relationship relating the vertical depth increments to water volume (Graph 4-5 of the SPLNT Existing Conditions Report [BC 2018b]). Water volume within any specified depth layer can be integrated from this relationship.

These data were used directly in the GLM model to dynamically calculate the volume of water within each thermal layer as they expand and shrink through time.

4.7.2 Upstream Inflow and Water Temperature

Daily inflow volume was obtained from a continuous record of flow from USGS Gage 13311000 EFSFSR at Stibnite, which is the nearest gage upstream of the YPP (Figure 6 of the SPLNT Existing Conditions Report [BC 2018b]). The volume of water entering the YPP is high relative to the size of the lake. When flows are their greatest during the spring, the residence time of the lake is under one day and inflow often provides enough water to refill the lake two to eight times in a single day. Even during the periods of low flow, the residence time of the lake is on the order of only 5 to 7 days. This rate of flow-through relative to the volume of the lake is the most important driver of conditions in the YPP. Figure 28 of the SPLNT Existing Conditions Report (BC 2018b) shows the observed flows upstream and downstream of the YPP and the estimated residence time.

The record of water temperature at USGS Gage 13311000 EFSFSR at Stibnite is not as complete as the flow record and only includes the periods between April 25, 2014, to Sept 20, 2014, and between March 29, 2016, and October 4, 2016. To develop a full record of temperature for input for the model, water temperatures from nearby sites with a more complete record were compared with water temperature at Gage 13311000 EFSFSR at Stibnite for all overlapping periods. Because of a strong coherence in temperature among sites on the stream network (slopes near 1 and R^2 values between 0.98 and 0.99), statistical relationships were used to develop a complete time series of temperatures for the water entering the YPP (Graph 4-6 of the SPLNT Existing Conditions Report [BC 2018b]). The closest upstream station with available data was used for each missing period (MWH-004, then MWH-003). For the last missing period, beginning in October 2016, no upstream data were available, and the next downstream station was used (USGS 13311250) (Graph 4-7 of the SPLNT Existing Conditions Report [BC 2018b]).

Shaded regions indicate periods without temperature data at the closest upstream gage (USGS-13311000), and the color identifies which temperature gage was used for generating the input data set during each period.

4.7.3 Meterological Drivers

The GLM requires at least daily values of air temperature, relative humidity, incoming solar radiation, wind speed, and precipitation. These datasets were primarily compiled from Perpetua Resources's on-site weather station record. For periods of missing data, values were obtained through the best available statistical relationships with other data sources, including the National Climatic Data Center dataset from McCall, Idaho (National Centers for Environmental Information, https://www.ncei.noaa.gov), and grid-based data sets including PRISM (PRISM Climate Group, http://prism.oregonstate.edu) and Daymet (Thornton et al. 2017).

Daymet provided the relationship with the on-site mean daily air temperatures (R^2 = 0.97) and was used to fill in all gaps in temperature when it was available. Daymet provided the only other source for incoming solar radiation during times the on-site station was down and was used to fill in missing values.

On-site relative humidity was best predicted from the data recorded at the National Climatic Data Center weather station in McCall (R^2 = 0.79), and the PRISM dataset was used to fill in the few times when data were unavailable from the McCall station. Wind speed and precipitation are typically more local phenomena with only longer-term averages showing spatial correspondance among distant stations. Data from the McCall weather station were used as surrogates when necessary, with the understanding that any single predicted value may not be accurate but that accuracy improves when averaged over several days.

The full set of daily meteorologic input values are provided in Figure 29 of the SPLNT Existing Conditions Report (BC 2018b).

Section 5

Results

This section summarizes results for the Existing Conditions and No Action models. The components of the SPLNT model (QUAL2K and GLM) each have different applications as described below.

QUAL2K Output. Streams in the study area are simulated with the QUAL2K model, which predicts the average, minimum, and maximum stream temperatures for each reach. Output from the QUAL2K maximum weekly summer and fall models were used to provide a comparison to evaluate the potential impacts associated with the Project Alternatives relative to thermal criteria published by the USFS and Idaho DEQ (Section 1.2). Output from the mean August QUAL2K models provides input to the bull trout and Westslope cutthroat trout occupancy models being developed by Ecosystem Sciences.

QUAL2K simulation days were selected to represent two-week periods with nearly constant diurnal observations of stream flow and water temperatures representing maximum weekly temperatures associated with low-flow summer and low-flow fall conditions. These near-constant periods were selected for comparison to weekly temperature criteria as well as daily criteria. Selecting periods with consistent conditions over two weeks, results in greater confidence that the models are appropriate for comparison to weekly-based criteria. The selection of the simulation days and the presentation of the observed flow and temperature data over the two weeks surrounding the selected date are provided in the SPLNT Existing Conditions Report (BC 2018b). Additional QUAL2K models for No Action and Project Alternatives were developed to represent mean August conditions to support the occupancy models. Meteorological inputs for the maximum weekly summer and fall periods and the mean August conditions are provided in Appendix A of the SPLNT Proposed Action Modeling Report (BC 2019).

GLM Output. Output from the GLM provides flow and temperature data to downstream QUAL2K reaches. GLM output defines the “headwater” condition for reaches that are downstream of the YPP. For the Existing Conditions and No Action models, the GLM output for the representative day was applied to the reaches downstream, as described in BC 2018b.

The SPLNT model predictions (predictions, P) were evaluated using the mean error (ME) and absolute mean error (AME) as measures of goodness of fit compared to observations (O) for daily minimum, mean, and maximum temperatures across all *N* sites with observations (sites, *i*). These performance measures were calculated as follows and are reported in measurement units (°C).

$$ME = \frac{1}{N}\sum_{i=1}^{N} P_i - O_i$$

$$AME = \frac{1}{N}\sum_{i=1}^{N} |P_i - O_i|$$

The time series of predicted outlet temperatures (P) from YPP were additionally evaluated against downstream observations (O) using the Nash-Sutcliffe efficiency coefficient (*E*) calculated as follows:

$$E = 1 - \frac{\sum_{t=1}^{T}(P_t - O_t)^2}{\sum_{t=1}^{T}(O_t - \bar{O})^2}$$

The Nash-Sutcliffe efficiency coefficient can range from negative infinity to 1. A value of zero indicates the model does no better than simply using the mean of the observed values as the prediction. A value of 1 indicates the model predicts the observations perfectly. A value of less than 0 indicates the model residual variance is greater than the variance in the data—that is, the model is a worse predictor of the observations than mean of all the observations.

5.1 Existing Conditions Model Output

The SPLNT Existing Conditions model was calibrated and validated to dates that are representative of low-flow, steady state, warm conditions. Two dates were selected for model development for comparison to maximum weekly summer and maximum weekly fall conditions. These conditions are the basis of applicable thermal criteria that are used to evaluate potential impacts of the Project. The SPLNT model was calibrated for July 29, 2016 to represent the maximum weekly summer condition and validated for September 24, 2014 to represent the maximum weekly fall condition.

The simulated daily maximums, daily minimums, and daily averages compared to observations for streams upstream and downstream of the YPP are shown in Table 5-1. Graphical comparisons are provided Figure 30 and Figure 33 of the SPLNT Existing Conditions Model Report (BC 2018b). For the July date, observations are available at eight locations above YPP and three locations below YPP for comparison to simulated water temperatures. The range of observed hourly temperatures in the calibration target dataset was 7.2 to 19.59°C; the model-simulated temperatures were within 1.05°C of the observed temperatures for all calibration targets. Across the model domain, the mean error of model simulated daily average and maximum temperatures indicates little bias with values less than 0.1 °C. The mean error of minimum daily temperatures was 0.4 °C, showing, on average, a slightly conservative overestimate of minimum temperature. Mean absolute errors for all three metrics were 0.3, 0.4, and 0.6 °C respectively. For the fall date, observations are available at seven locations upstream of YPP and four locations below YPP. The range of observed temperatures in the validation target dataset was 6.61 to 15.72°C; the model-simulated temperatures were within 1.58°C for all validation targets. The mean absolute error (error = simulated minus observed temperature) was 0.6, 0.4, and 0.7 for the minimum, average, and maximum temperatures, respectively, indicating the validated model was slightly conservative in its predictions (estimating temperatures slightly higher than those observed). For both calibration and validation, the model-simulated temperatures were sometimes higher and sometimes lower than those observed, indicating the model is not biased in either direction.

The GLM was calibrated to observed temperature data from the USGS gage (13311250) located approximately 1 kilometer downstream of the YPP using three years of simulated and observed daily flows and temperatures. A total of 417 temperature targets were utilized for the calibration Figure 31of SPLNT Existing Conditions Model Report (BC 2018b) shows the temperature results for the YPP GLM. The top half of the figure shows the time series of simulated outflow temperature values compared to those observed downstream of YPP. For periods when observations are available, the model output matches the observed data well, with a mean absolute error of 0.7 °C. Modeled YPP outlet temperatures are on average 0.4 °C lower than the observed temperatures at the USGS gage (13311250) approximately 1 kilometer downstream from YPP. This error is small compared to the daily range in observed temperatures of 2.4 °C and is in the right direction given that the water temperature should warm slightly as it moves out of the YPP and flows downstream in the EFSFSR. The lower half of the figure shows the daily average observed temperatures versus predicted (R^2 = 0.96, Nash-Sutcliffe efficiency = 0.94). This comparison to observed data indicates that the GLM is suitable for simulating pit lake temperatures as a component of the SPLNT model. Because the GLM output becomes an input for QUAL2K and influences downstream temperatures, the calibration performed for QUAL2K downstream of YPP is a further demonstration of GLM performance. The calibration exercise to compare modeled results to observed data indicates that the GLM is suitable for simulating pit lake temperatures.

Model results for DO and temperature over the depth of the YPP lake are shown Figure 32 of SPLNT Existing Conditions Model Report (BC 2018b). The model shows the lake beginning to stratify during periods of low flow and warm weather, but stratification often appears to be weak and easily disturbed by moderate flow events during its onset. For the summer of 2015, stratification appears to have been able to set in with less disturbance, allowing a stronger temperature gradient and thus stratification to persist for a longer period.

Table 5-1. Simulated, Observed, and Temperature Differences Compared to Observations for the QUAL2K Existing Conditions Model

Model Above or Below YPP	Reach Number	Reach Description	Distance Upstream from Mouth of Tributary (km)	Temperature (°C)								
				Simulated Average	Simulated Minimum	Simulated Maximum	Observed Average	Observed Minimum	Observed Maximum	Sim-Obs Average	Sim-Obs Minimum	Sim-Obs Maximum
For the Calibration Date												
Above	5	EFSFSR3	5.80	9.76	7.24	12.92	9.87	7.24	13.02	-0.11	0.00	-0.10
Above	6	EFSFSR4 (at Rabbit Creek)	3.40	9.83	7.62	12.23	10.00	7.20	13.20	-0.17	0.42	-0.97
Above	21	EFSFSR5 (at Meadow Creek)	2.60	11.79	8.02	16.56	12.20	8.20	17.00	-0.41	-0.18	-0.44
Above	11	MC2 (at MC Tributary 2)	4.50	11.27	9.58	13.73	10.99	8.53	13.95	0.28	1.05	-0.22
Above	14	MC4 (at MC Tributary 3)	3.70	10.92	9.22	13.16	10.60	8.20	13.50	0.32	1.02	-0.34
Above	15	MC6	3.00	11.88	8.98	16.02	11.29	8.27	15.26	0.59	0.71	0.76
Above	20	MC10	0.27	13.34	8.59	20.33	13.47	8.54	19.59	-0.13	0.05	0.74
Above	18	MC9	0.10	11.83	8.75	16.83	11.60	7.63	17.00	0.23	1.12	-0.18
Below	11	SC5	1.20	10.79	7.54	15.40	11.60	8.40	15.70	-0.81	-0.86	-0.30
Below	12	YPP Lake Headwater	0.25	13.46	12.82	14.99	13.60	12.00	14.70	-0.14	0.82	0.29
Below	12	YPP Lake Headwater	0.15	13.46	12.82	14.99	13.70	12.20	14.80	-0.24	0.62	0.19
			Average	11.67	9.20	15.20	11.72	8.76	15.25	-0.05	0.43	-0.05
			Mean Error	-0.05	0.43	-0.05	-	-	-	-	-	-
			Mean Absolute Error	0.31	0.62	0.41	-	-	-	-	-	-
For the Validation Date												
Above	6	EFSFSR4 (at Rabbit Creek)	3.40	8.39	6.99	10.27	8.40	6.70	10.40	-0.01	0.29	-0.13
Above	21	EFSFSR5 (at Meadow Creek)	2.60	9.41	6.95	13.20	9.60	7.00	13.20	-0.19	-0.05	0.00
Above	11	MC2 (at MC Tributary 2)	4.50	9.50	8.27	11.60	8.86	7.38	10.71	0.64	0.89	0.89
Above	14	MC4 (at MC Tributary 3)	3.70	9.29	8.04	11.32	8.40	7.00	10.80	0.89	1.04	0.52
Above	15	MC6	3.00	9.85	7.65	13.75	9.11	6.93	12.17	0.74	0.72	1.58
Above	20	MC10	0.27	10.54	7.32	16.23	10.49	7.03	15.72	0.05	0.29	0.51
Above	18	MC9	0.10	10.00	8.04	13.84	8.99	6.61	13.02	1.01	1.43	0.82
Below	11	SC5	1.60	8.87	7.13	11.78	8.77	7.02	11.08	0.10	0.11	0.70
Below	11	SC5	1.20	8.87	7.08	11.81	8.80	7.00	11.10	0.07	0.08	0.71
Below	12	YPP Lake Headwater	0.25	10.47	10.01	11.74	10.60	9.20	12.50	-0.13	0.81	-0.76
Below	12	YPP Lake Headwater	0.15	10.47	10.01	11.74	10.76	9.26	12.73	-0.29	0.75	-0.99
			Average	9.61	7.95	12.48	9.34	7.38	12.13	0.26	0.58	0.35
			Mean Error	0.26	0.58	0.35	-	-	-	-	-	-
			Mean Absolute Error	0.37	0.59	0.69	-	-	-	-	-	-

Abbreviations:

°C = degree Celsius

km = kilometer

Sim-Obs = Simulated minus Observed

YPP = Yellow Pine pit

5.2 No Action Model Output

The No Action model was developed to simulate stream and pit lake temperatures that would occur if the Proposed Action, or other alternative, is not implemented. The No Action model is similar to the existing conditions model with the exceptions noted in Section 2.3. The No Action model was not recalibrated to observed water temperatures. Comparisons were made in a similar format to those reported in the SPLNT Existing Conditions Report (BC 2018b) to demonstrate that No Action SPLNT models generate similar results compared to Existing Conditions SPLNT Models. Graphical comparisons to observed stream temperatures measured on the summer date (July 29, 2016) and fall date (September 24, 2014) are provided in Appendix B of the SPLNT Proposed Action Model Report (BC 2019). Table 5-2 provides a comparison of the simulated, observed, and temperature differences compared to observations for the QUAL2K No Action Model.

Table 5-2. Simulated, Observed, and Temperature Differences Compared to Observations for the QUAL2K No Action Model

Model Above or Below YPP	Reach Number	Reach Description	Distance Upstream from Mouth of Tributary (km)	Temperature (°C)								
				Simulated Average	Simulated Minimum	Simulated Maximum	Observed Average	Observed Minimum	Observed Maximum	Sim-Obs Average	Sim-Obs Minimum	Sim-Obs Maximum
For the Maximum Weekly Summer Condition Based on Observations Collected July 29, 2016												
Above	5	EFSFSR3	5.80	9.96	7.34	13.39	9.87	7.24	13.02	0.09	0.10	0.37
Above	6	EFSFSR4 (at Rabbit Creek)	3.30	10.44	7.83	13.62	10.00	7.20	13.20	0.44	0.63	0.42
Above	21	EFSFSR5 (at Meadow Creek)	2.70	12.07	8.35	17.00	12.20	8.20	17.00	-0.13	0.15	0.00
Above	11	MC2 (at MC Tributary 2)	4.50	11.59	9.59	14.47	10.99	8.53	13.95	0.60	1.06	0.52
Above	14	MC4 (at MC Tributary 3)	3.80	11.33	9.23	14.27	10.60	8.20	13.50	0.73	1.03	0.77
Above	15	MC6	2.90	11.89	9.24	15.74	11.29	8.27	15.26	0.60	0.97	0.48
Above	20	MC10	0.20	13.39	8.94	19.78	13.47	8.54	19.59	-0.08	0.40	0.19
Above	18	MC9	0.08	12.38	8.75	18.12	11.60	7.63	17.00	0.78	1.12	1.12
Below	11	SC5	1.10	11.63	9.20	15.21	11.60	8.40	15.70	0.03	0.80	-0.49
Below	12	YPP Lake Headwater	0.25	13.52	13.06	14.43	13.60	12.00	14.70	-0.08	1.06	-0.27
Below	12	YPP Lake Headwater	0.15	13.53	13.04	14.49	13.70	12.20	14.80	-0.17	0.84	-0.31
			Average	11.98	9.51	15.50	11.72	8.76	15.25	0.26	0.74	0.25
			Mean Error	0.26	0.74	0.25	-	-	-	-	-	-
			Mean Absolute Error	0.34	0.74	0.45	-	-	-	-	-	-
For the Maximum Weekly Fall Condition Based on Observations Collected September 24, 2014												
Above	6	EFSFSR4 (at Rabbit Creek)	3.30	8.89	7.38	11.25	8.40	6.70	10.40	0.49	0.68	0.85
Above	21	EFSFSR5 (at Meadow Creek)	2.70	9.82	7.42	13.74	9.60	7.00	13.20	0.22	0.42	0.54
Above	11	MC2 (at MC Tributary 2)	4.50	9.74	8.28	12.29	8.86	7.38	10.71	0.88	0.90	1.58
Above	14	MC4 (at MC Tributary 3)	3.80	9.57	8.04	12.26	8.40	7.00	10.80	1.17	1.04	1.46
Above	15	MC6	2.90	9.93	7.97	13.44	9.11	6.93	12.17	0.82	1.04	1.27
Above	20	MC10	0.20	10.79	7.67	16.17	10.49	7.03	15.72	0.30	0.64	0.45
Above	18	MC9	0.08	10.36	8.04	14.98	8.99	6.61	13.02	1.37	1.43	1.96
Below	11	SC5	1.40	9.17	7.45	12.31	8.77	7.02	11.08	0.40	0.43	1.23
Below	11	SC5	1.10	9.62	8.28	12.1	8.80	7.00	11.10	0.82	1.28	1.00
Below	12	YPP Lake Headwater	0.25	10.58	10.23	11.48	10.60	9.20	12.50	-0.02	1.03	-1.02
Below	12	YPP Lake Headwater	0.15	10.59	10.22	11.54	10.76	9.26	12.73	-0.17	0.96	-1.19
			Average	9.91	8.27	12.87	9.34	7.38	12.13	0.57	0.90	0.35
			Mean Error	0.57	0.90	0.74	-	-	-	-	-	-
			Mean Absolute Error	0.61	0.90	1.14	-	-	-	-	-	-

Abbreviations:

°C = degree Celsius

Km = kilometer

Sim-Obs = Simulated minus Observed

YPP = Yellow Pine pit

Section 6

Summary

The SPLNT model was developed for the SGP to evaluate the potential pit lake water temperatures, pit lake DO, and changes to stream water temperatures that may occur as a result of proposed mining features and subsequent site restoration. The following series of tools make up the SPLNT model: TTools, Shade.xls model, QUAL2K, and GLM.

Based on the SPLNT existing conditions model results, calibration, and validation, the SPLNT model is an accurate tool that is deemed appropriate for simulating water temperatures. The SPLNT Proposed Action model was developed primarily using data collected at the SGP and information associated with the PRO including pipes associated with diversion channels during operations. The SPLNT No Action model was developed using the same methods and procedures used to develop the Proposed Action SPLNT model based on input from the agencies. The SPLNT Existing Conditions and No Action models yield similar results because the primary drivers (meteorology, hydrology, and heat balance) are the same between the two models.

The SPLNT No Action models are compared to the SPLNT ModPRO2 models in the main report. The SPLNT No Action models did not require updating with the revised SGP hydrologic model because the SPLNT model, which runs on a daily time step, does not directly apply SGP hydrologic model estimates of stream baseflows (monthly time step). Rather, the SPLNT model applies the percent difference in monthly stream baseflows predicted by the SGP hydrologic model for No Action and a Project alternative. The percent difference is applied to the No Action stream baseflows to account for changes in hydrologic regime due to the Project. This process was conducted for the SPLNT ModPRO2 models using the revised SGP No Action and ModPRO2 hydrologic models to calculate the percent difference.

Section 7

Limitations

This document was prepared solely for Perpetua Resources in accordance with professional standards at the time the services were performed and in accordance with the contract between Perpetua Resources and BC dated January 1, 2021. This document is governed by the specific scope of work authorized by Perpetua Resources; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Perpetua Resources and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 8

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Appendix B: SPLNT Input and Output for the ModPRO2 Alternative

List of Tables

Section 1: Inputs for EOY6 for the ModPRO2

This section provides the reach-by-reach input for end of year (EOY) 6 for the ModPRO2. Due to the tunnel around the Yellow Pine pit (YPP), there is a single QUAL2K model for EOY6.

Table B-1. Reach Characteristics for EOY6 Disturbance Condition for the ModPRO2

Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
1	0.50	0.750	0.320	0.200	0.250
2	0.43	0.750	0.320	0.200	0.250
3	0.63	0.750	0.320	0.200	0.250
4	0.67	0.750	0.320	0.350	0.250
5	0.86	0.750	0.320	0.350	0.250
6	1.91	0.750	0.320	0.350	0.250
7	1.40	0.750	0.320	0.350	0.250
8	0.76	0.750	0.320	0.350	0.250
9	1.30	2.000	0.270	1.460	0.600
10	0.76	0.750	0.320	0.350	0.250
11	1.40	2.000	0.270	1.460	0.600
12	2.44	2.000	0.270	1.460	0.600
13	0.31	2.000	0.270	1.460	0.600
14	0.33	2.000	0.270	1.460	0.600
15	0.61	0.900	0.250	0.900	0.400
16	0.29	0.800	0.500	0.420	0.300
17	2.76	1.600	0.320	0.350	0.250
18	0.58	1.600	0.320	0.350	0.250
19	0.41	0.340	0.000	1.000	0.350
20	0.67	0.700	0.500	0.350	0.300
21	1.33	0.750	0.500	0.480	0.330
22	0.28	0.750	0.320	0.350	0.250
23	0.63	0.480	0.320	0.350	0.250
24	1.37	0.750	0.320	0.350	0.250
25	0.46	1.300	0.500	0.350	0.300
26	0.60	0.750	0.320	0.350	0.250
27	1.22	0.750	0.320	0.350	0.250
28	0.52	0.750	0.320	0.350	0.250
29	0.33	0.750	0.320	0.350	0.250
30	1.32	0.750	0.320	0.350	0.250
31	0.42	3.300	0.350	1.400	0.550
32	1.33	0.750	0.320	0.350	0.250
33	0.77	3.350	0.340	1.900	0.550

Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
34	0.27	3.500	0.340	1.850	0.550
35	0.15	0.750	0.320	0.350	0.250
36	0.14	0.750	0.320	0.350	0.250
37	1.53	0.750	0.320	0.350	0.250
38	0.28	5.100	0.400	0.400	0.600
39	0.70	0.750	0.320	0.350	0.250
40	0.33	4.000	0.400	0.450	0.600
41	0.08	1.900	0.400	0.250	0.600
42	0.22	0.750	0.320	0.350	0.250
43	1.63	1.150	0.310	0.460	0.500
44	0.49	0.750	0.320	0.350	0.250
45	0.55	0.750	0.320	0.350	0.250
46	0.58	0.750	0.320	0.350	0.250
47	0.26	0.750	0.320	0.350	0.250
48	0.17	0.750	0.320	0.350	0.250
49	0.24	0.750	0.320	0.350	0.250
50	0.71	0.750	0.320	0.350	0.250
51	0.92	0.750	0.320	0.350	0.250
52	0.77	0.750	0.320	0.350	0.250
53	0.33	1.950	0.400	0.500	0.600
54	0.82	4.000	0.400	0.800	0.600
55	0.25	9.500	0.400	0.300	0.600
56	0.54	0.750	0.320	0.350	0.250
57	1.19	0.750	0.320	0.350	0.250
58	0.86	0.750	0.320	0.350	0.250

Abbreviations:

EOY = end of year

km = kilometer

Table B-2. Diffuse Flow (cms) and Temperature (°C) for EOY6 Disturbance Condition for the ModPRO2

Number	Flow			Temperature		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
1	0.0060	0.0050	0.0060	11.90	10.60	11.00
2	0.0050	0.0040	0.0050	11.90	10.60	11.00
3	0.0070	0.0060	0.0070	11.90	10.60	11.00
4	0.0070	0.0060	0.0070	11.90	10.60	11.00
5	0.0100	0.0080	0.0100	11.90	10.60	11.00
6	0.0139	-0.0562	0.0139	11.90	N/A	11.00
7	0.0140	0.0080	0.0140	11.90	10.60	11.00

Number	Flow			Temperature		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
8	0.0070	0.0049	0.0070	11.90	10.60	11.00
9	0.0000	0.0000	0.0000	11.90	10.60	11.00
10	0.0071	0.0051	0.0071	11.90	10.60	11.00
11	0.0000	0.0000	0.0000	11.90	10.60	11.00
12	0.0000	0.0000	0.0000	11.90	10.60	11.00
13	0.0000	0.0000	0.0000	13.90	11.60	12.20
14	0.0000	0.0000	0.0000	13.90	11.60	12.20
15	-0.0053	-0.0131	-0.0053	N/A	N/A	N/A
16	0.0000	0.0000	0.0000	13.90	11.60	12.20
17	0.0200	0.0180	0.0200	11.90	10.60	11.00
18	0.0040	0.0040	0.0040	11.90	10.60	11.00
19	0.0023	0.0028	0.0023	11.90	10.60	11.00
20	0.0100	0.0000	0.0100	11.90	10.60	11.00
21	0.0000	0.0000	0.0000	13.90	11.60	12.20
22	0.0005	0.0004	0.0005	13.90	11.60	12.20
23	0.0037	0.0018	0.0037	11.90	10.60	11.00
24	0.0080	0.0040	0.0080	11.90	10.60	11.00
25	0.0029	0.0010	0.0029	11.90	10.60	11.00
26	0.0029	0.0019	0.0029	11.90	10.60	11.00
27	0.0065	0.0037	0.0065	11.90	10.60	11.00
28	0.0033	0.0021	0.0033	11.90	10.60	11.00
29	0.0020	0.0010	0.0020	11.90	10.60	11.00
30	0.0079	0.0045	0.0079	11.90	10.60	11.00
31	0.0000	0.0000	0.0000	11.90	10.60	11.00
32	0.0040	0.0009	0.0040	11.90	10.60	11.00
33	0.0000	0.0000	0.0000	11.90	10.60	11.00
34	0.0000	0.0000	0.0000	11.90	10.60	11.00
35	0.0033	0.0021	0.0033	11.90	10.60	11.00
36	0.0001	0.0001	0.0001	11.90	10.60	11.00
37	0.0090	0.0050	0.0090	11.90	10.60	11.00
38	0.0000	0.0000	0.0000	11.90	10.60	11.00
39	0.0019	0.0006	0.0019	11.90	10.60	11.00
40	0.0000	0.0000	0.0000	11.90	10.60	11.00
41	0.0004	0.0002	0.0004	11.90	10.60	11.00
42	0.0006	0.0006	0.0006	11.90	10.60	11.00
43	0.0000	0.0000	0.0000	11.90	10.60	11.00
44	0.0000	-0.0002	0.0000	11.90	N/A	11.00

Number	Flow			Temperature		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
45	0.0040	0.0020	0.0040	11.90	10.60	11.00
46	0.0040	0.0030	0.0040	11.90	10.60	11.00
47	0.0023	0.0012	0.0023	11.90	10.60	11.00
48	0.0010	0.0008	0.0010	11.90	10.60	11.00
49	0.0020	0.0011	0.0020	11.90	10.60	11.00
50	0.0048	0.0028	0.0048	11.90	10.60	11.00
51	0.0062	0.0034	0.0062	11.90	10.60	11.00
52	0.0050	0.0030	0.0050	11.90	10.60	11.00
53	0.0000	0.0000	0.0000	11.90	10.60	11.00
54	0.0000	0.0000	0.0000	11.90	10.60	11.00
55	0.0000	0.0000	0.0000	11.90	10.60	11.00
56	-0.0015	0.0001	-0.0015	N/A	10.60	N/A
57	0.0049	0.0029	0.0049	14.80	12.00	12.70
58	0.0029	0.0019	0.0029	14.80	12.00	12.70

Notes:

[a]Summer corresponds to the maximum weekly summer condition.

[b]Fall corresponds to the maximum weekly fall condition.

[c]August corresponds to the mean August condition.

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

N/A = not applicable for 0 flows or negative flows

Table B-3. Point Sources Flow (cms) and Temperature (°C) for EOY6 Disturbance Condition for the ModPRO2

Source	Flow			Temperature		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	20.00	20.00	20.00
Treated Water Discharge – Meadow Creek	0.0220	0.0000	0.0000	17.70	N/A	N/A

Notes:

[a]Summer corresponds to the maximum weekly summer condition.

[b]Fall corresponds to the maximum weekly fall condition.

[c]August corresponds to the mean August condition.

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B-4. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY6 Disturbance Condition for the ModPRO2

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
8	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	90.7	78.7	6.6	2.9	2.5	2.4	2.5	2.7	2.7	2.4	2.1	1.4	1.9	14.6	83.1	89.9	100	100	100
16	100	100	100	100	100	91.4	58.4	23.2	12.1	5.6	3.6	3.7	4.0	4.1	3.8	4.1	6.4	13.4	28.6	91.3	91.2	100	100	100
17	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
18	100	100	100	100	100	93.9	93.2	69.1	35.7	25.5	14.7	8.0	6.7	7.9	10.2	16.9	27.1	32.9	68.2	93.0	93.8	100	100	100
19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
20	100	100	100	100	100	92.9	88.0	57.5	41.5	22.9	10.7	8.0	9.7	9.4	9.0	14.0	24.7	37.8	43.0	68.6	92.9	100	100	100
21	100	100	100	100	100	91.6	62.7	22.5	13.5	6.8	3.5	3.8	4.2	4.4	4.2	3.8	5.4	13.6	38.8	91.2	91.3	100	100	100
22	100	100	100	100	100	95.7	95.2	74.0	59.8	42.3	25.2	13.1	7.7	9.3	14.3	25.9	50.4	65.7	80.3	95.0	95.9	100	100	100
23	100	100	100	100	100	95.3	95.0	82.5	62.5	39.4	24.7	18.5	15.1	13.5	17.7	28.9	44.1	59.6	90.7	94.8	95.3	100	100	100
24	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
25	100	100	100	100	100	94.1	93.9	60.3	40.6	34.5	21.7	17.8	18.4	24.1	32.1	37.7	40.5	44.5	69.3	95.2	95.6	100	100	100
26	100	100	100	100	100	94.8	94.6	80.8	59.4	38.6	24.9	13.4	8.4	9.0	13.6	23.6	43.3	67.5	91.8	94.9	95.1	100	100	100
27	100	100	100	100	100	95.4	95.2	93.0	67.4	41.2	24.4	16.0	14.3	14.2	18.5	30.1	44.6	64.3	85.1	95.0	95.3	100	100	100
28	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
29	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
30	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
32	100	100	100	100	100	98.5	92.0	86.9	82.1	79.5	77.9	75.9	73.5	69.4	60.4	64.8	72.3	86.0	96.1	98.7	98.8	100	100	100
33	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
34	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
35	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
36	100	100	100	100	100	94.7	94.4	86.3	42.9	14.5	4.8	5.4	4.2	4.0	6.2	22.9	44.9	61.5	80.5	94.3	94.8	100	100	100
37	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
38	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
39	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
41	100	100	100	100	100	92.2	92.2	73.1	11.2	2.9	2.8	2.9	3.0	3.0	3.0	3.0	2.6	3.4	33.9	91.6	91.9	100	100	100
42	100	100	100	100	100	93.8	93.7	66.9	22.3	7.9	4.7	4.5	5.2	6.8	10.2	16.4	24.1	33.2	65.5	93.0	93.6	100	100	100
43	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
44	100	100	100	100	100	94.9	87.2	65.9	43.2	23.3	16.6	16.7	18.7	23.0	28.9	36.9	44.6	57.9	78.3	94.4	94.7	100	100	100
45	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
46	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
47	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
48	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
49	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
50	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
51	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
52	100	100	100	100	100	96.6	96.5	95.0	76.5	50.2	29.8	31.9	43.0	48.8	54.7	60.5	70.5	76.0	80.2	81.1	94.2	100	100	100
53	100	100	100	100	100	92.6	92.7	92.6	88.1	45.0	7.9	4.2	4.0	3.6	3.6	4.2	5.2	7.7	12.3	14.6	91.9	100	100	100
54	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
56	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
57	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
58	100	100	100	100	100	95.1	93.5	86.3	48.5	21.6	13.3	12.1	15.5	22.2	29.9	38.5	50.9	67.8	82.0	95.0	95.2	100	100	100

Notes:

** Hours are in military format*

% = percent

EOY = end of year

Table B-5. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY6 Disturbance Condition for the ModPRO2

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
8	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5		100	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	88.1	77.0	14.8	5.8	4.4	3.6	3.2	3.1	2.9	2.5	2.2	46.5	87.1	100	100	100	100	100
16	100	100	100	100	100	100	88.5	60.2	24.1	16.9	10.4	6.9	6.0	6.4	8.4	12.6	20.9	55.0	88.6	100	100	100	100	100
17	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
18	100	100	100	100	100	100	92.1	91.1	72.5	36.8	30.0	22.3	18.8	20.3	24.8	32.8	47.5	87.1	91.0	100	100	100	100	100
19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
20	100	100	100	100	100	100	90.7	86.8	57.3	40.4	19.4	11.1	11.8	12.2	16.3	29.4	39.2	50.7	90.4	100	100	100	100	100
21	100	100	100	100	100	100	89.1	65.6	27.4	18.8	10.8	7.1	5.8	6.0	7.0	10.3	18.7	71.7	88.4	100	100	100	100	100
22	100	100	100	100	100	100	95.1	94.1	76.0	62.0	47.4	31.0	18.3	14.3	23.6	43.6	64.0	93.2	93.7	100	100	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
23	100	100	100	100	100	100	93.8	93.4	76.8	48.8	29.7	20.3	15.8	21.3	37.7	56.0	77.7	93.1	93.8	100	100	100	100	100
24	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
25	100	100	100	100	100	100	92.0	91.7	61.3	35.4	25.2	27.4	34.6	39.6	42.9	46.3	54.9	92.4	94.4	100	100	100	100	100
26	100	100	100	100	100	100	93.2	93.0	78.1	54.5	36.1	21.5	17.3	19.1	28.1	47.6	76.2	93.0	93.5	100	100	100	100	100
27	100	100	100	100	100	100	94.0	93.7	92.6	64.3	35.9	21.8	18.6	22.4	33.0	48.7	70.9	93.2	93.7	100	100	100	100	100
28	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
29	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
30	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
32	100	100	100	100	100	100	98.1	95.8	92.8	87.8	83.4	81.0	78.4	76.2	69.8	75.8	89.8	96.0	98.2	100	100	100	100	100
33	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
34	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
35	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
36	100	100	100	100	100	100	92.6	92.7	87.1	31.7	12.9	12.4	12.3	17.6	43.2	66.6	87.0	93.2	93.2	100	100	100	100	100
37	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
38	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
39	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
41	100	100	100	100	100	100	90.0	89.2	80.7	19.9	5.4	4.6	4.1	3.8	3.8	4.0	3.9	81.5	89.3	100	100	100	100	100
42	100	100	100	100	100	100	91.9	91.7	57.3	12.8	10.4	12.2	16.3	21.6	29.6	38.9	53.0	90.5	90.7	100	100	100	100	100
43	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
44	100	100	100	100	100	100	93.2	86.4	66.8	49.0	32.4	28.7	31.4	37.0	46.7	57.0	76.5	92.3	93.0	100	100	100	100	100
45	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
46	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
47	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
48	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
49	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
50	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
51	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
52	100	100	100	100	100	100	95.6	93.8	93.3	87.0	58.2	63.1	72.6	80.8	88.0	93.6	95.8	96.0	96.0	100	100	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
53	100	100	100	100	100	100	90.5	90.6	90.3	84.7	27.5	7.1	7.3	8.5	10.1	11.2	13.0	13.6	27.2	100	100	100	100	100
54	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
56	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
57	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
58	100	100	100	100	100	100	93.7	91.0	83.1	48.0	25.8	26.9	32.3	42.1	56.3	73.0	84.3	91.5	93.7	100	100	100	100	100

Notes:

** Hours are in military format*

% = percent

EOY = end of year

Table B-6. Hourly Effective Shade (%) for Mean August Condition for EOY6 Disturbance Condition for the ModPRO2

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	100	100	100	100	100	99.0	97.5	91.0	82.0	79.8	83.0	85.0	84.7	82.4	80.7	84.2	86.0	85.3	88.9	94.1	98.9	100	100	100
2	100	100	100	100	100	98.6	93.0	84.0	75.6	69.5	65.7	63.1	60.6	57.1	52.3	51.0	64.5	82.0	92.6	98.5	98.7	100	100	100
3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.5	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.8	99.6	99.6	100	100	100
4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.8	95.2	98.5	98.5	100	100	100
5	100	100	100	100	100	98.9	96.8	90.4	78.4	68.5	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.7	51.8	56.9	61.5	65.2	70.2	78.6	87.5	96.1	98.6	100	100	100
7	100	100	100	100	100	99	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	99	99	100	100	100
8	100	100	100	100	100	99	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99	100	100	100	100
9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	99	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99	99	100	100	100
11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	95.3	83.4	41.8	8.9	4.1	3.4	3.1	2.9	2.9	2.6	2.3	1.8	24.2	50.8	91.6	94.9	100	100	100
16	100	100	100	100	100	95.7	73.5	41.7	18.1	11.2	7.0	5.3	5.0	5.2	6.1	8.4	13.7	34.2	58.6	95.7	95.6	100	100	100
17	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.8	97.1	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
18	100	100	100	100	100	97.0	92.7	80.1	54.1	31.1	22.4	15.1	12.7	14.1	17.5	24.8	37.3	60.0	79.6	96.5	96.9	100	100	100
19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
20	100	100	100	100	100	96.5	89.3	72.2	49.4	31.6	15.0	9.6	10.7	10.8	12.6	21.7	32.0	44.2	66.7	84.3	96.4	100	100	100
21	100	100	100	100	100	95.8	75.9	44.0	20.4	12.8	7.2	5.4	5.0	5.2	5.6	7.1	12.1	42.7	63.6	95.6	95.6	100	100	100
22	100	100	100	100	100	97.9	95.2	84.0	67.9	52.2	36.3	22.1	13.0	11.8	18.9	34.8	57.2	79.4	87.0	97.5	97.9	100	100	100
23	100	100	100	100	100	97.7	94.4	88.0	69.7	44.1	27.2	19.4	15.5	17.4	27.7	42.4	60.9	76.3	92.2	97.4	97.7	100	100	100
24	100	100	100	100	100	98.8	96.7	94.7	85.7	77.7	72.7	69.8	66.7	63.3	62.5	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
25	100	100	100	100	100	97.1	92.9	76.0	50.9	34.9	23.4	22.6	26.5	31.8	37.5	42.0	47.7	68.4	81.8	97.6	97.8	100	100	100
26	100	100	100	100	100	97.4	93.9	86.9	68.7	46.6	30.5	17.4	12.9	14.1	20.8	35.6	59.8	80.2	92.7	97.4	97.6	100	100	100
27	100	100	100	100	100	97.7	94.6	93.3	80.0	52.8	30.1	18.9	16.4	18.3	25.8	39.4	57.7	78.8	89.4	97.5	97.7	100	100	100
28	100	100	100	100	100	99.7	98.4	97.8	95.8	94.3	93.6	91.8	91.8	93.2	93.9	94.7	95.8	95.1	97.7	99.3	99.7	100	100	100
29	100	100	100	100	100	99.7	98.9	97.9	97.0	96.3	95.9	95.6	95.1	95.2	95.0	95.8	96.6	97.9	99.2	99.7	99.7	100	100	100
30	100	100	100	100	100	99.5	98.3	95.8	94.4	92.7	91.5	89.4	87.2	84.4	84.7	87.9	93.4	96.4	98.8	99.5	99.5	100	100	100
31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
32	100	100	100	100	100	99.2	95.0	91.3	87.4	83.7	80.6	78.4	76.0	72.8	65.1	70.3	81.1	91.0	97.1	99.3	99.4	100	100	100
33	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
34	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
35	100	100	100	100	100	98.1	94.8	84.9	67.7	56.1	54.1	51.7	49.4	47.0	36.1	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
36	100	100	100	100	100	97.4	93.5	89.5	65.0	23.1	8.9	8.9	8.2	10.8	24.7	44.8	66.0	77.4	86.9	97.2	97.4	100	100	100
37	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.0	72.9	80.7	85.2	87.2	89.6	92.8	95.1	97.3	99.0	99.5	100	100	100
38	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
39	100	100	100	100	100	97.9	95.7	91.7	78.0	64.1	62.6	63.7	64.4	64.7	64.6	63.9	62.8	64.5	77.1	92.4	97.9	100	100	100
40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
41	100	100	100	100	100	96.1	91.1	81.2	45.9	11.4	4.1	3.8	3.6	3.4	3.4	3.5	3.2	42.5	61.6	95.8	96.0	100	100	100
42	100	100	100	100	100	96.9	92.8	79.3	39.8	10.4	7.6	8.4	10.7	14.2	19.9	27.7	38.5	61.8	78.1	96.5	96.8	100	100	100
43	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
44	100	100	100	100	100	97.4	90.2	76.1	55.0	36.2	24.5	22.7	25.1	30.0	37.8	46.9	60.5	75.1	85.7	97.2	97.3	100	100	100
45	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
46	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
47	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100

Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
48	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
49	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
50	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
51	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
52	100	100	100	100	100	98.3	96.0	94.4	84.9	68.6	44.0	47.5	57.8	64.8	71.3	77.1	83.1	86.0	88.1	90.6	97.1	100	100	100
53	100	100	100	100	100	96.3	91.6	91.6	89.2	64.9	17.7	5.7	5.7	6.0	6.9	7.7	9.1	10.6	19.8	57.3	95.9	100	100	100
54	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
55	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
56	100	100	100	100	100	99.5	98.7	97.3	93.1	86.7	79.5	80.5	87.9	92.5	94.1	94.9	95.0	96.7	97.8	99.3	99.5	100	100	100
57	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.4	36.0	34.3	33.8	35.8	41.7	56.2	77.6	95.2	97.6	100	100	100
58	100	100	100	100	100	97.6	93.6	88.7	65.8	34.8	19.5	19.5	23.9	32.2	43.1	55.8	67.6	79.7	87.8	97.5	97.6	100	100	100

Notes:

 ** Hours are in military format*

% = percent

Abbreviations:

EOY = end of year

Section 2: Outputs for EOY6 for the ModPRO2

This section provides the reach-by-reach output for EOY6 for the ModPRO2.

Table B-7. Simulated Reach Temperatures (°C) and Flows (cms) for Maximum Weekly Summer Conditions for EOY6 Disturbance Condition for the ModPRO2

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
1	0.50	13.53	9.85	7.11	0.0975
2	0.43	13.79	10.06	7.38	0.1028
3	0.63	11.64	8.64	6.34	0.0487
4	0.67	13.26	9.88	7.31	0.1603
5	0.86	13.17	10.04	7.53	0.1746
6	1.91	13.28	10.24	7.71	0.1960
7	1.40	14.75	11.43	8.99	0.0228
8	0.76	11.58	8.93	6.90	0.0273
9	1.30	11.51	9.02	7.15	0.0290
10	0.76	12.80	9.98	8.06	0.0123
11	1.40	11.79	9.34	7.50	0.0431
12	2.44	12.77	10.13	8.11	0.0711
13	0.31	12.67	10.05	8.05	0.0711
14	0.33	12.64	10.03	8.04	0.0711
15	0.61	13.54	11.10	9.22	0.0781
16	0.29	14.90	12.31	10.26	0.0878
17	2.76	13.63	10.35	8.06	0.0277
18	0.58	15.16	11.41	8.94	0.0390
19	0.41	15.04	11.43	9.04	0.0417
20	0.67	17.15	12.21	8.99	0.0498
21	1.33	17.32	12.79	9.56	0.1401
22	0.28	18.23	13.09	9.40	0.1405
23	0.63	15.83	11.68	8.40	0.3461
24	1.37	14.35	11.39	9.37	0.0063
25	0.46	16.57	12.25	9.20	0.0112
26	0.60	16.08	11.79	8.42	0.3602
27	1.22	16.45	11.93	8.40	0.3650
28	0.52	11.28	8.61	6.50	0.0225
29	0.33	11.11	8.81	7.05	0.0258
30	1.32	11.22	9.25	7.63	0.0317
31	0.42	11.25	9.36	7.75	0.0342
32	1.33	13.17	9.62	7.27	0.0075

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
33	0.77	13.62	10.00	7.59	0.0090
34	0.27	13.48	9.92	7.51	0.0090
35	0.15	11.92	9.71	7.94	0.0465
36	0.14	16.18	11.77	8.34	0.4140
37	1.53	12.54	10.84	9.38	0.0066
38	0.28	12.48	10.71	9.08	0.0100
39	0.70	13.66	10.99	8.81	0.0113
40	0.33	13.72	10.78	8.34	0.0119
41	0.08	15.75	11.42	8.14	0.0123
42	0.22	16.29	11.81	8.34	0.4269
43	1.63	16.10	11.71	8.29	0.4269
44	0.49	16.09	11.70	8.27	0.4269
45	0.55	13.99	9.90	6.92	0.3100
46	0.58	14.45	10.11	7.19	0.3140
47	0.26	11.94	9.43	7.55	0.0075
48	0.17	14.52	10.18	7.25	0.3235
49	0.24	11.56	8.82	6.73	0.0118
50	0.71	14.79	10.30	7.28	0.3401
51	0.92	15.10	10.44	7.33	0.3442
52	0.77	14.65	11.74	9.81	0.0038
53	0.33	21.73	13.71	8.42	0.0055
54	0.82	19.25	12.66	7.77	0.0055
55	0.25	17.21	11.74	7.19	0.0055
56	0.54	16.13	11.28	6.81	0.0044
57	1.19	15.66	10.79	7.46	0.3552
58	0.86	15.97	11.38	7.91	0.7843

Abbreviations:
°C = degree Celsius
cms = cubic meter per second
EOY = end of year

Table B-8. Simulated Reach Temperatures (°C) and Flows (cms) for Maximum Weekly Fall Conditions for EOY6 Disturbance Condition for the ModPRO2

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
1	0.50	10.07	8.69	7.57	0.0798
2	0.43	10.59	8.75	7.56	0.0840
3	0.63	9.65	8.08	6.94	0.0400

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
4	0.67	10.67	8.71	7.45	0.1316
5	0.86	10.81	8.79	7.48	0.1432
6	1.91	11.00	8.75	7.27	0.1211
7	1.40	11.76	9.34	7.97	0.0130
8	0.76	9.65	8.30	7.29	0.0167
9	1.30	9.73	8.27	7.23	0.0179
10	0.76	10.98	9.05	7.93	0.0078
11	1.40	10.16	8.45	7.30	0.0270
12	2.44	10.77	8.70	7.36	0.0430
13	0.31	10.64	8.59	7.23	0.0430
14	0.33	10.61	8.57	7.20	0.0430
15	0.61	11.04	8.68	7.13	0.0332
16	0.29	12.43	9.02	6.88	0.0299
17	2.76	11.85	9.43	8.15	0.0205
18	0.58	13.03	10.03	8.55	0.0310
19	0.41	12.84	10.03	8.61	0.0341
20	0.67	14.74	10.29	7.92	0.0348
21	1.33	15.29	10.06	6.97	0.0647
22	0.28	15.93	10.25	6.76	0.0650
23	0.63	13.20	9.43	6.87	0.1646
24	1.37	11.93	9.29	7.75	0.0037
25	0.46	13.78	9.71	7.15	0.0058
26	0.60	13.39	9.48	6.85	0.1720
27	1.22	13.62	9.55	6.79	0.1748
28	0.52	9.32	8.03	6.99	0.0161
29	0.33	9.44	8.07	7.07	0.0179
30	1.32	9.89	8.20	7.05	0.0212
31	0.42	10.03	8.19	6.93	0.0226
32	1.33	10.85	8.01	6.31	0.0046
33	0.77	11.10	7.91	5.89	0.0049
34	0.27	10.90	7.82	5.78	0.0049
35	0.15	10.43	8.32	6.91	0.0296
36	0.14	13.24	9.41	6.78	0.2059
37	1.53	10.84	9.21	8.07	0.0036
38	0.28	10.65	8.78	7.37	0.0055

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
39	0.70	11.55	8.83	6.94	0.0059
40	0.33	11.24	8.39	6.25	0.0061
41	0.08	13.81	8.99	5.95	0.0063
42	0.22	13.33	9.43	6.75	0.2128
43	1.63	13.05	9.30	6.67	0.2128
44	0.49	12.88	9.23	6.59	0.2127
45	0.55	10.35	8.79	7.53	0.2015
46	0.58	10.96	8.91	7.58	0.2043
47	0.26	10.23	8.51	7.43	0.0046
48	0.17	11.16	8.94	7.57	0.2104
49	0.24	9.49	8.17	7.14	0.0074
50	0.71	11.56	8.98	7.51	0.2206
51	0.92	11.83	9.01	7.47	0.2229
52	0.77	11.41	9.59	8.53	0.0023
53	0.33	17.06	10.43	6.55	0.0033
54	0.82	14.06	9.22	5.75	0.0033
55	0.25	12.21	8.30	5.09	0.0033
56	0.54	11.27	7.94	4.88	0.0034
57	1.19	12.29	9.10	7.30	0.2303
58	0.86	12.52	9.19	6.93	0.4443

Abbreviations:
°C = degree Celsius
cms = cubic meter per second
EOY = end of year

Table B-9. Simulated Reach Temperatures (°C) and Flows (cms) for Mean August Conditions for EOY6 Disturbance Condition for the ModPRO2

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
1	0.50	11.30	8.81	6.52	0.0975
2	0.43	11.86	8.99	6.61	0.1028
3	0.63	10.61	8.02	5.73	0.0487
4	0.67	11.80	8.93	6.58	0.1603
5	0.86	11.85	9.07	6.78	0.1746
6	1.91	12.05	9.23	6.95	0.1960
7	1.40	12.93	10.05	8.00	0.0228
8	0.76	10.52	8.27	6.26	0.0273
9	1.30	10.49	8.35	6.49	0.0290

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
10	0.76	11.80	9.20	7.36	0.0123
11	1.40	10.88	8.63	6.83	0.0431
12	2.44	11.63	9.20	7.32	0.0711
13	0.31	11.54	9.12	7.26	0.0711
14	0.33	11.51	9.11	7.25	0.0711
15	0.61	11.90	9.25	7.24	0.0671
16	0.29	12.90	9.61	7.16	0.0658
17	2.76	12.69	9.53	7.35	0.0277
18	0.58	14.11	10.43	8.19	0.0390
19	0.41	13.97	10.45	8.29	0.0417
20	0.67	15.79	11.09	8.23	0.0498
21	1.33	15.81	10.80	7.46	0.1181
22	0.28	16.71	11.10	7.36	0.1185
23	0.63	14.25	10.16	7.11	0.3241
24	1.37	13.07	10.35	8.62	0.0063
25	0.46	14.95	11.03	8.48	0.0112
26	0.60	14.45	10.26	7.16	0.3382
27	1.22	14.75	10.39	7.16	0.3430
28	0.52	10.24	8.00	5.91	0.0225
29	0.33	10.17	8.17	6.40	0.0258
30	1.32	10.43	8.55	6.95	0.0317
31	0.42	10.54	8.64	7.05	0.0342
32	1.33	12.02	8.82	6.60	0.0075
33	0.77	12.43	9.11	6.90	0.0090
34	0.27	12.30	9.03	6.83	0.0090
35	0.15	11.16	8.93	7.23	0.0465
36	0.14	14.50	10.30	7.17	0.3920
37	1.53	11.50	9.92	8.63	0.0066
38	0.28	11.50	9.78	8.37	0.0100
39	0.70	12.51	9.99	8.12	0.0113
40	0.33	12.53	9.78	7.68	0.0119
41	0.08	14.46	10.32	7.50	0.0123
42	0.22	14.60	10.34	7.19	0.4049
43	1.63	14.43	10.25	7.15	0.4049
44	0.49	14.36	10.23	7.13	0.4049
45	0.55	11.63	8.87	6.43	0.3100
46	0.58	12.21	9.05	6.47	0.3140
47	0.26	11.09	8.73	6.85	0.0075
48	0.17	12.38	9.10	6.49	0.3235
49	0.24	10.52	8.20	6.14	0.0118
50	0.71	12.80	9.21	6.50	0.3401

Number	Length	Temperature			Flow
		Maximum	Average	Minimum	Average
51	0.92	13.13	9.31	6.53	0.3442
52	0.77	12.78	10.50	9.04	0.0038
53	0.33	19.00	12.07	7.74	0.0055
54	0.82	16.80	11.15	7.13	0.0055
55	0.25	15.18	10.34	6.57	0.0055
56	0.54	14.21	9.91	6.20	0.0044
57	1.19	13.78	9.57	6.60	0.3552
58	0.86	14.14	9.99	6.89	0.7623

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EOY = end of year

Section 3: Inputs for EOY12 for the ModPRO2

This section includes model inputs representing mine year 12 for the ModPRO2. Stibnite Lake has been constructed and filled on the YPP backfill, which breaks the QUAL2K modeling into two models (upstream and downstream).

Table B-10. Reach Characteristics for EOY12 Disturbance Condition for the ModPRO2

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
Upper	1	0.5	0.750	0.320	0.200	0.250
	2	0.43	0.750	0.320	0.200	0.250
	3	0.63	0.750	0.320	0.200	0.250
	4	0.67	0.750	0.320	0.350	0.250
	5	0.86	0.750	0.320	0.350	0.250
	6	1.91	0.750	0.320	0.350	0.250
	7	1.4	0.750	0.320	0.350	0.250
	8	0.76	0.750	0.320	0.350	0.250
	9	1.3	2.000	0.270	1.460	0.600
	10	0.76	0.750	0.320	0.350	0.250
	11	1.4	2.000	0.270	1.460	0.600
	12	2.44	2.000	0.270	1.460	0.600
	13	0.31	2.000	0.270	1.460	0.600
	14	0.33	2.000	0.270	1.460	0.600
	15	0.61	0.900	0.250	0.900	0.400
	16	0.29	0.800	0.500	0.420	0.300
	17	2.76	1.600	0.320	0.350	0.250
	18	0.58	1.600	0.320	0.350	0.250
	19	0.41	0.340	0.000	1.000	0.350
	20	0.67	0.700	0.500	0.350	0.300
	21	1.33	0.750	0.500	0.480	0.330
	22	0.28	0.750	0.320	0.350	0.250
	23	0.63	0.480	0.320	0.350	0.250
	24	1.37	0.750	0.320	0.350	0.250
	25	0.46	1.300	0.500	0.350	0.300
	26	0.6	0.750	0.320	0.350	0.250
	27	1.22	0.750	0.320	0.350	0.250
	28	0.52	0.750	0.320	0.350	0.250
	29	0.33	0.750	0.320	0.350	0.250
	30	1.32	0.750	0.320	0.350	0.250
	31	0.42	3.300	0.350	1.400	0.550

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
	32	0.15	0.750	0.320	0.350	0.250
	33	0.14	0.750	0.320	0.350	0.250
	34	1.53	0.750	0.320	0.350	0.250
	35	0.28	0.750	0.320	0.350	0.250
	36	0.7	0.750	0.320	0.350	0.250
	37	0.33	4.000	0.400	0.450	0.600
	38	0.08	1.900	0.400	0.250	0.600
	39	0.32	0.750	0.320	0.350	0.250
	40	0.43	0.492	0.594	0.271	0.362
	41	0.38	0.484	0.594	0.271	0.363
	42	1.48	0.750	0.320	0.350	0.250
	43	0.45	4.300	0.320	0.137	0.489
	44	0.24	0.479	0.593	0.271	0.363
Lower	1	0.55	0.750	0.320	0.350	0.250
	2	0.58	0.750	0.320	0.350	0.250
	3	0.26	0.750	0.320	0.350	0.250
	4	0.17	0.750	0.320	0.350	0.250
	5	0.24	0.750	0.320	0.350	0.250
	6	0.71	0.750	0.320	0.350	0.250
	7	0.92	0.750	0.320	0.350	0.250
	8	0.77	0.750	0.320	0.350	0.250
	9	0.33	2.100	0.490	0.420	0.370
	10	0.82	4.000	0.400	0.800	0.600
	11	0.25	9.500	0.400	0.300	0.600
	12	0.54	0.750	0.320	0.350	0.250
	13	1.19	0.750	0.320	0.350	0.250
	14	0.06	0.479	0.593	0.271	0.363
	15	1.13	0.750	0.320	0.350	0.250
	16	0.86	0.750	0.320	0.350	0.250

Abbreviations:

EOY = end of year

km = kilometer

Table B-11. Diffuse Flow (cms) and Temperature (°C) for EOY12 Disturbance Condition for the ModPRO2

Model	Number	Flow			Temperature		
		Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Upper	1	0.0060	0.0050	0.0060	11.90	10.60	11.00
	2	0.0050	0.0040	0.0050	11.90	10.60	11.00
	3	0.0070	0.0060	0.0070	11.90	10.60	11.00
	4	0.0070	0.0060	0.0070	11.90	10.60	11.00
	5	0.0100	0.0080	0.0100	11.90	10.60	11.00
	6	0.0209	0.0167	0.0209	11.90	10.60	11.00
	7	0.0140	0.0080	0.0140	11.90	10.60	11.00
	8	0.0070	0.0050	0.0070	11.90	10.60	11.00
	9	0.0000	0.0000	0.0000	11.90	10.60	11.00
	10	0.0071	0.0050	0.0071	11.90	10.60	11.00
	11	0.0000	0.0000	0.0000	11.90	10.60	11.00
	12	0.0000	0.0000	0.0000	11.90	10.60	11.00
	13	0.0000	0.0000	0.0000	13.90	11.60	12.20
	14	0.0000	0.0000	0.0000	13.90	11.60	12.20
	15	0.0025	0.0028	0.0025	13.90	11.60	12.20
	16	0.0000	0.0000	0.0000	13.90	11.60	12.20
	17	0.0200	0.0180	0.0200	11.90	10.60	11.00
	18	0.0040	0.0040	0.0040	11.90	10.60	11.00
	19	0.0028	0.0028	0.0028	11.90	10.60	11.00
	20	0.0100	0.0080	0.0100	11.90	10.60	11.00
	21	0.0000	0.0000	0.0000	13.90	11.60	12.20
	22	0.0140	0.0130	0.0140	13.90	11.60	12.20
	23	0.0039	0.0020	0.0039	11.90	10.60	11.00
	24	0.0080	0.0050	0.0080	11.90	10.60	11.00
	25	0.0029	0.0019	0.0029	11.90	10.60	11.00
	26	0.0039	0.0019	0.0039	11.90	10.60	11.00
	27	0.0066	0.0037	0.0066	11.90	10.60	11.00
	28	0.0030	0.0018	0.0030	11.90	10.60	11.00
	29	0.0020	0.0010	0.0020	11.90	10.60	11.00
	30	0.0090	0.0045	0.0090	11.90	10.60	11.00
	31	0.0000	0.0000	0.0000	11.90	10.60	11.00
	32	0.0012	0.0006	0.0012	11.90	10.60	11.00
	33	0.0002	0.0001	0.0002	11.90	10.60	11.00
	34	0.0090	0.0050	0.0090	11.90	10.60	11.00
	35	0.0020	0.0010	0.0020	11.90	10.60	11.00
	36	0.0024	0.0009	0.0024	11.90	10.60	11.00

Model	Number	Flow			Temperature		
		Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
	37	0.0000	0.0000	0.0000	11.90	10.60	11.00
	38	0.0005	0.0003	0.0005	11.90	10.60	11.00
	39	0.0016	0.0008	0.0016	11.90	10.60	11.00
	40	0.0000	0.0000	0.0000	11.90	10.60	11.00
	41	0.0000	0.0000	0.0000	11.90	10.60	11.00
	42	0.0016	0.0000	0.0016	11.90	10.60	11.00
	43	0.0000	0.0000	0.0000	11.90	10.60	11.00
	44	0.0000	0.0000	0.0000	11.90	10.60	11.00
Lower	1	0.0040	0.0020	0.0040	11.90	10.60	11.00
	2	0.0040	0.0030	0.0040	11.90	10.60	11.00
	3	0.0012	0.0010	0.0012	11.90	10.60	11.00
	4	0.0010	0.0010	0.0010	11.90	10.60	11.00
	5	0.0019	0.0009	0.0019	11.90	10.60	11.00
	6	0.0046	0.0027	0.0046	11.90	10.60	11.00
	7	0.0045	0.0028	0.0045	11.90	10.60	11.00
	8	0.0050	0.0030	0.0050	11.90	10.60	11.00
	9	0.0000	0.0000	0.0000	11.90	10.60	11.00
	10	0.0000	0.0000	0.0000	11.90	10.60	11.00
	11	0.0000	0.0000	0.0000	11.90	10.60	11.00
	12	0.0002	0.0000	0.0002	11.90	10.60	11.00
	13	0.0051	0.0030	0.0051	11.90	10.60	11.00
	14	0.0000	0.0000	0.0000	11.90	10.60	11.00
	15	0.0094	0.0042	0.0094	14.80	12.00	12.70
	16	0.0031	0.0020	0.0031	14.80	12.00	12.70

Notes:

[a]Summer corresponds to the maximum weekly summer condition

[b]Fall corresponds to the maximum weekly fall condition

[c]August corresponds to the mean August condition

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EOY = end of year

Table B-12. Point Sources Flow (cms) and Temperature (°C) for EOY12 Disturbance Condition for the ModPRO2

	Source	Flow			Temperature		
		Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Upper	Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
	Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
	Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
	Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	20.00	20.00	20.00
	Treated Water Discharge – Meadow Creek	0.0000	0.0000	0.0000	N/A	N/A	N/A

Notes:

[a]*Summer corresponds to the maximum weekly summer condition*

[b]*Fall corresponds to the maximum weekly fall condition*

[c]August corresponds to the mean August *condition*

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B-13. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY12 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	90.7	78.7	6.6	2.9	2.5	2.4	2.5	2.7	2.7	2.4	2.1	1.4	1.9	14.6	83.1	89.9	100	100	100
	16	100	100	100	100	100	93.8	73.3	51.0	42.6	30.1	18.4	10.7	7.2	7.5	11.0	18.2	30.4	43.9	52.2	93.7	93.7	100	100	100
	17	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	18	100	100	100	100	100	95.1	94.4	74.7	48.9	40.1	29.4	19.9	14.8	16.8	23.0	33.9	42.1	45.5	75.6	94.2	95.0	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	95.3	92.3	72.4	63.7	56.1	41.4	20.9	12.2	13.2	26.7	45.5	56.4	59.6	62.8	79.2	95.3	100	100	100
	21	100	100	100	100	100	94.1	74.6	48.4	42.4	33.0	20.8	11.3	7.3	6.9	9.1	15.7	28.9	42.9	59.2	93.7	93.7	100	100	100
	22	100	100	100	100	100	96.6	96.0	79.1	68.7	59.5	41.9	22.8	10.7	9.8	17.4	35.3	59.8	71.8	83.7	95.9	96.8	100	100	100
	23	100	100	100	100	100	96.0	95.7	85.8	71.9	50.2	29.2	19.4	15.3	13.6	21.8	38.3	55.5	65.6	91.7	95.5	96.0	100	100	100
	24	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	25	100	100	100	100	100	94.7	94.5	70.9	55.0	51.1	37.6	29.7	32.9	42.6	50.1	54.5	55.3	57.4	73.5	95.6	95.9	100	100	100
	26	100	100	100	100	100	95.6	95.4	84.7	71.5	49.9	30.0	14.6	8.9	9.7	16.1	33.0	57.5	75.2	92.9	95.7	95.9	100	100	100
	27	100	100	100	100	100	96.0	95.8	94.0	77.1	53.5	30.4	17.3	14.5	14.7	20.3	34.5	52.1	68.9	86.1	95.6	95.9	100	100	100
	28	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	29	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	30	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	33	100	100	100	100	100	95.7	95.3	86.8	53.6	29.4	8.2	5.2	6.2	5.3	14.4	35.2	50.5	63.6	81.6	95.3	95.8	100	100	100
	34	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	35	100	100	100	100	100	91.4	92.4	89.8	18.3	3.6	3.3	2.9	2.7	3.0	3.8	4.1	3.7	6.7	12.6	46.3	89.7	100	100	100
	36	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	37	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	38	100	100	100	100	100	92.2	92.2	73.1	11.2	2.9	2.8	2.9	3.0	3.0	3.0	3.0	2.6	3.4	33.9	91.6	91.9	100	100	100
	39	100	100	100	100	100	95.6	95.4	84.9	57.1	30.5	16.6	7.5	5.8	8.3	16.6	31.2	47.4	58.5	79.4	94.5	94.9	100	100	100
	40	100	100	100	100	100	90.5	90.7	23.7	11.5	6.5	2.0	1.7	1.7	1.7	1.7	1.6	1.4	12.7	85.3	90.5	90.6	100	100	100
	41	100	100	100	100	100	90.1	90.2	39.6	4.5	1.4	1.2	1.2	1.2	1.2	1.2	1.2	1.1	35.2	90.4	90.3	90.2	100	100	100
	42	100	100	100	100	100	97.7	89.7	78.8	73.9	71.2	69.6	67.7	65.5	61.9	54.0	57.8	64.7	84.1	95.6	97.7	97.8	100	100	100
	43	100	100	100	100	100	90.4	87.8	28.8	1.5	1.5	1.6	1.7	1.7	1.7	1.9	5.1	27.2	68.1	90.5	89.9	89.7	100	100	100
	44	100	100	100	100	100	90.4	90.4	86.4	5.4	1.2	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.5	63.7	90.6	90.3	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	96.6	96.5	95.0	76.5	50.2	29.8	31.9	43.0	48.8	54.7	60.5	70.5	76.0	80.2	81.1	94.2	100	100	100
	9	100	100	100	100	100	96.9	96.9	96.8	93.3	62.0	25.8	10.7	7.7	5.4	13.5	27.7	40.0	43.5	46.4	47.7	93.7	100	100	100
	10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	13	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	14	100	100	100	100	100	90.9	90.4	47.7	1.0	1.6	2.0	2.1	2.1	2.1	2.1	2.0	1.7	2.3	39.9	90.8	91.0	100	100	100
	15	100	100	100	100	100	95.5	90.3	77.5	64.8	41.2	24.6	17.4	16.5	19.5	26.9	37.6	46.7	58.8	79.9	95.0	95.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	16	100	100	100	100	100	95.1	93.5	86.3	48.5	21.6	13.3	12.1	15.5	22.3	29.9	38.6	51.1	68.0	82.1	95.0	95.2	100	100	100

Notes:

** Hours are in military format*

Abbreviations:

%= percent

EOY = end of year

Table B-14. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY12 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2		88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	100	88.1	77.0	14.8	5.8	4.4	3.6	3.2	3.1	2.9	2.5	2.2	46.5	87.1	100	100	100	100	100
	16	100	100	100	100	100	100	91.8	73.5	47.7	42.8	39.0	33.0	29.9	30.4	33.6	39.0	46.3	71.1	91.8	100	100	100	100	100
	17	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	18	100	100	100	100	100	100	93.6	92.7	77.3	48.9	44.3	38.2	33.2	33.5	39.3	46.6	58.9	89.6	92.7	100	100	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	100	93.9	91.5	72.7	62.1	50.8	33.1	20.8	27.8	46.8	56.3	60.8	67.4	93.6	100	100	100	100	100
	21	100	100	100	100	100	100	92.3	77.1	51.8	48.8	43.6	34.6	28.4	26.0	28.9	36.1	43.9	80.2	91.7	100	100	100	100	100
	22	100	100	100	100	100	100	96.2	95.2	80.1	68.2	60.4	45.5	29.5	21.6	32.0	50.8	68.3	94.3	94.9	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	23	100	100	100	100	100	100	94.7	94.3	80.8	57.9	36.2	23.5	19.3	28.9	49.6	64.1	80.0	94.0	94.7	100	100	100	100	100
	24	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	25	100	100	100	100	100	100	92.8	92.5	71.5	50.6	39.1	43.3	51.3	54.9	56.6	58.7	63.1	92.9	94.8	100	100	100	100	100
	26	100	100	100	100	100	100	94.2	94.0	82.9	63.9	44.8	26.5	21.2	23.7	38.1	58.9	80.5	94.1	94.5	100	100	100	100	100
	27	100	100	100	100	100	100	94.7	94.5	93.6	72.6	44.5	26.3	20.9	25.3	37.1	54.3	73.9	93.9	94.4	100	100	100	100	100
	28	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	29	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	30	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	33	100	100	100	100	100	100	93.8	94.1	89.5	51.6	23.6	18.0	17.9	30.1	58.6	74.1	89.5	94.5	94.5	100	100	100	100	100
	34	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	35	100	100	100	100	100	100	88.9	89.5	90.1	48.0	21.3	9.8	5.7	3.8	3.6	5.8	10.5	26.6	87.3	100	100	100	100	100
	36	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	37	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	38	100	100	100	100	100	100	90.0	89.2	80.7	19.9	5.4	4.6	4.1	3.8	3.8	4.0	3.9	81.5	89.3	100	100	100	100	100
	39	100	100	100	100	100	100	94.1	93.8	76.8	39.6	21.3	15.9	23.0	33.5	48.9	62.5	73.1	92.9	93.1	100	100	100	100	100
	40	100	100	100	100	100	100	87.3	87.4	23.6	11.7	4.6	1.8	1.8	1.6	1.4	4.7	52.2	87.2	87.3	100	100	100	100	100
	41	100	100	100	100	100	100	87.0	86.9	44.5	5.5	1.8	1.3	1.4	1.4	1.3	11.1	80.9	87.2	87.3	100	100	100	100	100
	42	100	100	100	100	100	100	97.1	93.1	86.3	80.4	75.1	72.6	70.1	68.0	62.4	72.0	89.9	95.3	97.0	100	100	100	100	100
	43	100	100	100	100	100	100	87.4	86.4	32.4	1.8	4.7	3.3	2.1	3.1	5.3	54.1	85.3	87.8	86.7	100	100	100	100	100
	44	100	100	100	100	100	100	87.1	87.1	85.6	11.7	1.3	1.5	1.6	1.8	1.8	1.9	26.9	87.8	87.3	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	95.6	93.8	93.3	87.0	58.2	63.1	72.6	80.8	88.0	93.6	95.8	96.0	96.0	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	9	100	100	100	100	100	100	96.1	96.2	95.5	89.4	38.8	13.5	12.9	23.9	38.5	44.8	46.1	46.3	54.8	100	100	100	100	100
	10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	14	100	100	100	100	100	100	88.0	87.4	54.5	1.8	2.5	2.7	2.7	2.7	2.2	2.2	15.6	88.1	88.1	100	100	100	100	100
	15	100	100	100	100	100	100	94.1	89.5	77.1	65.4	39.2	28.8	29.5	36.6	47.7	58.0	75.8	93.1	93.8	100	100	100	100	100
	16	100	100	100	100	100	100	93.7	91.0	83.1	48.1	25.9	27.0	32.5	42.3	56.5	73.1	84.3	91.5	93.7	100	100	100	100	100

Notes:

** Hours are in military form*

Abbreviations:

%= percent

EOY = end of year

Table B-15. Hourly Effective Shade (%) for Mean August Conditions for EOY12 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0		99.2	99.6	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	15	100	100	100	100	100	95.4	83.4	41.8	8.9	4.2	3.4	3.1	3.0	2.9	2.7	2.3	1.8	24.2	50.9	91.6	95.0	100	100	100
	16	100	100	100	100	100	96.9	82.6	62.3	45.2	36.5	28.7	21.9	18.6	19.0	22.3	28.6	38.4	57.5	72.0	96.9	96.9	100	100	100
	17	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	18	100	100	100	100	100	97.6	94.0	83.7	63.1	44.5	36.9	29.1	24.0	25.2	31.2	40.3	50.5	67.6	84.2	97.1	97.5	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	97.7	93.1	82.0	68.2	59.1	46.1	27.0	16.5	20.5	36.8	50.9	58.6	63.5	78.2	89.6	97.7	100	100	100
	21	100	100	100	100	100	97.1	83.5	62.8	47.1	40.9	32.2	23.0	17.9	16.5	19.0	25.9	36.4	61.6	75.5	96.9	96.9	100	100	100
	22	100	100	100	100	100	98.3	96.1	87.2	74.4	63.9	51.2	34.2	20.1	15.7	24.7	43.1	64.1	83.1	89.3	98.0	98.4	100	100	100
	23	100	100	100	100	100	98.0	95.2	90.1	76.4	54.1	32.7	21.5	17.3	21.3	35.7	51.2	67.8	79.8	93.2	97.8	98.0	100	100	100
	24	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	25	100	100	100	100	100	97.4	93.7	81.7	63.3	50.9	38.4	36.5	42.1	48.8	53.4	56.6	59.2	75.2	84.2	97.8	98.0	100	100	100
	26	100	100	100	100	100	97.8	94.8	89.4	77.2	56.9	37.4	20.6	15.1	16.7	27.1	46.0	69.0	84.7	93.7	97.9	98.0	100	100	100
	27	100	100	100	100	100	98.0	95.3	94.3	85.4	63.1	37.5	21.8	17.7	20.0	28.7	44.4	63.0	81.4	90.3	97.8	98.0	100	100	100
	28	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	29	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	30	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	33	100	100	100	100	100	97.9	94.6	90.5	71.6	40.5	15.9	11.6	12.1	17.7	36.5	54.7	70.0	79.1	88.1	97.7	97.9	100	100	100
	34	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	35	100	100	100	100	100	95.7	90.7	89.7	54.2	25.8	12.3	6.4	4.2	3.4	3.7	5.0	7.1	16.7	50.0	73.2	94.9	100	100	100
	36	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	37	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	38	100	100	100	100	100	96.1	91.1	81.2	46.0	11.4	4.1	3.8	3.6	3.4	3.4	3.5	3.3	42.5	61.6	95.8	96.0	100	100	100
	39	100	100	100	100	100	97.8	94.8	89.4	67.0	35.1	19.0	11.7	14.4	20.9	32.8	46.9	60.3	75.7	86.3	97.3	97.5	100	100	100
	40	100	100	100	100	100	95.3	89.0	55.6	17.6	9.1	3.3	1.8	1.8	1.7	1.6	3.2	26.8	50.0	86.3	95.3	95.3	100	100	100
	41	100	100	100	100	100	95.1	88.6	63.3	24.5	3.5	1.5	1.3	1.3	1.3	1.3	6.2	41.0	61.2	88.9	95.2	95.1	100	100	100
	42	100	100	100	100	100	98.9	93.4	86.0	80.1	75.8	72.4	70.2	67.8	65.0	58.2	64.9	77.3	89.7	96.3	98.9	98.9	100	100	100
	43	100	100	100	100	100	95.2	87.6	57.6	17.0	1.7	3.2	2.5	1.9	2.4	3.6	29.6	56.3	78.0	88.6	95.0	94.9	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	44	100	100	100	100	100	95.2	88.8	86.8	45.5	6.5	1.3	1.5	1.5	1.6	1.6	1.7	14.2	44.7	75.5	95.3	95.2	100	100	100
Lower	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	98.3	96.1	94.4	84.9	68.6	44.0	47.5	57.8	64.8	71.4	77.1	83.2	86.0	88.1	90.6	97.1	100	100	100
	9	100	100	100	100	100	98.5	96.5	96.5	94.4	75.7	32.3	12.1	10.3	14.7	26.0	36.3	43.1	44.9	50.6	73.9	96.9	100	100	100
	10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	13	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	14	100	100	100	100	100	95.5	89.2	67.6	27.8	1.7	2.3	2.4	2.4	2.4	2.2	2.1	8.7	45.2	64.0	95.4	95.5	100	100	100
	15	100	100	100	100	100	97.8	92.2	83.5	71.0	53.3	31.9	23.1	23.0	28.1	37.3	47.8	61.3	76.0	86.9	97.5	97.6	100	100	100
	16	100	100	100	100	100	97.6	93.6	88.7	65.8	34.9	19.6	19.6	24.0	32.3	43.2	55.9	67.7	79.8	87.9	97.5	97.6	100	100	100

Notes:

** Hours are in military form*

Abbreviations:

% = percent

EOY = end of year

Section 4: Outputs for EOY12 for the ModPRO2

This section provides the reach-by-reach output for EOY12 for the ModPRO2.

Table B-16. Simulated Reach Temperatures and Flows for Maximum Weekly Summer Conditions for EOY12 Disturbance Condition for the ModPRO2

Model	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
Upper	1	0.50	13.53	9.85	7.11	0.0975
	2	0.43	13.79	10.06	7.38	0.1028
	3	0.63	11.64	8.64	6.34	0.0487
	4	0.67	13.26	9.87	7.31	0.1603
	5	0.86	13.30	10.09	7.51	0.1696
	6	1.91	13.25	10.27	7.79	0.2001
	7	1.40	14.75	11.43	8.99	0.0228
	8	0.76	11.58	8.93	6.90	0.0272
	9	1.30	11.51	9.02	7.14	0.0290
	10	0.76	12.80	9.98	8.06	0.0123
	11	1.40	11.79	9.34	7.50	0.0431
	12	2.44	12.77	10.13	8.11	0.0711
	13	0.31	12.67	10.05	8.05	0.0711
	14	0.33	12.64	10.03	8.04	0.0711
	15	0.61	13.00	10.30	8.20	0.0729
	16	0.29	13.65	10.64	8.18	0.0736
	17	2.76	13.63	10.35	8.06	0.0277
	18	0.58	15.03	11.37	8.94	0.0390
	19	0.41	14.85	11.38	9.06	0.0421
	20	0.67	16.39	11.89	9.01	0.0503
	21	1.33	16.23	11.64	8.35	0.1264
	22	0.28	16.98	12.08	8.65	0.1369
	23	0.63	15.19	11.29	8.23	0.3530
	24	1.37	14.35	11.39	9.37	0.0063
	25	0.46	15.71	11.99	9.21	0.0112
	26	0.60	15.40	11.40	8.26	0.3678
	27	1.22	15.78	11.54	8.25	0.3729
	28	0.52	11.39	8.59	6.38	0.0212
	29	0.33	11.09	8.77	7.01	0.0255
	30	1.32	11.21	9.28	7.69	0.0321
	31	0.42	11.26	9.42	7.84	0.0350
	32	0.15	11.54	9.58	7.91	0.0362
	33	0.14	15.66	11.45	8.21	0.4117

Model	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
	34	1.53	12.54	10.84	9.38	0.0066
	35	0.28	14.88	11.74	9.48	0.0120
	36	0.70	15.36	11.80	9.21	0.0136
	37	0.33	15.07	11.51	8.78	0.0144
	38	0.08	16.60	11.99	8.60	0.0149
	39	0.32	15.84	11.53	8.23	0.4281
	40	0.43	16.58	11.75	8.21	0.4281
	41	0.38	17.44	12.01	8.15	0.4281
	42	1.48	13.93	9.45	6.41	0.0060
	43	0.45	18.75	11.21	6.20	0.0066
	44	0.24	18.15	12.23	8.05	0.4347
Lower	1	0.55	13.99	9.90	6.92	0.3100
	2	0.58	14.45	10.11	7.19	0.3140
	3	0.26	11.89	9.05	6.90	0.0065
	4	0.17	14.53	10.17	7.23	0.3224
	5	0.24	11.55	8.81	6.70	0.0117
	6	0.71	14.80	10.30	7.26	0.3388
	7	0.92	15.11	10.43	7.30	0.3418
	8	0.77	14.65	11.74	9.81	0.0038
	9	0.33	19.13	12.72	9.02	0.0055
	10	0.82	17.05	11.84	8.28	0.0055
	11	0.25	15.51	11.06	7.60	0.0055
	12	0.54	14.57	10.72	7.25	0.0057
	13	1.19	15.62	10.74	7.40	0.3541
	14	0.06	13.75	13.59	13.50	0.4271
	15	1.13	14.40	13.65	13.29	0.4272
	16	0.86	14.96	12.42	10.53	0.7836

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EOY = end of year

km = kilometer

Table B-17. Simulated Reach Temperatures and Flows for Maximum Weekly Fall Conditions for EOY12 Disturbance Condition for the ModPRO2

Model	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
Upper	1	0.50	10.07	8.69	7.57	0.0798
	2	0.43	10.59	8.75	7.56	0.0840
	3	0.63	9.65	8.08	6.94	0.0400

Model	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
	4	0.67	10.67	8.71	7.45	0.1316
	5	0.86	10.88	8.82	7.47	0.1392
	6	1.91	10.97	8.86	7.47	0.1637
	7	1.40	11.76	9.34	7.97	0.0130
	8	0.76	9.65	8.31	7.30	0.0167
	9	1.30	9.73	8.28	7.24	0.0180
	10	0.76	10.98	9.05	7.92	0.0078
	11	1.40	10.16	8.45	7.30	0.0270
	12	2.44	10.77	8.70	7.36	0.0430
	13	0.31	10.64	8.59	7.23	0.0430
	14	0.33	10.61	8.57	7.20	0.0430
	15	0.61	11.08	8.82	7.33	0.0451
	16	0.29	11.78	9.00	7.20	0.0458
	17	2.76	11.85	9.43	8.15	0.0205
	18	0.58	12.91	10.00	8.55	0.0310
	19	0.41	12.69	9.99	8.61	0.0341
	20	0.67	13.58	10.10	8.26	0.0408
	21	1.33	13.53	9.66	7.36	0.0886
	22	0.28	13.78	9.91	7.57	0.0983
	23	0.63	12.25	9.36	7.44	0.2742
	24	1.37	11.90	9.42	7.99	0.0043
	25	0.46	12.89	9.67	7.62	0.0075
	26	0.60	12.41	9.39	7.40	0.2836
	27	1.22	12.69	9.44	7.32	0.2864
	28	0.52	9.34	8.00	6.92	0.0154
	29	0.33	9.41	8.04	7.03	0.0176
	30	1.32	9.87	8.18	7.03	0.0209
	31	0.42	10.01	8.17	6.92	0.0224
	32	0.15	10.30	8.26	6.91	0.0229
	33	0.14	12.64	9.38	7.24	0.3108
	34	1.53	10.84	9.21	8.07	0.0036
	35	0.28	13.03	9.74	7.89	0.0065
	36	0.70	13.06	9.60	7.49	0.0071
	37	0.33	12.29	9.07	6.84	0.0074
	38	0.08	14.14	9.52	6.57	0.0077
	39	0.32	12.72	9.39	7.21	0.3193
	40	0.43	13.38	9.53	7.11	0.3193

Model	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
	41	0.38	14.08	9.67	6.98	0.3193
	42	1.48	11.39	7.87	5.78	0.0040
	43	0.45	15.64	8.58	4.71	0.0040
	44	0.24	14.66	9.78	6.84	0.3233
Lower	1	0.55	10.35	8.79	7.53	0.2015
	2	0.58	10.96	8.91	7.58	0.2042
	3	0.26	10.19	8.42	7.31	0.0044
	4	0.17	11.16	8.94	7.57	0.2103
	5	0.24	9.47	8.12	7.07	0.0072
	6	0.71	11.56	8.98	7.51	0.2203
	7	0.92	11.84	9.01	7.46	0.2222
	8	0.77	11.41	9.59	8.53	0.0023
	9	0.33	17.30	10.27	4.47	0.0033
	10	0.82	14.13	9.12	4.39	0.0033
	11	0.25	12.16	8.25	4.27	0.0033
	12	0.54	11.13	7.88	4.27	0.0033
	13	1.19	12.27	9.08	7.27	0.2294
	14	0.06	10.53	10.34	10.26	0.3143
	15	1.13	11.04	10.34	10.07	0.3141
	16	0.86	11.65	9.82	8.77	0.5449

Abbreviations:
°C = degree Celsius
cms = cubic meter per second
EOY = end of year
km = kilometer

Table B-18. Simulated Reach Temperatures and Flows for Mean August Conditions for EOY12 Disturbance Condition for the ModPRO2

	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
Upper	1	0.50	11.34	8.83	6.53	0.0975
	2	0.43	11.95	9.03	6.63	0.1028
	3	0.63	10.68	8.06	5.78	0.0487
	4	0.67	11.91	8.98	6.60	0.1603
	5	0.86	12.10	9.18	6.78	0.1696
	6	1.91	12.18	9.34	7.04	0.2001
	7	1.40	13.04	10.10	8.01	0.0228
	8	0.76	10.59	8.31	6.30	0.0272
	9	1.30	10.60	8.40	6.53	0.0290
	10	0.76	11.90	9.25	7.38	0.0123
	11	1.40	11.02	8.70	6.85	0.0431

	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
	12	2.44	11.80	9.28	7.33	0.0711
	13	0.31	11.72	9.22	7.27	0.0711
	14	0.33	11.70	9.20	7.26	0.0711
	15	0.61	12.10	9.43	7.36	0.0729
	16	0.29	12.80	9.71	7.31	0.0736
	17	2.76	12.77	9.57	7.37	0.0277
	18	0.58	14.11	10.46	8.19	0.0390
	19	0.41	13.91	10.47	8.30	0.0421
	20	0.67	14.98	10.84	8.24	0.0503
	21	1.33	14.85	10.52	7.52	0.1264
	22	0.28	15.36	10.84	7.77	0.1369
	23	0.63	13.85	10.18	7.39	0.3530
	24	1.37	13.07	10.35	8.62	0.0063
	25	0.46	14.24	10.81	8.48	0.0112
	26	0.60	14.00	10.26	7.42	0.3678
	27	1.22	14.28	10.37	7.41	0.3729
	28	0.52	10.34	7.98	5.79	0.0212
	29	0.33	10.15	8.14	6.36	0.0255
	30	1.32	10.43	8.58	7.01	0.0321
	31	0.42	10.54	8.69	7.14	0.0350
	32	0.15	10.87	8.83	7.20	0.0362
	33	0.14	14.15	10.30	7.38	0.4117
	34	1.53	11.50	9.92	8.63	0.0066
	35	0.28	13.73	10.67	8.75	0.0120
	36	0.70	14.06	10.70	8.50	0.0136
	37	0.33	13.74	10.41	8.09	0.0144
	38	0.08	15.16	10.82	7.93	0.0149
	39	0.32	14.28	10.36	7.40	0.4281
	40	0.43	14.99	10.54	7.38	0.4281
	41	0.38	15.78	10.76	7.32	0.4281
	42	1.48	12.66	8.61	5.78	0.0060
	43	0.45	17.23	9.98	5.57	0.0066
	44	0.24	16.43	10.94	7.24	0.4347
Lower	1	0.55	11.63	8.87	6.43	0.3100
	2	0.58	12.21	9.05	6.47	0.3140
	3	0.26	11.03	8.39	6.24	0.0065
	4	0.17	12.38	9.10	6.47	0.3224
	5	0.24	10.51	8.18	6.11	0.0117
	6	0.71	12.80	9.20	6.49	0.3388
	7	0.92	13.14	9.30	6.50	0.3418

	Number	Length (km)	Temperature (°C)			Flow (cms)
			Maximum	Average	Minimum	Average
	8	0.77	12.78	10.50	9.04	0.0038
	9	0.33	16.55	11.24	8.31	0.0055
	10	0.82	14.77	10.47	7.61	0.0055
	11	0.25	13.44	9.80	6.98	0.0055
	12	0.54	12.74	9.48	6.63	0.0057
	13	1.19	13.73	9.54	6.55	0.3541
	14	0.06	12.53	12.37	12.29	0.4271
	15	1.13	13.10	12.41	12.10	0.4272
	16	0.86	13.49	11.16	9.50	0.7836

Abbreviations:

°C = degree Celsius

cms = cubic meter per second

EOY = end of year

km = kilometer

Section 5: Inputs for Post Closure Years for the ModPRO2

Two configurations represent the post mining conditions for ModPRO2. Up until EOY23, the diversion channels and low flow pipes at the tailings storage facility (TSF) remain in use. By EOY23, the channels on the TSF are restored. Reach inputs and outputs are provided in this section for these configurations.

Table B-19. Reach Characteristics (EOY18 through EOY22 Disturbance Conditions) for the ModPRO2

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
Upper	1	0.50	0.750	0.320	0.200	0.250
	2	0.43	0.750	0.320	0.200	0.250
	3	0.63	0.750	0.320	0.200	0.250
	4	0.67	0.750	0.320	0.350	0.250
	5	0.86	0.750	0.320	0.350	0.250
	6	1.91	0.750	0.320	0.350	0.250
	7	1.40	0.750	0.320	0.350	0.250
	8	0.76	0.750	0.320	0.350	0.250
	9	1.30	2.000	0.270	1.460	0.600
	10	0.76	0.750	0.320	0.350	0.250
	11	1.40	2.000	0.270	1.460	0.600
	12	2.44	2.000	0.270	1.460	0.600
	13	0.31	2.000	0.270	1.460	0.600
	14	0.35	2.000	0.270	1.460	0.600
	15	0.61	0.900	0.250	0.900	0.400
	16	0.29	0.800	0.500	0.420	0.300
	17	2.76	1.600	0.320	0.350	0.250
	18	0.58	1.600	0.320	0.350	0.250
	19	0.41	0.340	0	1.000	0.350
	20	0.67	0.700	0.500	0.350	0.300
	21	1.33	0.750	0.500	0.480	0.330
	22	0.28	0.750	0.320	0.350	0.250
	23	0.63	0.480	0.320	0.350	0.250
	24	1.37	0.750	0.320	0.350	0.250
	25	0.46	1.300	0.500	0.350	0.300
	26	0.60	0.750	0.320	0.350	0.250
	27	1.22	0.750	0.320	0.350	0.250
	28	0.52	0.750	0.320	0.350	0.250
	29	0.33	0.750	0.320	0.350	0.250
	30	1.32	0.750	0.320	0.350	0.250
	31	0.42	3.300	0.350	1.400	0.550

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
	32	0.15	0.750	0.320	0.350	0.250
	33	0.36	0.750	0.320	0.350	0.250
	34	0.43	0.492	0.594	0.271	0.362
	35	1.53	0.750	0.320	0.350	0.250
	36	0.28	0.750	0.320	0.350	0.250
	37	0.70	0.750	0.320	0.350	0.250
	38	0.71	1.340	0.510	0.392	0.412
	39	0.38	0.484	0.594	0.271	0.363
	40	1.48	0.750	0.320	0.350	0.250
	41	0.45	4.30	0.320	0.137	0.489
	42	0.24	0.479	0.593	0.271	0.363
Lower	1	0.55	0.750	0.320	0.350	0.250
	2	0.58	0.750	0.320	0.350	0.250
	3	0.26	0.750	0.320	0.350	0.250
	4	0.17	0.750	0.320	0.350	0.250
	5	0.24	0.750	0.320	0.350	0.250
	6	0.71	0.750	0.320	0.350	0.250
	7	0.92	0.750	0.320	0.350	0.250
	8	0.23	1.000	0.450	0.280	0.350
	9	0.54	0.750	0.320	0.350	0.250
	10	1.19	0.750	0.320	0.350	0.250
	11	0.06	0.479	0.593	0.271	0.363
	12	1.13	0.750	0.320	0.350	0.250
	13	0.86	0.750	0.320	0.350	0.250

Abbreviations:

EOY = end of year

km = kilometer

Table B-20. Reach Characteristics (EOY27 through EOY112 Disturbance Conditions) for the ModPRO2

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
Upper	1	0.50	0.750	0.320	0.200	0.250
	2	0.43	0.750	0.320	0.200	0.250
	3	0.63	0.750	0.320	0.200	0.250
	4	0.67	0.750	0.320	0.350	0.250
	5	0.86	0.750	0.320	0.350	0.250
	6	1.91	0.750	0.320	0.350	0.250
	7	1.40	0.750	0.320	0.350	0.250

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
	8	1.87	0.900	0.450	0.360	0.400
	9	0.76	0.750	0.320	0.350	0.250
	10	0.83	1.300	0.450	0.410	0.400
	11	0.91	0.700	0.450	0.420	0.400
	12	0.76	0.750	0.320	0.350	0.250
	13	1.33	1.150	0.480	0.390	0.400
	14	1.27	0.550	0.450	0.420	0.400
	15	0.56	0.800	0.480	0.320	0.400
	16	0.73	0.850	0.450	0.320	0.340
	17	0.80	0.900	0.250	0.900	0.400
	18	0.29	0.800	0.500	0.420	0.300
	19	2.76	1.600	0.320	0.350	0.250
	20	0.58	1.600	0.320	0.350	0.250
	21	0.41	0.340	0.000	1.000	0.350
	22	0.67	0.700	0.500	0.350	0.300
	23	1.33	0.750	0.500	0.480	0.330
	24	0.28	0.750	0.320	0.350	0.250
	25	0.63	0.480	0.320	0.350	0.250
	26	1.37	0.750	0.320	0.350	0.250
	27	0.46	1.300	0.500	0.350	0.300
	28	0.60	0.750	0.320	0.350	0.250
	29	1.22	0.750	0.320	0.350	0.250
	30	0.52	0.750	0.320	0.350	0.250
	31	0.33	0.750	0.320	0.350	0.250
	32	1.32	0.750	0.320	0.350	0.250
	33	0.42	3.300	0.350	1.400	0.550
	34	0.15	0.750	0.320	0.350	0.250
	35	0.36	0.750	0.320	0.350	0.250
	36	0.43	0.492	0.594	0.271	0.362
	37	1.53	0.750	0.320	0.350	0.250
	38	0.28	0.750	0.320	0.350	0.250
	39	0.70	0.750	0.320	0.350	0.250
	40	0.71	1.340	0.510	0.392	0.412
	41	0.38	0.484	0.594	0.271	0.363
	42	1.48	0.750	0.320	0.350	0.250
	43	0.45	4.300	0.320	0.137	0.489

Model	Number	Length (km)	Velocity coefficient	Velocity exponent	Depth coefficient	Depth exponent
	44	0.24	0.479	0.593	0.271	0.363
Lower	1	0.55	0.750	0.320	0.350	0.250
	2	0.58	0.750	0.320	0.350	0.250
	3	0.26	0.750	0.320	0.350	0.250
	4	0.17	0.750	0.320	0.350	0.250
	5	0.24	0.750	0.320	0.350	0.250
	6	0.71	0.750	0.320	0.350	0.250
	7	0.92	0.750	0.320	0.350	0.250
	8	0.23	1.000	0.450	0.280	0.350
	9	0.54	0.750	0.320	0.350	0.250
	10	1.19	0.750	0.320	0.350	0.250
	11	0.06	0.479	0.593	0.271	0.363
	12	1.13	0.750	0.320	0.350	0.250
	13	0.86	0.750	0.320	0.350	0.250

Abbreviations:
EOY = end of year
km = kilometer

Table B-21. Diffuse Flow and Temperature (EOY18 through EOY22 Disturbance Conditions) for the ModPRO2

Model	Number	Temperature (^{o}C)			Flow by Mine Year (cms)			
					18		22	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall
Upper	1	11.90	10.60	11.00	0.0060	0.0050	0.0060	0.0050
	2	11.90	10.60	11.00	0.0050	0.0040	0.0050	0.0040
	3	11.90	10.60	11.00	0.0072	0.0061	0.0071	0.0061
	4	11.90	10.60	11.00	0.0070	0.0060	0.0070	0.0060
	5	11.90	10.60	11.00	0.0102	0.0082	0.0102	0.0081
	6	11.90	10.60	11.00	0.0201	0.0151	0.0201	0.0163
	7	11.90	10.60	11.00	0.0140	0.0080	0.0140	0.0080
	8	11.90	10.60	11.00	0.0069	0.0049	0.0070	0.0055
	9	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	10	11.90	10.60	11.00	0.0050	0.0040	0.0056	0.0040
	11	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	12	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	13	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000
	14	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000
	15	13.90	11.60	12.20	0.0106	0.0143	0.0098	0.0098

Model	Number	Temperature (^{0}C)			Flow by Mine Year (cms)			
					18		22	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall
	16	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000
	17	11.90	10.60	11.00	0.0202	0.0180	0.0203	0.0182
	18	11.90	10.60	11.00	0.0041	0.0040	0.0040	0.0040
	19	11.90	10.60	11.00	0.0036	0.0030	0.0030	0.0030
	20	11.90	10.60	11.00	0.0100	0.0080	0.0100	0.0080
	21	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000
	22	13.90	11.60	12.20	0.0140	0.0130	0.0140	0.0130
	23	11.90	10.60	11.00	0.0040	0.0020	0.0041	0.0020
	24	11.90	10.60	11.00	0.0080	0.0040	0.0080	0.0040
	25	11.90	10.60	11.00	0.0035	0.0012	0.0035	0.0012
	26	11.90	10.60	11.00	0.0039	0.0020	0.0040	0.0020
	27	11.90	10.60	11.00	0.0065	0.0037	0.0066	0.0038
	28	11.90	10.60	11.00	0.0031	0.0020	0.0032	0.0020
	29	11.90	10.60	11.00	0.0022	0.0012	0.0022	0.0011
	30	11.90	10.60	11.00	0.0079	0.0040	0.0079	0.0040
	31	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	32	11.90	10.60	11.00	0.0010	0.0005	0.0010	0.0005
	33	11.90	10.60	11.00	0.0019	0.0009	0.0019	0.0009
	34	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	35	11.90	10.60	11.00	0.0090	0.0050	0.0090	0.0050
	36	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010
	37	11.90	10.60	11.00	0.0027	0.0010	0.0029	0.0013
	38	11.90	10.60	11.00	0.0037	0.0019	0.0040	0.0019
	39	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	40	11.90	10.60	11.00	0.0090	0.0050	0.0090	0.0050
	41	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	42	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
Lower	1	11.90	10.60	11.00	0.0050	0.0030	0.0050	0.0030
	2	11.90	10.60	11.00	0.0050	0.0040	0.0050	0.0040
	3	11.90	10.60	11.00	0.0020	0.0020	0.0021	0.0020
	4	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010
	5	11.90	10.60	11.00	0.0019	0.0010	0.0020	0.0010
	6	11.90	10.60	11.00	0.0067	0.0037	0.0067	0.0038
	7	11.90	10.60	11.00	0.0075	0.0048	0.0079	0.0053
	8	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010

Model	Number	Temperature (^{0}C)			Flow by Mine Year (cms)			
					18		22	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall
	9	11.90	10.60	11.00	0.0006	0.0000	0.0001	0.0003
	10	11.90	10.60	11.00	0.0082	0.0051	0.0087	0.0051
	11	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000
	12	14.80	12.00	12.70	0.0164	0.0082	0.0164	0.0082
	13	14.80	12.00	12.70	0.0034	0.0022	0.0034	0.0024

Notes:

[a]*Summer corresponds to the maximum weekly summer condition*

[b]*Fall corresponds to the maximum weekly fall condition*

[c]August corresponds to the mean August *condition*

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EOY = end of year

Table B-22. Diffuse Flow and Temperature (EOY27 through EOY112 Disturbance Conditions) for the ModPRO2

Model	Number	Temperature (^{0}C)			Flow by Mine Year (cms)							
					27		32		52		112	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall
Upper	1	11.90	10.60	11.00	0.0060	0.0050	0.0060	0.0050	0.0060	0.0050	0.0060	0.0050
	2	11.90	10.60	11.00	0.0050	0.0040	0.0050	0.0040	0.0050	0.0040	0.0050	0.0040
	3	11.90	10.60	11.00	0.0072	0.0061	0.0072	0.0061	0.0072	0.0061	0.0071	0.0061
	4	11.90	10.60	11.00	0.0070	0.0060	0.0070	0.0060	0.0070	0.0060	0.0070	0.0060
	5	11.90	10.60	11.00	0.0102	0.0082	0.0102	0.0082	0.0102	0.0082	0.0102	0.0081
	6	11.90	10.60	11.00	0.0206	0.0162	0.0200	0.0161	0.0203	0.0123	0.0209	0.0164
	7	11.90	10.60	11.00	0.0120	0.0070	0.0120	0.0070	0.0120	0.0070	0.0120	0.0070
	8	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	9	11.90	10.60	11.00	0.0050	0.0031	0.0072	0.0041	0.0055	0.0030	0.0045	0.0028
	10	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	11	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	12	11.90	10.60	11.00	0.0070	0.0040	0.0069	0.0039	0.0069	0.0039	0.0070	0.0040
	13	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	14	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	15	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	16	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	17	13.90	11.60	12.20	0.0670	0.0450	0.0670	0.0450	0.0670	0.0450	0.0670	0.0450
	18	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	19	11.90	10.60	11.00	0.0181	0.0160	0.0180	0.0159	0.0180	0.0160	0.0180	0.0160

Model	Number	Temperature (^{o}C)			Flow by Mine Year (cms)							
					27		32		52		112	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall
	20	11.90	10.60	11.00	0.0040	0.0030	0.0039	0.0030	0.0040	0.0030	0.0040	0.0030
	21	11.90	10.60	11.00	0.0030	0.0020	0.0030	0.0020	0.0030	0.0020	0.0030	0.0020
	22	11.90	10.60	11.00	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080
	23	13.90	11.60	12.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	24	13.90	11.60	12.20	0.0130	0.0120	0.0130	0.0120	0.0130	0.0120	0.0150	0.0120
	25	11.90	10.60	11.00	0.0041	0.0020	0.0040	0.0020	0.0041	0.0020	0.0041	0.0020
	26	11.90	10.60	11.00	0.0080	0.0040	0.0080	0.0040	0.0080	0.0040	0.0080	0.0040
	27	11.90	10.60	11.00	0.0035	0.0012	0.0036	0.0012	0.0035	0.0012	0.0035	0.0012
	28	11.90	10.60	11.00	0.0040	0.0020	0.0040	0.0020	0.0040	0.0020	0.0040	0.0020
	29	11.90	10.60	11.00	0.0067	0.0038	0.0066	0.0037	0.0067	0.0038	0.0068	0.0039
	30	11.90	10.60	11.00	0.0038	0.0020	0.0030	0.0020	0.0031	0.0020	0.0030	0.0019
	31	11.90	10.60	11.00	0.0022	0.0012	0.0023	0.0012	0.0022	0.0012	0.0022	0.0011
	32	11.90	10.60	11.00	0.0079	0.0040	0.0080	0.0040	0.0080	0.0040	0.0079	0.0040
	33	11.90	10.60	11.00	0.0013	0.0005	0.0012	0.0005	0.0012	0.0005	0.0014	0.0006
	34	11.90	10.60	11.00	0.0010	0.0005	0.0010	0.0005	0.0010	0.0005	0.0010	0.0005
	35	11.90	10.60	11.00	0.0019	0.0009	0.0019	0.0009	0.0019	0.0010	0.0019	0.0010
	36	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	37	11.90	10.60	11.00	0.0090	0.0050	0.0090	0.0050	0.0090	0.0050	0.0090	0.0050
	38	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010
	39	11.90	10.60	11.00	0.0029	0.0012	0.0029	0.0007	0.0030	0.0014	0.0033	0.0014
	40	11.90	10.60	11.00	0.0040	0.0020	0.0040	0.0020	0.0040	0.0020	0.0040	0.0020
	41	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	42	11.90	10.60	11.00	0.0090	0.0050	0.0090	0.0050	0.0090	0.0050	0.0090	0.0050
	43	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	44	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lower	1	11.90	10.60	11.00	0.0050	0.0030	0.0050	0.0030	0.0050	0.0030	0.0050	0.0030
	2	11.90	10.60	11.00	0.0050	0.0040	0.0050	0.0040	0.0050	0.0040	0.0050	0.0040
	3	11.90	10.60	11.00	0.0021	0.0020	0.0020	0.0020	0.0020	0.0020	0.0019	0.0020
	4	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010
	5	11.90	10.60	11.00	0.0020	0.0010	0.0019	0.0010	0.0020	0.0010	0.0020	0.0010
	6	11.90	10.60	11.00	0.0068	0.0038	0.0067	0.0038	0.0069	0.0039	0.0069	0.0025
	7	11.90	10.60	11.00	0.0080	0.0051	0.0079	0.0052	0.0085	0.0057	0.0086	0.0057
	8	11.90	10.60	11.00	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010	0.0020	0.0010
	9	11.90	10.60	11.00	0.0009	0.0002	0.0010	0.0000	0.0020	0.0010	0.0026	0.0015
	10	11.90	10.60	11.00	0.0087	0.0054	0.0088	0.0055	0.0085	0.0054	0.0088	0.0055

Model	Number	Temperature (°C)			Flow by Mine Year (cms)							
					27		32		52		112	
		Summer[a]	Fall[b]	August[c]	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall	Summer/ August	Fall
	11	11.90	10.60	11.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	12	14.80	12.00	12.70	0.0164	0.0082	0.0164	0.0082	0.0164	0.0082	0.0164	0.0082
	13	14.80	12.00	12.70	0.0035	0.0023	0.0034	0.0022	0.0034	0.0022	0.0033	0.0022

Notes:
[a]Summer corresponds to the maximum weekly summer condition
[b]Fall corresponds to the maximum weekly fall condition
[c]August corresponds to the mean August condition
Abbreviations:
ºC = degree Celsius
cms = cubic meter per second
EOY = end of year

Table B-23. Point Sources Flow and Temperature for the ModPRO2 (EOY18)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0007	0.0000	0.0000	12.70	N/A	N/A
Treated Water Discharge – Meadow Creek	0.0000	0.0000	0.0000	N/A	N/A	N/A

Notes:
[a]Summer corresponds to the maximum weekly summer condition
[b]Fall corresponds to the maximum weekly fall condition
[c]August corresponds to the mean August condition
Abbreviations:
ºC = degree Celsius
cms = cubic meter per second
EFSFSR = East Fork of the South fork of the Salmon River
EOY = end of year
N/A = not applicable for 0 flows or negative flows

Table B-24. Point Sources Flow and Temperature for the ModPRO2 (EOY22)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0163	0.0042	0.0122	19.50	12.00	17.70

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Treated Water Discharge – Meadow Creek	0.0000	0.0000	0.0000	N/A	N/A	N/A

Notes:

[a]Summer corresponds to the maximum weekly summer condition

[b]Fall corresponds to the maximum weekly fall condition

[c]August corresponds to the mean August condition

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B-25. Point Sources Flow and Temperature for the ModPRO2 (EOY27)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	N/A	N/A	N/A
Treated Water Discharge – Meadow Creek	0.0057	0.0055	0.0056	12.70	10.90	12.50

Notes:

[a]Summer corresponds to the maximum weekly summer condition

[b]Fall corresponds to the maximum weekly fall condition

[c]August corresponds to the mean August condition

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B-26. Point Sources Flow and Temperature for the ModPRO2 (EOY32)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	N/A	N/A	N/A
Treated Water Discharge – Meadow Creek	0.0029	0.0028	0.0030	12.70	10.90	12.50

Notes:

[a]Summer corresponds to the maximum weekly summer condition

[b]Fall corresponds to the maximum weekly fall condition

[c]August corresponds to the mean August *condition*

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

Km = kilometer

N/A = not applicable for 0 flows or negative flows

Table B-27. Point Sources Flow and Temperature for the ModPRO2 (EOY52)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	N/A	N/A	N/A
Treated Water Discharge – Meadow Creek	0.0000	0.0000	0.0000	N/A	N/A	N/A

Notes:

[a]*Summer corresponds to the maximum weekly summer condition*

[b]*Fall corresponds to the maximum weekly fall condition*

[c]August corresponds to the mean August *condition*

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B-28. Point Sources Flow and Temperature for the ModPRO2 (EOY112)

Source	Flow (cms)			Temperature (°C)		
	Summer[a]	Fall[b]	August[c]	Summer[a]	Fall[b]	August[c]
Rabbit Creek	0.0150	0.0120	0.0150	8.30	7.90	7.73
Fiddle Creek Trib 3	0.0020	0.0010	0.0020	8.30	7.90	7.73
Stibnite Lodge	0.0009	0.0009	0.0009	25.00	25.00	25.00
Treated Water Discharge - EFSFSR	0.0000	0.0000	0.0000	N/A	N/A	N/A
Treated Water Discharge – Meadow Creek	0.0000	0.0000	0.0000	N/A	N/A	N/A

Notes:

[a]*Summer corresponds to the maximum weekly summer condition*

[b]*Fall corresponds to the maximum weekly fall condition*

[c]August corresponds to the mean August *condition*

Abbreviations:

ºC = degree Celsius

cms = cubic meter per second

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

N/A = not applicable for 0 flows or negative flows

Table B- 29. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY18 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	90.7	78.7	6.6	2.9	2.5	2.4	2.5	2.7	2.7	2.4	2.1	1.4	1.9	14.6	83.1	89.9	100	100	100
	16	100	100	100	100	100	94.4	76.1	55.6	48.3	37.6	25.6	16.0	11.0	11.2	15.8	25.2	37.9	50.3	56.7	94.2	94.3	100	100	100
	17	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	18	100	100	100	100	100	95.3	94.7	77.6	55.9	47.3	37.6	28.2	22.6	24.3	31.4	42.3	49.0	52.2	79.5	94.5	95.3	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	95.8	93.2	78.2	71.6	66.3	54.7	33.0	19.2	21.0	39.2	57.9	66.0	68.3	71.0	83.7	95.8	100	100	100
	21	100	100	100	100	100	94.6	77.2	53.9	48.6	40.8	29.2	17.5	11.1	9.9	12.9	22.0	36.2	48.7	63.1	94.3	94.3	100	100	100
	22	100	100	100	100	100	96.9	96.3	80.0	70.3	63.6	47.8	27.7	12.8	10.6	19.2	39.1	62.3	73.2	84.4	96.2	97.1	100	100	100
	23	100	100	100	100	100	95.7	95.4	82.7	69.0	48.4	24.6	12.4	8.0	6.7	16.8	36.0	53.5	62.7	91.3	95.1	95.5	100	100	100
	24	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	25	100	100	100	100	100	95.1	95.0	79.9	66.3	61.7	47.0	35.6	40.6	53.9	62.0	66.2	66.1	68.6	81.3	95.9	96.6	100	100	100
	26	100	100	100	100	100	95.9	95.7	85.6	74.5	54.5	33.1	15.7	9.3	10.4	18.0	37.5	62.1	76.5	93.2	95.9	96.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	27	100	100	100	100	100	95.5	95.3	93.6	74.3	51.0	26.1	10.6	6.9	7.3	13.6	28.9	47.2	63.1	82.8	95.1	95.4	100	100	100
	28	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	29	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	30	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	33	100	100	100	100	100	95.9	95.7	85.9	60.1	33.4	16.2	7.8	6.6	9.6	20.8	37.6	53.3	62.4	81.1	95.0	95.3	100	100	100
	34	100	100	100	100	100	93.0	92.6	47.6	27.5	14.0	6.8	5.6	4.7	3.9	4.8	10.2	19.1	35.8	89.0	92.6	93.1	100	100	100
	35	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	36	100	100	100	100	100	94.7	94.7	92.6	48.8	37.9	34.8	32.3	29.4	23.3	14.1	11.8	21.6	42.4	52.4	71.2	94.0	100	100	100
	37	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	38	100	100	100	100	100	93.7	93.6	65.0	32.1	23.7	16.3	14.8	16.1	17.6	20.4	23.0	25.0	31.6	74.1	93.7	93.6	100	100	100
	39	100	100	100	100	100	92.8	92.2	61.0	29.8	13.6	6.3	4.2	4.3	4.6	4.5	6.0	13.1	50.2	92.2	92.4	93.2	100	100	100
	40	100	100	100	100	100	98.2	91.2	83.5	78.8	76.2	74.0	71.4	68.1	62.9	54.5	59.4	68.4	85.6	96.0	98.2	98.3	100	100	100
	41	100	100	100	100	100	94.0	92.3	60.0	41.9	39.5	34.0	27.0	20.9	16.3	15.5	21.8	47.2	78.3	93.7	94.0	94.0	100	100	100
	42	100	100	100	100	100	93.0	92.5	89.1	29.2	14.4	6.0	3.7	4.1	4.4	4.4	5.2	10.0	25.7	76.3	92.6	93.5	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	92.3	92.2	92.1	87.9	47.2	21.5	9.2	14.3	19.6	21.3	21.9	23.2	25.3	40.1	71.1	92.5	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	94.0	93.2	71.3	40.9	21.4	6.7	4.4	5.3	4.5	4.1	11.0	26.2	39.7	62.8	93.1	94.0	100	100	100

Brown AND Caldwell

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	12	100	100	100	100	100	95.7	90.7	78.5	67.6	45.4	26.7	18.1	16.8	19.8	28.0	39.1	48.0	59.6	80.4	95.2	95.4	100	100	100
	13	100	100	100	100	100	95.1	93.5	86.4	48.5	21.6	13.3	12.1	15.5	22.3	30.0	38.7	51.1	68.0	82.2	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-30. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY18 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	100		91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	100	88.1	77.0	14.8	5.8	4.4	3.6	3.2	3.1	2.9	2.5	2.2	46.5	87.1	100	100	100	100	100
	16	100	100	100	100	100	100	92.5	76.1	52.4	48.2	45.9	41.1	38.1	37.9	40.4	44.8	51.0	74.3	92.6	100	100	100	100	100
	17	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	18	100	100	100	100	100	100	94.0	92.9	79.5	55.3	51.3	45.8	41.0	40.5	46.4	53.1	64.6	90.6	93.0	100	100	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	100	94.5	92.6	78.3	69.7	61.7	45.2	29.5	38.2	57.9	65.2	69.2	74.3	94.3	100	100	100	100	100
	21	100	100	100	100	100	100	93.1	79.4	56.5	53.9	50.7	42.8	36.2	33.3	36.0	42.4	49.2	81.9	92.4	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	22	100	100	100	100	100	100	96.5	95.6	80.9	69.6	63.0	49.8	33.9	25.1	35.4	53.3	69.2	94.6	95.3	100	100	100	100	100
	23	100	100	100	100	100	100	94.3	93.9	77.9	55.7	33.0	18.1	13.9	24.9	46.7	60.4	78.5	93.4	94.2	100	100	100	100	100
	24	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	25	100	100	100	100	100	100	93.6	93.2	80.5	64.5	50.0	54.5	62.8	66.7	67.0	69.0	71.6	94.8	95.5	100	100	100	100	100
	26	100	100	100	100	100	100	94.6	94.4	84.2	66.4	48.4	29.1	23.3	26.1	42.2	62.0	81.7	94.4	94.9	100	100	100	100	100
	27	100	100	100	100	100	100	94.1	93.8	93.1	71.0	41.0	21.0	14.6	19.1	31.5	50.1	69.4	93.2	93.8	100	100	100	100	100
	28	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	29	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	30	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	33	100	100	100	100	100	100	94.5	94.1	80.2	43.8	23.7	18.9	25.9	39.5	55.9	67.9	76.9	93.5	93.7	100	100	100	100	100
	34	100	100	100	100	100	100	90.8	90.3	46.3	28.6	18.0	15.0	15.9	19.5	27.5	38.5	69.9	90.1	90.7	100	100	100	100	100
	35	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	36	100	100	100	100	100	100	94.3	94.3	94.0	71.3	57.9	51.7	48.4	45.9	42.1	36.7	35.8	53.4	92.4	100	100	100	100	100
	37	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	38	100	100	100	100	100	100	91.7	91.9	67.8	48.0	42.5	40.0	41.3	43.7	45.7	44.6	60.4	90.5	91.6	100	100	100	100	100
	39	100	100	100	100	100	100	90.9	89.9	64.5	34.5	21.5	13.6	10.2	9.7	12.9	28.0	85.2	89.8	90.5	100	100	100	100	100
	40	100	100	100	100	100	100	97.7	94.6	89.7	84.4	79.9	77.5	74.6	71.5	64.2	73.0	90.1	95.7	97.6	100	100	100	100	100
	41	100	100	100	100	100	100	92.1	91.4	63.8	47.6	48.4	44.3	40.2	37.7	37.9	69.2	90.6	91.9	92.1	100	100	100	100	100
	42	100	100	100	100	100	100	90.7	90.3	88.9	41.4	22.8	15.3	10.4	9.5	11.4	16.5	44.3	90.2	90.5	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	90.1	89.7	89.7	90.7	32.3	15.5	21.7	23.6	27.7	26.0	32.8	57.5	90.2	100	100	100	100	100
	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	92.1	90.8	72.1	31.4	13.2	6.0	5.7	8.9	18.6	35.1	47.9	90.9	92.0	100	100	100	100	100
	12	100	100	100	100	100	100	94.3	89.9	78.2	67.5	41.3	30.2	30.8	38.2	49.1	58.8	76.3	93.4	94.0	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.1	83.1	48.1	26.0	27.1	32.5	42.3	56.6	73.1	84.3	91.5	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-31. Hourly Effective Shade (%) for Mean August Conditions for EOY18 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	95.4	83.4	41.8	8.9	4.2	3.4	3.1	3.0	2.9	2.7	2.3	1.8	24.2	50.9	91.6	95.0	100	100	100
	16	100	100	100	100	100	97.2	84.3	65.9	50.4	42.9	35.8	28.6	24.6	24.6	28.1	35.0	44.5	62.3	74.7	97.1	97.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	17	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	18	100	100	100	100	100	97.7	94.4	85.3	67.7	51.3	44.5	37.0	31.8	32.4	38.9	47.7	56.8	71.4	86.3	97.3	97.7	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	97.9	93.9	85.4	75.0	68.0	58.2	39.1	24.4	29.6	48.6	61.6	67.6	71.3	82.7	91.9	97.9	100	100	100
	21	100	100	100	100	100	97.3	85.2	66.7	52.6	47.4	40.0	30.2	23.7	21.6	24.5	32.2	42.7	65.3	77.8	97.2	97.2	100	100	100
	22	100	100	100	100	100	98.5	96.4	87.8	75.6	66.6	55.4	38.8	23.4	17.9	27.3	46.2	65.8	83.9	89.9	98.1	98.6	100	100	100
	23	100	100	100	100	100	97.9	94.9	88.3	73.5	52.1	28.8	15.3	11.0	15.8	31.8	48.2	66.0	78.1	92.8	97.6	97.8	100	100	100
	24	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	25	100	100	100	100	100	97.6	94.3	86.6	73.4	63.1	48.5	45.1	51.7	60.3	64.5	67.6	68.9	81.7	88.4	98.0	98.3	100	100	100
	26	100	100	100	100	100	98.0	95.2	90.0	79.4	60.5	40.8	22.4	16.3	18.3	30.1	49.8	71.9	85.5	94.1	98.0	98.1	100	100	100
	27	100	100	100	100	100	97.8	94.7	93.7	83.7	61.0	33.6	15.8	10.8	13.2	22.6	39.5	58.3	78.2	88.3	97.6	97.7	100	100	100
	28	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	29	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	30	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	33	100	100	100	100	100	98.0	95.1	90.0	70.2	38.6	20.0	13.4	16.3	24.6	38.4	52.8	65.1	78.0	87.4	97.5	97.7	100	100	100
	34	100	100	100	100	100	96.5	91.7	69.0	36.9	21.3	12.4	10.3	10.3	11.7	16.2	24.4	44.5	63.0	89.9	96.3	96.6	100	100	100
	35	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	36	100	100	100	100	100	97.4	94.5	93.5	71.4	54.6	46.4	42.0	38.9	34.6	28.1	24.3	28.7	47.9	72.4	85.6	97.0	100	100	100
	37	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	38	100	100	100	100	100	96.9	92.7	78.5	50.0	35.9	29.4	27.4	28.7	30.7	33.1	33.8	42.7	61.1	82.9	96.9	96.8	100	100	100
	39	100	100	100	100	100	96.4	91.6	75.5	47.2	24.1	13.9	8.9	7.3	7.2	8.7	17.0	49.2	70.0	91.4	96.2	96.6	100	100	100
	40	100	100	100	100	100	99.1	94.5	89.1	84.3	80.3	77.0	74.5	71.4	67.2	59.4	66.2	79.3	90.7	96.8	99.1	99.2	100	100	100
	41	100	100	100	100	100	97.0	92.2	75.7	52.9	43.6	41.2	35.7	30.6	27.0	26.7	45.5	68.9	85.1	92.9	97.0	97.0	100	100	100
	42	100	100	100	100	100	96.5	91.6	89.7	59.1	27.9	14.4	9.5	7.3	7.0	7.9	10.9	27.2	58.0	83.4	96.3	96.8	100	100	100
Lower	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	96.2	91.2	90.9	88.8	69.0	26.9	12.4	18.0	21.6	24.5	24.0	28.0	41.4	65.2	85.6	96.3	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	97.0	92.7	81.1	56.5	26.4	10.0	5.2	5.5	6.7	11.4	23.1	37.1	65.3	77.4	96.6	97.0	100	100	100
	12	100	100	100	100	100	97.9	92.5	84.2	72.9	56.5	34.0	24.2	23.8	29.0	38.6	49.0	62.2	76.5	87.2	97.6	97.7	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.8	65.8	34.9	19.7	19.6	24.0	32.3	43.3	55.9	67.7	79.8	88.0	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-32. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY22 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	90.7	78.7	6.6	2.9	2.5	2.4	2.5	2.7	2.7	2.4	2.1	1.4	1.9	14.6	83.1	89.9	100	100	100
	16	100	100	100	100	100	94.6	76.9	57.1	50.1	40.3	28.4	18.7	13.0	13.4	18.2	28.3	40.9	52.3	58.2	94.5	94.5	100	100	100
	17	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	18	100	100	100	100	100	95.5	94.8	79.5	60.5	52.1	42.9	33.7	27.7	29.3	36.9	47.7	53.5	56.6	82.1	94.6	95.4	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	96.0	93.8	81.5	76.0	71.7	61.5	40.0	24.0	26.2	46.3	64.3	71.2	73.2	75.6	86.1	95.9	100	100	100
	21	100	100	100	100	100	94.8	78.0	55.7	50.7	43.6	32.7	20.6	13.2	11.5	14.9	24.8	39.0	50.7	64.3	94.5	94.5	100	100	100
	22	100	100	100	100	100	97.0	96.5	80.5	71.2	65.7	51.0	31.1	14.6	11.1	20.4	41.4	63.7	74.0	84.8	96.3	97.3	100	100	100
	23	100	100	100	100	100	95.9	95.5	83.2	70.3	51.0	26.5	12.9	8.0	7.3	18.8	39.0	55.4	63.5	91.5	95.3	95.7	100	100	100
	24	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	25	100	100	100	100	100	95.8	95.7	87.5	79.0	75.2	60.7	47.6	52.3	62.7	68.2	71.8	75.3	80.4	87.4	96.7	97.4	100	100	100
	26	100	100	100	100	100	96.1	95.9	86.1	76.1	57.4	35.3	16.8	9.5	10.8	19.7	40.5	64.6	77.1	93.4	96.1	96.4	100	100	100
	27	100	100	100	100	100	95.8	95.6	93.8	75.8	54.0	28.7	11.5	7.1	7.7	15.0	31.7	50.8	65.4	84.3	95.3	95.7	100	100	100
	28	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	29	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	30	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	33	100	100	100	100	100	96.1	95.9	86.4	62.1	36.0	17.1	8.1	7.1	10.9	23.7	41.3	56.0	63.7	81.7	95.1	95.5	100	100	100
	34	100	100	100	100	100	94.0	93.6	56.3	38.8	21.1	9.8	7.4	6.5	6.1	10.1	19.7	31.8	46.3	90.6	93.6	94.1	100	100	100
	35	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	36	100	100	100	100	100	95.6	95.6	94.3	69.5	62.8	60.1	58.9	56.7	49.7	35.8	28.8	43.0	65.2	71.9	82.4	95.1	100	100	100
	37	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	38	100	100	100	100	100	94.9	94.8	75.4	47.0	38.8	35.9	36.5	39.2	41.9	43.8	45.4	47.3	49.6	80.9	94.8	94.8	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	39	100	100	100	100	100	93.8	93.3	67.8	44.2	26.1	12.8	6.7	4.9	5.1	6.4	11.9	25.1	60.2	93.2	93.5	94.2	100	100	100
	40	100	100	100	100	100	98.3	91.8	85.6	81.1	78.7	76.8	74.4	71.2	65.3	55.9	61.6	71.5	86.4	96.1	98.3	98.4	100	100	100
	41	100	100	100	100	100	95.1	94.2	75.0	64.5	63.4	60.1	53.5	46.3	39.4	36.1	42.4	63.9	84.7	94.9	95.1	95.1	100	100	100
	42	100	100	100	100	100	94.0	93.6	90.4	41.7	27.5	13.2	6.7	4.7	5.1	5.4	8.3	19.4	38.8	79.7	93.6	94.5	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	92.3	92.2	92.1	87.9	47.2	21.5	9.2	14.3	19.6	21.3	21.9	23.2	25.3	40.1	71.1	92.5	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	94.8	94.1	76.6	55.7	37.3	13.4	5.0	6.0	5.0	8.4	22.9	42.1	49.5	68.0	93.9	94.7	100	100	100
	12	100	100	100	100	100	95.8	90.9	79.2	69.0	48.0	28.2	18.6	17.0	20.1	28.8	40.1	48.9	60.0	80.8	95.3	95.5	100	100	100
	13	100	100	100	100	100	95.1	93.5	86.4	48.6	21.6	13.3	12.0	15.5	22.3	30.0	38.7	51.2	68.1	82.2	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-33. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY22 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	100		91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	100	88.1	77.0	14.8	5.8	4.4	3.6	3.2	3.1	2.9	2.5	2.2	46.5	87.1	100	100	100	100	100
	16	100	100	100	100	100	100	92.8	76.9	53.9	50.3	48.3	44.2	41.3	40.7	43.1	46.6	52.4	75.3	92.9	100	100	100	100	100
	17	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	18	100	100	100	100	100	100	94.2	93.1	80.9	59.6	55.8	50.7	45.9	45.1	51.0	57.5	68.4	91.2	93.2	100	100	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	100	94.7	93.2	81.4	73.9	67.4	51.5	35.4	44.2	63.9	70.3	73.8	78.0	94.5	100	100	100	100	100
	21	100	100	100	100	100	100	93.3	80.2	58.0	55.5	52.9	45.9	39.2	36.3	38.8	44.7	51.0	82.6	92.7	100	100	100	100	100
	22	100	100	100	100	100	100	96.7	95.8	81.4	70.5	64.3	52.5	36.6	27.1	37.5	54.9	70.0	94.9	95.5	100	100	100	100	100
	23	100	100	100	100	100	100	94.5	94.1	78.6	57.3	35.0	19.5	15.4	27.3	49.1	61.3	78.9	93.6	94.4	100	100	100	100	100
	24	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	25	100	100	100	100	100	100	94.6	94.2	87.5	76.3	63.3	69.2	77.2	80.7	78.5	76.3	79.7	95.8	96.5	100	100	100	100	100
	26	100	100	100	100	100	100	94.8	94.6	85.1	67.8	50.4	30.9	24.7	27.8	44.9	63.6	82.4	94.7	95.1	100	100	100	100	100
	27	100	100	100	100	100	100	94.5	94.2	93.2	72.3	43.5	22.9	16.4	21.6	34.6	52.8	71.9	93.6	94.1	100	100	100	100	100
	28	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	29	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	30	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	33	100	100	100	100	100	100	94.7	94.4	81.1	46.2	25.4	20.7	28.2	42.8	58.8	69.4	77.6	93.7	93.9	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	34	100	100	100	100	100	100	92.1	91.5	55.0	38.7	25.4	22.6	25.8	33.1	43.6	52.4	75.2	91.5	92.0	100	100	100	100	100
	35	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	36	100	100	100	100	100	100	95.4	95.4	95.2	83.4	76.2	72.5	71.0	69.6	65.8	59.7	57.5	70.2	93.9	100	100	100	100	100
	37	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	38	100	100	100	100	100	100	93.2	93.3	77.2	64.6	59.7	59.2	61.0	63.3	63.7	61.5	71.9	92.5	93.1	100	100	100	100	100
	39	100	100	100	100	100	100	92.2	91.3	72.0	47.7	34.8	24.0	18.7	18.1	22.5	38.8	87.2	91.2	91.8	100	100	100	100	100
	40	100	100	100	100	100	100	97.8	95.2	91.4	86.5	82.2	79.9	77.4	74.5	66.7	74.2	90.3	95.8	97.7	100	100	100	100	100
	41	100	100	100	100	100	100	93.6	93.2	77.6	68.8	69.4	65.9	63.0	61.7	59.7	78.9	92.3	93.4	93.6	100	100	100	100	100
	42	100	100	100	100	100	100	92.1	91.5	90.5	56.6	39.5	28.1	20.0	16.8	20.5	27.5	54.6	91.5	91.9	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	90.1	89.7	89.7	90.7	32.3	15.5	21.7	23.6	27.7	26.0	32.8	57.5	90.2	100	100	100	100	100
	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	93.2	92.0	78.2	44.5	24.2	7.1	8.3	15.2	32.3	47.3	55.3	92.1	93.0	100	100	100	100	100
	12	100	100	100	100	100	100	94.5	90.2	79.0	68.8	42.7	31.2	31.7	39.3	50.0	59.3	76.6	93.5	94.1	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.1	83.1	48.1	26.0	27.2	32.6	42.4	56.6	73.1	84.4	91.5	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-34. Hourly Effective Shade (%) for Mean August Conditions for EOY22 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100
	9	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	10	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	11	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	12	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	13	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	14	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	15	100	100	100	100	100	95.4	83.4	41.8	8.9	4.2	3.4	3.1	3.0	2.9	2.7	2.3	1.8	24.2	50.9	91.6	95.0	100	100	100
	16	100	100	100	100	100	97.3	84.9	67.0	52.0	45.3	38.4	31.5	27.2	27.1	30.7	37.5	46.7	63.8	75.6	97.3	97.3	100	100	100
	17	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	18	100	100	100	100	100	97.8	94.5	86.3	70.7	55.9	49.4	42.2	36.8	37.2	44.0	52.6	61.0	73.9	87.7	97.3	97.7	100	100	100
	19	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	20	100	100	100	100	100	98.0	94.3	87.4	78.7	72.8	64.5	45.8	29.7	35.2	55.1	67.3	72.5	75.6	85.1	93.1	98.0	100	100	100
	21	100	100	100	100	100	97.4	85.7	68.0	54.4	49.6	42.8	33.3	26.2	23.9	26.9	34.8	45.0	66.7	78.5	97.3	97.3	100	100	100
	22	100	100	100	100	100	98.5	96.6	88.2	76.3	68.1	57.7	41.8	25.6	19.1	29.0	48.2	66.9	84.5	90.2	98.2	98.7	100	100	100
	23	100	100	100	100	100	98.0	95.0	88.7	74.5	54.2	30.8	16.2	11.7	17.3	34.0	50.2	67.2	78.6	93.0	97.7	97.9	100	100	100
	24	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	25	100	100	100	100	100	97.9	95.2	90.9	83.3	75.8	62.0	58.4	64.8	71.7	73.4	74.1	77.5	88.1	92.0	98.4	98.7	100	100	100
	26	100	100	100	100	100	98.1	95.4	90.4	80.6	62.6	42.9	23.9	17.1	19.3	32.3	52.1	73.5	85.9	94.3	98.1	98.2	100	100	100
	27	100	100	100	100	100	97.9	95.1	94.0	84.5	63.2	36.1	17.2	11.8	14.7	24.8	42.3	61.4	79.5	89.2	97.7	97.9	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	28	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	29	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	30	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	31	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	32	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	33	100	100	100	100	100	98.1	95.3	90.4	71.6	41.1	21.3	14.4	17.7	26.9	41.3	55.4	66.8	78.7	87.8	97.6	97.8	100	100	100
	34	100	100	100	100	100	97.0	92.9	73.9	46.9	29.9	17.6	15.0	16.2	19.6	26.9	36.1	53.5	68.9	91.3	96.8	97.1	100	100	100
	35	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	36	100	100	100	100	100	97.8	95.5	94.9	82.4	73.1	68.2	65.7	63.9	59.7	50.8	44.3	50.3	67.7	82.9	91.2	97.6	100	100	100
	37	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	38	100	100	100	100	100	97.5	94.0	84.4	62.1	51.7	47.8	47.9	50.1	52.6	53.8	53.5	59.6	71.1	87.0	97.4	97.4	100	100	100
	39	100	100	100	100	100	96.9	92.8	79.6	58.1	36.9	23.8	15.4	11.8	11.6	14.5	25.4	56.2	75.7	92.5	96.8	97.1	100	100	100
	40	100	100	100	100	100	99.2	94.8	90.4	86.3	82.6	79.5	77.2	74.3	69.9	61.3	67.9	80.9	91.1	96.9	99.2	99.2	100	100	100
	41	100	100	100	100	100	97.6	93.9	84.1	71.1	66.1	64.8	59.7	54.7	50.6	47.9	60.7	78.1	89.1	94.3	97.6	97.6	100	100	100
	42	100	100	100	100	100	97.0	92.9	91.0	66.1	42.1	26.4	17.4	12.4	11.0	13.0	17.9	37.0	65.2	85.8	96.8	97.3	100	100	100
	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
Lower	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	96.2	91.2	90.9	88.8	69.0	26.9	12.4	18.0	21.6	24.5	24.0	28.0	41.4	65.2	85.6	96.3	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	97.4	93.7	84.3	67.0	40.9	18.8	6.1	7.2	10.1	20.4	35.1	48.7	70.8	80.5	97.0	97.4	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	12	100	100	100	100	100	97.9	92.7	84.7	74.0	58.4	35.5	24.9	24.4	29.7	39.4	49.7	62.8	76.8	87.5	97.7	97.8	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.8	65.9	34.9	19.7	19.6	24.1	32.4	43.3	55.9	67.8	79.8	88.0	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-35. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY27 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	92.0	92.1	87.2	29.2	13.2	6.5	4.7	4.8	4.6	4.6	7.1	14.8	27.6	74.4	92.1	92.1	100	100	100
	9	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	10	100	100	100	100	100	93.6	83.2	55.3	49.5	47.9	47.8	44.5	40.9	38.6	37.4	40.6	45.5	50.9	76.8	93.8	93.7	100	100	100
Upper	11	100	100	100	100	100	92.0	74.1	34.9	19.8	9.1	4.5	3.6	4.3	4.2	4.1	5.9	12.1	23.7	70.0	92.0	92.1	100	100	100
	12	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	13	100	100	100	100	100	94.5	60.6	54.1	49.5	45.3	40.8	39.7	39.7	41.2	45.0	47.5	48.2	49.7	58.2	89.7	94.2	100	100	100
	14	100	100	100	100	100	92.0	86.5	62.7	34.1	18.3	7.7	5.9	5.4	4.5	4.0	5.9	12.0	24.4	34.2	69.4	92.0	100	100	100
	15	100	100	100	100	100	91.7	49.0	37.3	23.9	13.1	7.0	5.3	5.0	4.5	3.5	5.2	12.1	27.1	37.5	55.3	91.8	100	100	100
	16	100	100	100	100	100	93.0	60.2	35.1	29.1	22.5	17.9	14.1	11.6	8.1	7.7	12.6	19.0	43.4	77.6	87.3	92.9	100	100	100
	17	100	100	100	100	100	94.0	75.6	50.4	44.4	36.8	23.8	12.5	7.6	7.6	10.5	19.7	35.2	45.8	63.0	93.4	94.0	100	100	100
	18	100	100	100	100	100	94.9	78.0	58.7	52.4	43.4	32.0	22.2	15.9	16.1	21.2	32.0	44.3	54.8	60.1	94.7	94.8	100	100	100
	19	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	20	100	100	100	100	100	95.6	95.0	82.0	66.4	58.1	49.4	40.7	34.3	35.7	43.8	54.3	59.2	62.2	85.4	94.8	95.6	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	22	100	100	100	100	100	96.2	94.6	85.7	81.7	78.4	69.8	48.8	30.7	33.3	55.1	72.2	77.8	79.4	81.5	89.1	96.1	100	100	100
	23	100	100	100	100	100	95.1	78.9	57.8	53.0	46.8	36.8	24.7	16.1	13.9	17.6	28.1	42.1	53.1	65.8	94.7	94.8	100	100	100
	24	100	100	100	100	100	97.2	96.6	82.0	73.4	69.0	55.8	36.4	17.7	12.9	23.1	45.0	66.3	76.0	85.9	96.5	97.5	100	100	100
	25	100	100	100	100	100	96.1	95.7	83.7	71.5	54.1	29.0	13.7	8.2	8.2	21.4	42.6	57.6	64.5	91.7	95.5	95.9	100	100	100
	26	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	27	100	100	100	100	100	96.2	96.1	91.8	86.9	85.0	74.9	61.4	67.5	77.4	78.1	78.4	83.6	87.8	92.1	97.1	97.7	100	100	100
	28	100	100	100	100	100	96.3	96.1	86.6	77.6	60.7	38.1	18.0	10.1	11.5	21.8	44.1	67.3	77.7	93.7	96.3	96.6	100	100	100
	29	100	100	100	100	100	96.0	95.8	94.1	77.8	57.8	31.9	12.9	7.4	8.5	16.9	34.8	53.7	67.3	85.1	95.6	95.9	100	100	100
	30	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	31	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	32	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	33	100	100	100	100	100	92.4	92.4	42.1	29.8	23.6	15.7	8.7	5.2	5.3	6.3	10.1	18.6	38.7	88.9	92.4	92.5	100	100	100
	34	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	35	100	100	100	100	100	96.3	96.2	87.0	64.2	39.4	18.5	8.8	7.7	12.8	27.6	45.7	59.0	65.2	82.4	95.3	95.8	100	100	100
	36	100	100	100	100	100	94.3	93.9	58.3	42.0	24.2	11.4	8.3	7.5	7.4	13.0	23.7	35.8	48.9	91.0	93.9	94.4	100	100	100
	37	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	38	100	100	100	100	100	95.9	95.8	94.9	77.6	72.7	70.4	69.5	67.6	61.2	46.6	37.9	53.2	74.4	79.8	86.9	95.4	100	100	100
	39	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	40	100	100	100	100	100	95.3	95.2	82.9	59.8	52.3	52.5	53.4	56.2	59.4	60.6	61.8	63.9	63.9	86.0	95.2	95.3	100	100	100
	41	100	100	100	100	100	94.1	93.6	69.2	47.7	30.7	16.0	8.4	5.7	5.5	7.6	14.8	29.3	62.8	93.5	93.8	94.5	100	100	100
	42	100	100	100	100	100	98.3	92.1	86.4	82.0	79.7	77.9	75.5	72.5	66.5	56.9	62.7	72.6	86.7	96.1	98.4	98.4	100	100	100
	43	100	100	100	100	100	95.3	94.7	81.4	73.8	72.9	70.5	64.5	57.3	50.4	46.3	51.8	71.3	87.1	95.1	95.3	95.4	100	100	100
	44	100	100	100	100	100	94.3	93.9	90.7	44.8	31.9	16.9	8.6	5.4	5.8	6.2	10.0	22.8	41.8	80.5	93.9	94.8	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	92.3	92.2	92.1	87.9	47.2	21.5	9.2	14.3	19.6	21.3	21.9	23.2	25.3	40.1	71.1	92.5	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	95.1	94.3	77.6	58.4	42.3	16.6	5.6	6.3	5.0	10.7	27.6	46.0	51.0	68.9	94.1	95.0	100	100	100
	12	100	100	100	100	100	96.0	91.2	79.9	70.4	51.1	30.3	19.4	17.4	20.6	29.9	41.4	50.0	60.6	81.2	95.4	95.6	100	100	100
	13	100	100	100	100	100	95.1	93.5	86.4	48.6	21.6	13.3	12.0	15.5	22.4	30.0	38.8	51.2	68.2	82.3	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-36. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY27 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	89.5	89.6	87.5	34.6	16.6	11.2	10.2	11.0	14.4	23.1	48.0	88.4	89.5	100	100	100	100	100
	9	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	10	100	100	100	100	100	100	91.6	83.0	55.8	51.6	50.6	49.5	48.3	48.5	47.6	46.6	60.7	91.8	91.8	100	100	100	100	100
	11	100	100	100	100	100	100	89.6	74.0	36.7	24.4	15.0	10.0	8.9	9.6	13.2	20.8	42.1	86.6	89.6	100	100	100	100	100
	12	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	13	100	100	100	100	100	100	92.7	58.8	51.0	48.9	49.1	49.8	48.6	49.5	51.0	51.6	53.3	73.7	91.8	100	100	100	100	100
	14	100	100	100	100	100	100	89.5	84.6	61.9	37.5	17.7	10.3	8.3	8.7	12.5	20.4	29.7	45.2	89.4	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	15	100	100	100	100	100	100	89.4	48.4	34.0	23.7	12.4	7.9	6.9	7.9	11.7	23.7	37.5	42.9	89.3	100	100	100	100	100
	16	100	100	100	100	100	100	91.0	69.9	50.2	43.3	33.1	26.6	22.3	17.7	16.0	29.1	58.8	77.5	90.6	100	100	100	100	100
	17	100	100	100	100	100	100	92.1	76.1	54.8	52.9	48.1	36.3	27.7	25.7	33.0	43.5	55.2	81.6	92.2	100	100	100	100	100
	18	100	100	100	100	100	100	93.2	77.8	55.8	52.6	51.0	47.6	44.8	43.7	46.1	48.9	54.2	76.5	93.2	100	100	100	100	100
	19	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	20	100	100	100	100	100	100	94.4	93.3	82.7	65.0	61.6	56.8	52.1	51.0	56.8	63.0	73.2	92.0	93.5	100	100	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	100	95.0	93.9	85.4	79.4	74.4	59.5	43.0	51.7	71.3	76.6	79.8	82.8	94.8	100	100	100	100	100
	23	100	100	100	100	100	100	93.6	81.1	59.9	57.5	55.4	49.3	42.7	39.7	42.0	47.3	53.3	83.3	93.0	100	100	100	100	100
	24	100	100	100	100	100	100	97.0	96.0	82.9	72.7	66.9	56.6	40.8	31.0	40.9	57.6	71.7	95.1	95.8	100	100	100	100	100
	25	100	100	100	100	100	100	94.8	94.3	79.2	59.2	37.5	21.3	17.3	30.2	51.8	62.3	79.4	93.9	94.6	100	100	100	100	100
	26	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	27	100	100	100	100	100	100	95.1	94.7	91.5	84.4	74.4	79.8	86.1	88.9	86.9	82.9	86.6	96.4	97.0	100	100	100	100	100
	28	100	100	100	100	100	100	95.1	94.8	86.0	69.4	52.8	33.1	26.7	29.8	47.9	65.4	83.1	94.9	95.4	100	100	100	100	100
	29	100	100	100	100	100	100	94.8	94.5	93.6	73.7	46.2	25.3	18.8	24.1	37.1	55.1	73.2	93.9	94.4	100	100	100	100	100
	30	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	31	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	32	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	33	100	100	100	100	100	100	90.0	89.9	47.8	34.6	31.2	22.8	16.5	12.7	12.0	17.5	69.1	90.0	90.0	100	100	100	100	100
	34	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	35	100	100	100	100	100	100	95.1	94.7	82.1	49.0	27.7	23.0	30.9	46.7	62.0	71.0	78.6	94.0	94.3	100	100	100	100	100
	36	100	100	100	100	100	100	92.5	91.9	57.2	41.7	28.0	25.2	29.3	37.6	48.1	55.2	76.2	91.9	92.4	100	100	100	100	100
	37	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	38	100	100	100	100	100	100	95.7	95.7	95.4	87.6	83.3	80.6	79.5	78.4	74.8	68.8	66.8	77.4	94.2	100	100	100	100	100
	39	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	40	100	100	100	100	100	100	93.8	93.8	84.0	76.5	72.6	72.8	74.4	76.7	76.9	74.5	80.7	93.4	93.7	100	100	100	100	100
	41	100	100	100	100	100	100	92.6	91.7	73.6	50.7	38.8	27.7	22.4	21.5	26.1	41.9	87.7	91.6	92.2	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	42	100	100	100	100	100	100	97.8	95.4	92.1	87.3	83.1	80.8	78.5	75.7	67.9	74.9	90.3	95.9	97.8	100	100	100	100	100
	43	100	100	100	100	100	100	93.9	93.6	83.0	77.5	77.8	74.6	71.9	71.2	68.6	82.8	92.6	93.7	93.9	100	100	100	100	100
	44	100	100	100	100	100	100	92.5	91.9	90.9	59.7	44.5	32.8	24.1	19.8	23.8	31.0	57.4	91.9	92.3	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	90.1	89.7	89.7	90.7	32.3	15.5	21.7	23.6	27.7	26.0	32.8	57.5	90.2	100	100	100	100	100
	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	93.5	92.4	79.2	47.5	28.3	8.5	9.3	17.8	36.6	49.5	56.6	92.4	93.3	100	100	100	100	100
	12	100	100	100	100	100	100	94.7	90.6	79.9	70.2	44.5	32.3	32.9	40.7	50.9	59.8	77.0	93.7	94.3	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.1	83.1	48.1	26.1	27.2	32.6	42.4	56.6	73.2	84.4	91.5	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-37. Hourly Effective Shade (%) for Mean August Conditions for EOY27 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	8	100	100	100	100	100	96.0	90.8	88.4	58.4	23.9	11.6	8.0	7.5	7.8	9.5	15.1	31.4	58.0	82.0	96.1	96.1	100	100	100
	9	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	10	100	100	100	100	100	96.8	87.4	69.2	52.7	49.8	49.2	47.0	44.6	43.6	42.5	43.6	53.1	71.4	84.3	96.9	96.9	100	100	100
	11	100	100	100	100	100	96.0	81.9	54.5	28.3	16.8	9.8	6.8	6.6	6.9	8.7	13.4	27.1	55.2	79.8	96.0	96.1	100	100	100
	12	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100
	13	100	100	100	100	100	97.3	76.7	56.5	50.3	47.1	45.0	44.8	44.2	45.4	48.0	49.6	50.8	61.7	75.0	94.9	97.1	100	100	100
	14	100	100	100	100	100	96.0	88.0	73.7	48.0	27.9	12.7	8.1	6.9	6.6	8.3	13.2	20.9	34.8	61.8	84.7	96.0	100	100	100
	15	100	100	100	100	100	95.9	69.2	42.9	29.0	18.4	9.7	6.6	6.0	6.2	7.6	14.5	24.8	35.0	63.4	77.7	95.9	100	100	100
	16	100	100	100	100	100	96.5	75.6	52.5	39.7	32.9	25.5	20.4	17.0	12.9	11.9	20.9	38.9	60.5	84.1	93.7	96.5	100	100	100
	17	100	100	100	100	100	97.0	83.9	63.3	49.6	44.9	36.0	24.4	17.7	16.7	21.8	31.6	45.2	63.7	77.6	96.7	97.0	100	100	100
	18	100	100	100	100	100	97.5	85.6	68.3	54.1	48.0	41.5	34.9	30.4	29.9	33.7	40.5	49.3	65.7	76.7	97.4	97.4	100	100	100
	19	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	20	100	100	100	100	100	97.8	94.7	87.7	74.6	61.6	55.5	48.8	43.2	43.4	50.3	58.7	66.2	77.1	89.5	97.4	97.8	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	98.1	94.8	89.8	83.6	78.9	72.1	54.2	36.9	42.5	63.2	74.4	78.8	81.1	88.2	94.6	98.1	100	100	100
	23	100	100	100	100	100	97.6	86.3	69.5	56.5	52.2	46.1	37.0	29.4	26.8	29.8	37.7	47.7	68.2	79.4	97.4	97.4	100	100	100
	24	100	100	100	100	100	98.6	96.8	89.0	78.2	70.9	61.4	46.5	29.3	22.0	32.0	51.3	69.0	85.6	90.9	98.3	98.8	100	100	100
	25	100	100	100	100	100	98.1	95.3	89.0	75.4	56.7	33.3	17.5	12.8	19.2	36.6	52.5	68.5	79.2	93.2	97.8	98.0	100	100	100
	26	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	27	100	100	100	100	100	98.1	95.6	93.3	89.2	84.7	74.7	70.6	76.8	83.2	82.5	80.7	85.1	92.1	94.6	98.6	98.9	100	100	100
	28	100	100	100	100	100	98.2	95.6	90.7	81.8	65.1	45.5	25.6	18.4	20.7	34.9	54.8	75.2	86.3	94.6	98.2	98.3	100	100	100
	29	100	100	100	100	100	98.0	95.3	94.3	85.7	65.8	39.1	19.1	13.1	16.3	27.0	45.0	63.5	80.6	89.8	97.8	98.0	100	100	100
	30	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	31	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	32	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	33	100	100	100	100	100	96.2	91.2	66.0	38.8	29.1	23.5	15.8	10.9	9.0	9.2	13.8	43.9	64.4	89.5	96.2	96.3	100	100	100
	34	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	35	100	100	100	100	100	98.2	95.7	90.9	73.2	44.2	23.1	15.9	19.3	29.8	44.8	58.4	68.8	79.6	88.4	97.7	97.9	100	100	100
	36	100	100	100	100	100	97.2	93.2	75.1	49.6	33.0	19.7	16.8	18.4	22.5	30.6	39.5	56.0	70.4	91.7	97.0	97.2	100	100	100
	37	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	38	100	100	100	100	100	98.0	95.8	95.3	86.5	80.2	76.9	75.1	73.6	69.8	60.7	53.4	60.0	75.9	87.0	93.5	97.7	100	100	100
	39	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	40	100	100	100	100	100	97.7	94.5	88.4	71.9	64.4	62.6	63.1	65.3	68.1	68.8	68.2	72.3	78.7	89.9	97.6	97.7	100	100	100
	41	100	100	100	100	100	97.1	93.1	80.5	60.7	40.7	27.4	18.1	14.1	13.5	16.9	28.4	58.5	77.2	92.9	96.9	97.3	100	100	100
	42	100	100	100	100	100	99.2	95.0	90.9	87.1	83.5	80.5	78.2	75.5	71.1	62.4	68.8	81.5	91.3	97.0	99.2	99.2	100	100	100
	43	100	100	100	100	100	97.7	94.3	87.5	78.4	75.2	74.2	69.6	64.6	60.8	57.5	67.3	82.0	90.4	94.5	97.7	97.7	100	100	100
	44	100	100	100	100	100	97.2	93.2	91.3	67.9	45.8	30.7	20.7	14.8	12.8	15.0	20.5	40.1	66.9	86.4	97.0	97.4	100	100	100
Lower	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	96.2	91.2	90.9	88.8	69.0	26.9	12.4	18.0	21.6	24.5	24.0	28.0	41.4	65.2	85.6	96.3	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	97.6	93.9	85.0	68.8	44.9	22.5	7.1	7.8	11.4	23.7	38.6	51.3	71.7	81.1	97.1	97.5	100	100	100
	12	100	100	100	100	100	98.0	93.0	85.3	75.2	60.7	37.4	25.9	25.2	30.7	40.4	50.6	63.5	77.2	87.8	97.7	97.8	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.8	65.9	34.9	19.7	19.6	24.1	32.4	43.3	56.0	67.8	79.9	88.0	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-38. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY32 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	93.8	93.8	90.1	48.5	32.6	18.9	10.2	7.5	8.1	12.2	23.0	37.9	47.1	80.7	93.8	93.8	100	100	100
	9	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	10	100	100	100	100	100	95.4	95.1	95.0	93.6	92.9	94.1	93.1	91.6	91.1	88.5	90.3	91.4	94.7	95.0	95.5	95.4	100	100	100
	11	100	100	100	100	100	93.8	80.5	51.1	40.9	29.2	17.1	9.4	6.7	7.2	10.4	19.3	32.6	43.3	77.6	93.7	93.9	100	100	100
	12	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	13	100	100	100	100	100	96.0	95.5	94.5	93.2	92.1	89.5	91.5	91.5	91.5	93.5	93.2	93.3	93.4	94.6	95.6	95.8	100	100	100
	14	100	100	100	100	100	93.8	89.9	72.3	53.4	36.4	19.0	11.7	7.1	6.7	10.8	19.8	33.8	45.7	51.0	77.2	93.8	100	100	100
	15	100	100	100	100	100	93.6	61.9	53.4	45.1	31.1	17.2	9.1	6.0	6.5	10.7	22.1	38.2	48.5	55.7	67.3	93.7	100	100	100
	16	100	100	100	100	100	94.6	69.5	54.4	52.3	44.8	35.2	26.3	18.7	11.2	11.2	18.4	30.2	59.2	84.0	90.5	94.5	100	100	100
	17	100	100	100	100	100	94.3	76.8	52.6	46.8	40.9	28.7	16.3	9.8	9.3	13.3	23.8	39.2	48.4	64.9	93.7	94.3	100	100	100
	18	100	100	100	100	100	95.1	80.3	62.8	56.9	48.6	37.6	28.1	21.5	21.7	26.8	37.8	49.9	59.4	64.3	95.0	95.0	100	100	100
	19	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	20	100	100	100	100	100	95.8	95.2	84.5	72.3	64.2	56.0	47.6	41.0	42.1	50.7	60.9	64.9	67.9	88.8	94.9	95.7	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	96.4	95.3	90.0	87.3	85.1	77.9	57.8	37.4	40.5	63.9	80.0	84.6	85.8	87.4	92.1	96.3	100	100	100
	23	100	100	100	100	100	95.3	81.0	62.2	57.6	52.1	43.0	31.1	21.7	18.8	22.8	33.7	47.5	57.7	69.2	95.0	95.0	100	100	100
	24	100	100	100	100	100	97.4	96.8	84.9	77.7	74.3	62.5	43.8	23.7	17.4	27.9	50.6	70.9	79.8	88.1	96.7	97.7	100	100	100
	25	100	100	100	100	100	96.2	95.9	84.2	72.7	56.8	31.6	14.5	8.5	9.2	24.2	45.9	59.5	65.4	91.9	95.6	96.1	100	100	100
	26	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	27	100	100	100	100	100	96.4	96.3	93.3	89.9	88.7	82.6	70.1	77.0	84.1	80.9	81.1	86.7	90.5	93.9	97.2	97.9	100	100	100
	28	100	100	100	100	100	96.4	96.3	87.2	78.7	63.7	40.9	19.6	10.5	12.1	24.1	47.5	69.5	78.4	93.9	96.5	96.8	100	100	100
	29	100	100	100	100	100	96.2	96.0	94.4	78.9	60.7	35.1	14.3	7.7	9.1	18.4	37.0	55.4	67.9	85.5	95.7	96.1	100	100	100
	30	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	31	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	32	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	33	100	100	100	100	100	94.6	94.5	63.0	55.6	54.7	49.7	40.7	26.8	16.7	18.1	30.0	47.0	60.9	92.3	94.6	94.7	100	100	100
	34	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	35	100	100	100	100	100	96.6	96.4	87.6	65.9	42.6	20.1	9.4	8.6	15.0	31.4	49.7	61.6	66.5	82.9	95.6	96.0	100	100	100
	36	100	100	100	100	100	94.6	94.1	60.1	44.9	27.2	13.1	9.2	8.6	9.1	16.0	27.7	39.1	51.2	91.4	94.1	94.7	100	100	100
	37	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	38	100	100	100	100	100	95.9	95.9	95.4	85.4	82.3	80.4	79.9	78.1	72.3	57.5	47.6	63.3	83.2	87.8	91.4	95.6	100	100	100
	39	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	40	100	100	100	100	100	95.5	95.5	87.6	68.5	61.7	63.6	64.5	67.2	70.5	71.4	72.4	74.5	73.3	89.2	95.4	95.5	100	100	100
	41	100	100	100	100	100	94.4	93.9	70.4	50.6	35.1	19.6	10.3	6.7	6.2	9.1	17.8	33.2	65.0	93.7	94.1	94.8	100	100	100
	42	100	100	100	100	100	98.3	92.3	87.3	82.9	80.6	79.0	76.7	73.7	67.8	57.8	63.8	73.8	86.9	96.1	98.4	98.5	100	100	100
	43	100	100	100	100	100	95.5	95.2	87.7	83.1	82.3	80.6	75.1	68.0	61.2	56.6	61.5	78.6	89.7	95.4	95.5	95.6	100	100	100
	44	100	100	100	100	100	94.5	94.1	91.1	47.5	36.0	20.7	11.0	6.5	6.4	7.3	11.8	26.4	44.3	81.1	94.2	95.1	100	100	100
	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
Lower	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	95.6	95.5	94.9	91.7	59.0	28.8	12.9	18.3	28.7	39.4	48.6	56.3	58.5	66.6	83.4	95.5	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	95.3	94.6	78.4	60.7	46.8	19.9	6.1	6.3	5.7	13.3	32.2	49.0	52.3	69.8	94.3	95.2	100	100	100
	12	100	100	100	100	100	96.1	91.5	80.6	71.6	53.9	32.4	20.4	17.9	21.2	31.0	42.7	51.0	61.0	81.6	95.5	95.8	100	100	100
	13	100	100	100	100	100	95.1	93.5	86.4	48.6	21.6	13.3	12.1	15.5	22.4	30.1	38.8	51.3	68.2	82.3	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-39. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY32 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	91.8	91.9	90.2	51.5	36.9	28.5	25.6	27.2	34.7	44.5	61.8	91.0	91.9	100	100	100	100	100
	9	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	10	100	100	100	100	100	100	93.9	93.9	93.5	93.6	93.0	92.7	92.4	92.4	91.8	91.4	92.9	94.0	94.0	100	100	100	100	100
	11	100	100	100	100	100	100	92.0	80.7	53.3	44.8	37.8	30.3	27.0	27.7	33.7	41.8	57.3	89.2	91.9	100	100	100	100	100
	12	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	13	100	100	100	100	100	100	94.7	93.9	92.8	92.3	92.5	92.8	91.9	92.7	93.0	93.4	93.2	94.0	94.0	100	100	100	100	100
	14	100	100	100	100	100	100	91.9	88.3	72.4	53.4	37.9	29.0	26.4	27.7	33.5	40.9	47.6	59.4	91.8	100	100	100	100	100
	15	100	100	100	100	100	100	91.7	63.2	50.5	42.0	32.0	23.6	21.0	26.0	36.9	48.9	54.7	57.7	91.7	100	100	100	100	100
	16	100	100	100	100	100	100	93.0	78.0	63.9	61.3	56.3	48.0	40.3	34.3	29.6	39.8	64.0	81.2	92.7	100	100	100	100	100
	17	100	100	100	100	100	100	92.5	77.3	56.9	55.6	52.1	41.1	32.1	29.5	36.8	46.9	57.8	82.4	92.5	100	100	100	100	100
	18	100	100	100	100	100	100	93.5	79.7	60.0	57.3	55.7	53.2	50.3	49.0	51.1	53.7	58.3	78.9	93.5	100	100	100	100	100
	19	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	20	100	100	100	100	100	100	94.6	93.6	84.5	70.6	67.5	62.8	58.3	56.8	62.7	68.6	78.2	92.8	93.7	100	100	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	100	95.3	94.6	89.5	84.9	81.5	67.2	50.7	59.6	78.6	83.2	85.8	87.6	95.1	100	100	100	100	100
	23	100	100	100	100	100	100	94.0	82.9	63.9	61.7	60.0	54.6	48.2	45.1	47.3	52.2	57.7	84.7	93.4	100	100	100	100	100
	24	100	100	100	100	100	100	97.2	96.2	85.7	77.0	71.5	62.6	47.0	36.9	46.4	62.3	75.3	95.3	96.0	100	100	100	100	100
	25	100	100	100	100	100	100	95.0	94.5	79.8	60.9	39.8	23.3	19.5	32.9	54.2	63.3	79.8	94.1	94.8	100	100	100	100	100
	26	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	27	100	100	100	100	100	100	95.4	94.9	92.8	87.9	80.7	85.1	89.1	91.3	89.7	85.6	89.2	96.7	97.2	100	100	100	100	100
	28	100	100	100	100	100	100	95.3	95.1	86.8	70.8	54.8	35.3	28.6	31.9	50.7	66.9	83.8	95.1	95.6	100	100	100	100	100
	29	100	100	100	100	100	100	95.0	94.7	93.8	74.8	48.6	27.4	20.5	25.5	38.5	56.3	73.7	94.1	94.6	100	100	100	100	100
	30	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	31	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	32	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	33	100	100	100	100	100	100	92.9	92.9	66.4	57.9	57.3	55.2	46.2	37.9	35.7	40.2	80.0	92.8	92.9	100	100	100	100	100
	34	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	35	100	100	100	100	100	100	95.3	95.0	82.9	51.5	29.6	25.0	33.7	50.3	64.8	72.3	79.4	94.3	94.5	100	100	100	100	100
	36	100	100	100	100	100	100	92.9	92.2	59.1	44.6	30.4	27.6	32.5	41.9	51.9	57.5	77.2	92.2	92.8	100	100	100	100	100
	37	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	38	100	100	100	100	100	100	95.9	95.8	95.7	91.7	89.9	88.4	87.9	87.1	83.8	77.8	75.9	84.4	94.4	100	100	100	100	100
	39	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	40	100	100	100	100	100	100	94.1	94.1	88.5	84.1	80.9	81.6	83.0	85.3	85.4	82.9	86.3	93.9	94.0	100	100	100	100	100
	41	100	100	100	100	100	100	93.0	92.1	75.0	53.1	42.3	31.1	25.8	24.9	29.5	44.5	88.3	91.9	92.6	100	100	100	100	100
	42	100	100	100	100	100	100	97.8	95.6	92.7	88.0	84.0	81.7	79.5	76.8	69.1	75.5	90.3	95.9	97.8	100	100	100	100	100
	43	100	100	100	100	100	100	94.2	94.0	88.6	86.2	86.1	83.3	80.8	80.5	77.4	86.7	93.3	94.0	94.2	100	100	100	100	100
	44	100	100	100	100	100	100	92.8	92.3	91.3	62.0	48.8	37.0	28.1	23.1	26.7	34.1	60.0	92.2	92.6	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	94.4	93.9	92.0	92.9	39.3	28.5	41.4	51.6	58.7	58.2	62.0	75.8	94.0	100	100	100	100	100
	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	93.8	92.7	80.0	50.4	31.9	9.5	10.8	20.9	40.5	51.3	57.8	92.7	93.6	100	100	100	100	100
	12	100	100	100	100	100	100	94.8	90.9	80.7	71.7	46.2	33.4	34.1	42.0	51.9	60.3	77.4	93.9	94.5	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.1	83.1	48.2	26.1	27.3	32.7	42.5	56.7	73.2	84.4	91.5	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-40. Hourly Effective Shade (%) for Mean August Conditions for EOY32 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	96.9	92.8	91.0	69.4	42.1	27.9	19.4	16.6	17.7	23.5	33.8	49.9	69.1	86.3	96.9	96.9	100	100	100
	9	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	10	100	100	100	100	100	97.7	94.5	94.5	93.6	93.3	93.6	92.9	92.0	91.8	90.2	90.9	92.2	94.4	94.5	97.8	97.7	100	100	100
	11	100	100	100	100	100	96.9	86.3	65.9	47.1	37.0	27.5	19.9	16.9	17.5	22.1	30.6	45.0	66.3	84.8	96.9	97.0	100	100	100
	12	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	13	100	100	100	100	100	98.0	95.1	94.2	93.0	92.2	91.0	92.2	91.7	92.1	93.3	93.3	93.3	93.7	94.3	97.8	97.9	100	100	100
	14	100	100	100	100	100	96.9	90.9	80.3	62.9	44.9	28.5	20.4	16.8	17.2	22.2	30.4	40.7	52.6	71.4	88.6	96.9	100	100	100
	15	100	100	100	100	100	96.8	76.8	58.3	47.8	36.6	24.6	16.4	13.5	16.3	23.8	35.5	46.5	53.1	73.7	83.7	96.9	100	100	100
	16	100	100	100	100	100	97.3	81.3	66.2	58.1	53.1	45.8	37.2	29.5	22.8	20.4	29.1	47.1	70.2	88.4	95.3	97.3	100	100	100
	17	100	100	100	100	100	97.2	84.7	65.0	51.9	48.3	40.4	28.7	21.0	19.4	25.1	35.4	48.5	65.4	78.7	96.9	97.2	100	100	100
	18	100	100	100	100	100	97.6	86.9	71.3	58.5	53.0	46.7	40.7	35.9	35.4	39.0	45.8	54.1	69.2	78.9	97.5	97.5	100	100	100
	19	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	20	100	100	100	100	100	97.9	94.9	89.1	78.4	67.4	61.8	55.2	49.7	49.5	56.7	64.8	71.6	80.4	91.3	97.5	97.9	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	98.2	95.3	92.3	88.4	85.0	79.7	62.5	44.1	50.1	71.3	81.6	85.2	86.7	91.3	96.1	98.2	100	100	100
	23	100	100	100	100	100	97.7	87.5	72.6	60.8	56.9	51.5	42.9	35.0	32.0	35.1	43.0	52.6	71.2	81.3	97.5	97.5	100	100	100
	24	100	100	100	100	100	98.7	97.0	90.6	81.7	75.7	67.0	53.2	35.4	27.2	37.2	56.5	73.1	87.6	92.1	98.4	98.9	100	100	100
	25	100	100	100	100	100	98.1	95.5	89.4	76.3	58.9	35.7	18.9	14.0	21.1	39.2	54.6	69.7	79.8	93.4	97.8	98.1	100	100	100
	26	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	27	100	100	100	100	100	98.2	95.9	94.1	91.4	88.3	81.7	77.6	83.1	87.7	85.3	83.4	88.0	93.6	95.6	98.6	99.0	100	100	100
	28	100	100	100	100	100	98.2	95.8	91.2	82.8	67.3	47.9	27.5	19.6	22.0	37.4	57.2	76.7	86.8	94.8	98.3	98.4	100	100	100
	29	100	100	100	100	100	98.1	95.5	94.6	86.4	67.8	41.9	20.9	14.1	17.3	28.5	46.7	64.6	81.0	90.1	97.9	98.1	100	100	100
	30	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	31	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	32	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	33	100	100	100	100	100	97.3	93.7	78.0	61.0	56.3	53.5	48.0	36.5	27.3	26.9	35.1	63.5	76.9	92.6	97.3	97.4	100	100	100
	34	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	35	100	100	100	100	100	98.3	95.9	91.3	74.4	47.1	24.9	17.2	21.2	32.7	48.1	61.0	70.5	80.4	88.7	97.8	98.0	100	100	100
	36	100	100	100	100	100	97.3	93.5	76.2	52.0	35.9	21.8	18.4	20.6	25.5	34.0	42.6	58.2	71.7	92.1	97.1	97.4	100	100	100
	37	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	38	100	100	100	100	100	98.0	95.9	95.6	90.6	87.0	85.2	84.2	83.0	79.7	70.7	62.7	69.6	83.8	91.1	95.7	97.8	100	100	100
	39	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	40	100	100	100	100	100	97.8	94.8	90.9	78.5	72.9	72.3	73.1	75.1	77.9	78.4	77.7	80.4	83.6	91.6	97.7	97.8	100	100	100
	41	100	100	100	100	100	97.2	93.5	81.3	62.8	44.1	31.0	20.7	16.3	15.6	19.3	31.2	60.8	78.5	93.2	97.1	97.4	100	100	100
	42	100	100	100	100	100	99.2	95.1	91.5	87.8	84.3	81.5	79.2	76.6	72.3	63.5	69.7	82.1	91.4	97.0	99.2	99.3	100	100	100
	43	100	100	100	100	100	97.8	94.7	90.9	85.9	84.3	83.4	79.2	74.4	70.9	67.0	74.1	86.0	91.9	94.8	97.8	97.8	100	100	100
	44	100	100	100	100	100	97.3	93.5	91.7	69.4	49.0	34.8	24.0	17.3	14.8	17.0	23.0	43.2	68.3	86.9	97.1	97.6	100	100	100
	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
Lower	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	97.8	95.0	94.4	91.9	76.0	34.1	20.7	29.9	40.2	49.1	53.4	59.2	67.2	80.3	91.7	97.8	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	97.7	94.2	85.6	70.4	48.6	25.9	7.8	8.6	13.3	26.9	41.8	53.4	72.5	81.7	97.2	97.6	100	100	100
	12	100	100	100	100	100	98.1	93.2	85.8	76.2	62.8	39.3	26.9	26.0	31.6	41.5	51.5	64.2	77.5	88.1	97.8	97.9	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.8	65.9	34.9	19.7	19.7	24.1	32.5	43.4	56.0	67.9	79.9	88.0	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-41. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY52 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
Upper	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	95.1	95.1	92.2	61.9	50.9	38.0	25.5	19.1	20.5	29.9	44.0	55.5	60.8	85.5	95.0	95.1	100	100	100
	9	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	10	100	100	100	100	100	96.3	96.2	96.2	95.4	95.1	95.8	95.3	94.6	94.2	93.0	93.9	94.4	96.0	96.3	96.4	96.4	100	100	100
	11	100	100	100	100	100	95.1	85.5	62.5	56.1	49.1	37.8	26.5	20.1	20.1	27.6	38.6	50.7	57.7	83.2	95.0	95.2	100	100	100
	12	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100
	13	100	100	100	100	100	96.8	96.5	95.9	95.3	94.9	93.4	94.5	94.5	94.5	95.5	95.4	95.3	95.4	95.9	96.4	96.6	100	100	100
	14	100	100	100	100	100	95.0	92.2	79.2	65.9	55.2	37.2	27.0	19.6	19.8	27.9	39.9	53.0	60.1	63.2	82.4	95.1	100	100	100
	15	100	100	100	100	100	94.9	71.1	65.5	60.6	49.4	35.0	22.1	15.9	19.5	31.0	46.2	57.4	62.4	68.1	76.0	95.0	100	100	100
	16	100	100	100	100	100	95.7	77.5	67.6	68.1	65.2	57.4	47.1	34.9	23.0	19.9	27.1	44.2	71.7	88.0	92.6	95.6	100	100	100
	17	100	100	100	100	100	95.3	83.6	66.7	61.7	59.1	51.1	39.4	27.7	24.9	31.8	45.1	57.7	63.3	75.7	94.9	95.3	100	100	100
	18	100	100	100	100	100	95.4	87.2	75.4	70.2	63.0	53.3	44.8	38.1	37.6	42.4	53.9	65.2	72.8	76.8	95.5	95.5	100	100	100
	19	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	20	100	100	100	100	100	96.1	95.5	87.4	79.4	72.7	67.4	61.9	55.0	55.3	64.1	70.8	72.0	74.4	92.5	95.2	96.0	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	96.8	96.6	96.6	95.7	95.4	93.0	79.0	55.1	59.2	84.2	93.6	95.1	95.5	96.2	96.5	96.8	100	100	100
	23	100	100	100	100	100	95.8	87.0	75.3	71.0	66.8	59.6	48.7	38.4	34.0	38.1	49.5	62.4	71.2	79.5	95.5	95.5	100	100	100
	24	100	100	100	100	100	97.7	97.1	90.3	85.8	83.8	74.6	57.4	35.4	26.4	37.9	61.4	79.2	86.9	92.2	97.0	97.9	100	100	100
	25	100	100	100	100	100	96.5	96.2	85.2	74.6	61.3	36.5	16.5	9.0	11.7	29.7	51.7	62.2	66.9	92.3	95.9	96.4	100	100	100
	26	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	27	100	100	100	100	100	96.8	96.6	96.0	95.1	94.6	92.0	84.7	90.4	94.8	90.9	91.1	94.4	95.6	97.0	97.6	98.2	100	100	100
	28	100	100	100	100	100	96.7	96.6	88.1	80.4	68.3	46.1	22.9	11.8	14.0	28.7	53.5	72.6	79.5	94.3	96.8	97.0	100	100	100
	29	100	100	100	100	100	96.5	96.3	94.8	81.2	66.2	41.1	17.5	8.6	11.0	22.0	41.5	58.6	69.3	86.2	96.0	96.3	100	100	100
	30	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	31	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	32	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	33	100	100	100	100	100	95.9	95.8	94.8	94.2	94.2	94.4	93.0	82.0	66.3	65.2	78.2	89.9	94.5	95.8	95.9	96.0	100	100	100
	34	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	35	100	100	100	100	100	96.9	96.7	88.6	68.6	48.4	23.3	10.8	10.2	19.6	38.8	56.7	65.4	68.7	84.1	96.0	96.4	100	100	100
	36	100	100	100	100	100	95.5	95.1	66.5	54.2	39.4	21.3	14.5	14.4	18.5	30.4	42.9	50.2	59.3	92.9	95.1	95.6	100	100	100
	37	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	38	100	100	100	100	100	96.7	96.7	96.4	95.1	94.1	94.5	95.7	95.6	95.0	88.8	81.4	87.2	94.3	95.9	95.9	96.3	100	100	100
	39	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100
	40	100	100	100	100	100	96.3	96.2	95.0	88.5	87.1	91.6	91.4	92.9	94.9	93.7	92.3	93.3	91.5	95.1	96.2	96.3	100	100	100
	41	100	100	100	100	100	95.4	94.9	74.5	59.1	49.9	34.1	20.2	12.1	10.7	16.9	30.2	45.9	71.4	94.8	95.1	95.7	100	100	100
	42	100	100	100	100	100	98.4	92.6	88.0	83.7	81.5	80.0	78.2	76.0	71.7	61.9	67.2	75.0	87.2	96.2	98.5	98.5	100	100	100
	43	100	100	100	100	100	96.3	96.2	95.2	94.7	94.4	94.6	94.5	91.8	90.0	87.0	86.1	92.8	94.6	96.1	96.3	96.3	100	100	100
	44	100	100	100	100	100	95.4	95.1	92.3	55.4	50.1	37.2	22.8	13.7	10.2	13.3	21.1	38.9	51.7	83.7	95.2	96.0	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	97.3	97.1	96.5	95.7	88.5	61.8	46.3	66.3	84.2	92.4	96.0	96.1	96.2	96.2	96.5	97.3	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	96.0	95.4	81.8	67.5	61.3	34.3	11.1	6.2	9.3	26.0	48.0	57.1	57.4	73.1	95.1	95.9	100	100	100
	12	100	100	100	100	100	96.3	92.0	81.9	73.4	58.1	36.7	22.3	18.8	22.6	33.2	44.9	52.8	61.8	82.3	95.7	96.0	100	100	100
	13	100	100	100	100	100	95.2	93.5	86.4	48.7	21.6	13.3	12.1	15.6	22.5	30.2	38.9	51.4	68.4	82.5	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-42. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY52 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	93.5	93.5	92.3	63.3	53.8	47.3	43.1	44.9	52.3	58.8	71.4	92.9	93.6	100	100	100	100	100
	9	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	10	100	100	100	100	100	100	95.1	95.1	95.0	95.0	94.8	94.5	94.5	94.4	93.9	94.0	94.6	95.2	95.3	100	100	100	100	100
	11	100	100	100	100	100	100	93.6	85.4	65.5	58.4	55.4	50.8	46.4	47.4	51.6	56.4	69.1	91.7	93.6	100	100	100	100	100
	12	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	13	100	100	100	100	100	100	95.8	95.3	94.5	94.4	94.5	94.5	94.3	94.6	94.6	94.9	94.8	95.2	95.2	100	100	100	100	100
	14	100	100	100	100	100	100	93.6	90.8	79.8	65.1	53.4	48.9	47.6	48.8	51.3	55.4	61.0	69.3	93.4	100	100	100	100	100
	15	100	100	100	100	100	100	93.4	72.8	61.9	55.5	50.4	43.7	40.1	45.8	56.5	64.3	66.3	68.0	93.4	100	100	100	100	100
	16	100	100	100	100	100	100	94.5	83.5	73.3	71.4	68.8	64.7	57.8	53.2	48.1	52.3	70.6	84.9	94.2	100	100	100	100	100
	17	100	100	100	100	100	100	93.8	83.9	69.9	70.5	68.2	61.2	52.8	48.7	54.1	63.2	71.3	87.3	93.8	100	100	100	100	100
	18	100	100	100	100	100	100	94.2	85.6	72.6	71.0	69.2	68.1	65.3	63.3	65.2	67.7	70.6	85.9	94.1	100	100	100	100	100
	19	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	20	100	100	100	100	100	100	95.0	93.9	86.7	77.5	75.2	71.3	68.0	65.8	70.5	74.9	83.5	93.7	94.1	100	100	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	100	95.8	95.8	95.7	93.4	93.2	82.3	68.2	76.5	90.8	93.5	94.7	95.0	95.6	100	100	100	100	100
	23	100	100	100	100	100	100	94.6	88.2	76.2	74.2	73.1	69.1	63.2	60.2	61.9	66.1	70.7	88.5	94.1	100	100	100	100	100
	24	100	100	100	100	100	100	97.5	96.6	90.7	85.1	80.2	73.4	58.7	48.5	56.7	71.2	81.5	95.8	96.4	100	100	100	100	100
	25	100	100	100	100	100	100	95.4	94.9	81.0	63.7	43.9	27.2	23.4	37.9	57.7	64.8	80.6	94.5	95.2	100	100	100	100	100
	26	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	27	100	100	100	100	100	100	95.9	95.5	95.1	93.2	89.6	92.1	94.0	95.3	94.9	93.0	95.1	97.2	97.6	100	100	100	100	100
	28	100	100	100	100	100	100	95.7	95.5	88.1	73.0	58.1	39.6	32.5	36.0	55.0	69.4	84.9	95.5	96.0	100	100	100	100	100
	29	100	100	100	100	100	100	95.4	95.1	94.3	76.9	52.9	31.9	24.6	28.8	41.5	58.3	74.9	94.4	95.0	100	100	100	100	100
	30	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	31	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	32	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100
	33	100	100	100	100	100	100	94.6	94.6	94.5	94.2	93.7	94.2	89.2	81.7	83.0	81.8	93.5	94.5	94.6	100	100	100	100	100
	34	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	35	100	100	100	100	100	100	95.8	95.5	84.5	56.0	33.7	29.0	38.7	56.6	69.1	74.6	81.0	94.8	95.0	100	100	100	100	100
	36	100	100	100	100	100	100	94.1	93.5	66.0	54.0	40.2	36.2	44.4	56.3	63.6	64.7	80.9	93.4	94.0	100	100	100	100	100
	37	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	38	100	100	100	100	100	100	96.7	96.6	96.4	96.0	95.7	95.2	95.1	95.0	94.2	91.6	91.5	94.0	95.4	100	100	100	100	100
	39	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	40	100	100	100	100	100	100	95.1	95.0	94.6	94.0	93.1	93.8	94.0	94.9	94.9	93.9	94.2	95.0	95.0	100	100	100	100	100
	41	100	100	100	100	100	100	94.2	93.4	79.3	60.8	52.9	43.6	39.0	38.2	42.2	52.8	89.9	93.2	93.8	100	100	100	100	100
	42	100	100	100	100	100	100	97.9	95.8	93.2	88.7	84.8	82.6	80.3	78.2	71.8	77.4	90.4	96.0	97.9	100	100	100	100	100
	43	100	100	100	100	100	100	95.2	95.0	94.5	94.8	94.5	94.0	92.6	93.6	91.5	93.5	94.8	95.0	95.2	100	100	100	100	100
	44	100	100	100	100	100	100	94.0	93.6	92.7	69.6	60.5	51.2	43.1	35.8	37.0	43.9	68.3	93.4	93.9	100	100	100	100	100
Lower	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
Lower	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
Lower	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
Lower	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
Lower	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
Lower	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
Lower	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
Lower	8	100	100	100	100	100	100	96.5	95.9	94.4	94.5	79.6	78.6	88.9	94.6	95.0	95.0	95.2	95.9	96.4	100	100	100	100	100
Lower	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	94.8	93.7	83.0	60.4	43.2	17.1	17.1	32.2	52.3	57.0	62.4	93.8	94.5	100	100	100	100	100
	12	100	100	100	100	100	100	95.1	91.6	82.1	73.9	49.0	35.5	36.4	44.6	53.3	61.1	78.1	94.2	94.7	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.2	83.1	48.3	26.2	27.4	32.8	42.5	56.7	73.2	84.4	91.6	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-43. Hourly Effective Shade (%) for Mean August Conditions for EOY52 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	97.6	94.3	92.9	77.1	57.1	45.9	36.4	31.1	32.7	41.1	51.4	63.5	76.9	89.6	97.5	97.6	100	100	100
	9	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	10	100	100	100	100	100	98.2	95.7	95.7	95.2	95.1	95.3	94.9	94.6	94.3	93.5	94.0	94.5	95.6	95.8	98.2	98.2	100	100	100
	11	100	100	100	100	100	97.6	89.6	74.0	60.8	53.8	46.6	38.7	33.3	33.8	39.6	47.5	59.9	74.7	88.4	97.5	97.6	100	100	100
	12	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100
	13	100	100	100	100	100	98.4	96.2	95.6	94.9	94.7	94.0	94.5	94.4	94.6	95.1	95.2	95.1	95.3	95.6	98.2	98.3	100	100	100
	14	100	100	100	100	100	97.5	92.9	85.0	72.9	60.2	45.3	38.0	33.6	34.3	39.6	47.7	57.0	64.7	78.3	91.2	97.6	100	100	100
	15	100	100	100	100	100	97.5	82.3	69.2	61.3	52.5	42.7	32.9	28.0	32.7	43.8	55.3	61.9	65.2	80.8	88.0	97.5	100	100	100
	16	100	100	100	100	100	97.9	86.0	75.6	70.7	68.3	63.1	55.9	46.4	38.1	34.0	39.7	57.4	78.3	91.1	96.3	97.8	100	100	100
	17	100	100	100	100	100	97.7	88.7	75.3	65.8	64.8	59.7	50.3	40.3	36.8	43.0	54.2	64.5	75.3	84.8	97.5	97.7	100	100	100
	18	100	100	100	100	100	97.7	90.7	80.5	71.4	67.0	61.3	56.5	51.7	50.5	53.8	60.8	67.9	79.4	85.5	97.8	97.8	100	100	100
	19	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	20	100	100	100	100	100	98.1	95.3	90.7	83.1	75.1	71.3	66.6	61.5	60.6	67.3	72.9	77.8	84.1	93.3	97.6	98.0	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	98.4	96.2	96.2	95.7	94.4	93.1	80.7	61.7	67.9	87.5	93.6	94.9	95.3	95.9	98.3	98.4	100	100	100
	23	100	100	100	100	100	97.9	90.8	81.8	73.6	70.5	66.4	58.9	50.8	47.1	50.0	57.8	66.6	79.9	86.8	97.8	97.8	100	100	100
	24	100	100	100	100	100	98.9	97.3	93.5	88.3	84.5	77.4	65.4	47.1	37.5	47.3	66.3	80.4	91.4	94.3	98.5	99.0	100	100	100
	25	100	100	100	100	100	98.3	95.8	90.1	77.8	62.5	40.2	21.9	16.2	24.8	43.7	58.3	71.4	80.7	93.8	98.0	98.2	100	100	100
	26	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100
	27	100	100	100	100	100	98.4	96.3	95.8	95.1	93.9	90.8	88.4	92.2	95.1	92.9	92.1	94.8	96.4	97.3	98.8	99.1	100	100	100
	28	100	100	100	100	100	98.4	96.2	91.8	84.3	70.7	52.1	31.3	22.2	25.0	41.9	61.5	78.8	87.5	95.2	98.4	98.5	100	100	100
	29	100	100	100	100	100	98.3	95.9	95.0	87.8	71.6	47.0	24.7	16.6	19.9	31.8	49.9	66.8	81.9	90.6	98.0	98.2	100	100	100
	30	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	31	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	32	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	33	100	100	100	100	100	98.0	95.2	94.7	94.4	94.2	94.1	93.6	85.6	74.0	74.1	80.0	91.7	94.5	95.2	98.0	98.0	100	100	100
	34	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	35	100	100	100	100	100	98.5	96.3	92.1	76.6	52.2	28.5	19.9	24.5	38.1	54.0	65.7	73.2	81.8	89.6	98.0	98.2	100	100	100
	36	100	100	100	100	100	97.8	94.6	80.0	60.1	46.7	30.8	25.4	29.4	37.4	47.0	53.8	65.6	76.4	93.5	97.6	97.8	100	100	100
	37	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	38	100	100	100	100	100	98.4	96.7	96.5	95.8	95.1	95.1	95.5	95.4	95.0	91.5	86.5	89.4	94.2	95.7	98.0	98.2	100	100	100
	39	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	40	100	100	100	100	100	98.2	95.7	95.0	91.6	90.6	92.4	92.6	93.5	94.9	94.3	93.1	93.8	93.3	95.1	98.1	98.2	100	100	100
	41	100	100	100	100	100	97.7	94.6	84.0	69.2	55.4	43.5	31.9	25.6	24.5	29.6	41.5	67.9	82.3	94.3	97.6	97.9	100	100	100
	42	100	100	100	100	100	99.2	95.3	91.9	88.5	85.1	82.4	80.4	78.2	75.0	66.9	72.3	82.7	91.6	97.1	99.3	99.3	100	100	100
	43	100	100	100	100	100	98.2	95.7	95.1	94.6	94.6	94.6	94.3	92.2	91.8	89.3	89.8	93.8	94.8	95.7	98.2	98.2	100	100	100
	44	100	100	100	100	100	97.7	94.6	93.0	74.1	59.9	48.9	37.0	28.4	23.0	25.2	32.5	53.6	72.6	88.8	97.6	98.0	100	100	100
Lower	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	98.9	97.1	96.5	95.4	92.7	79.2	77.4	88.6	95.1	95.6	95.8	96.0	96.4	96.7	98.6	99.0	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	98.1	95.2	88.3	76.4	62.9	41.6	15.3	11.8	21.8	41.7	55.0	60.7	76.6	84.4	97.7	98.1	100	100	100
	12	100	100	100	100	100	98.2	93.7	87.1	78.3	67.2	44.2	29.6	28.0	34.1	44.0	53.6	65.9	78.3	88.7	97.9	98.1	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.9	66.0	35.0	19.8	19.8	24.2	32.5	43.5	56.1	68.0	80.0	88.1	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-44. Hourly Effective Shade (%) for Maximum Weekly Summer Conditions for EOY112 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	98.0	97.8	85.4	75.6	72.9	76.2	77.9	78.3	74.7	75.0	80.0	82.1	79.7	80.3	88.2	97.8	100	100	100
	2	100	100	100	100	100	97.3	89.4	76.3	71.5	66.9	60.7	57.3	54.8	50.3	42.4	46.3	60.8	72.2	88.6	97.0	97.5	100	100	100
	3	100	100	100	100	100	99.1	97.7	92.2	88.5	85.5	83.5	82.7	78.7	77.1	80.7	82.8	85.9	91.2	98.7	99.1	99.3	100	100	100
	4	100	100	100	100	100	96.7	89.4	74.6	60.6	49.3	40.8	33.7	36.1	44.4	55.1	65.6	73.4	84.8	94.1	97.0	97.1	100	100	100
	5	100	100	100	100	100	97.9	96.4	84.0	73.9	63.4	54.9	52.2	53.4	58.7	61.7	68.9	79.8	86.9	90.1	95.4	97.8	100	100	100
	6	100	100	100	100	100	97.0	95.5	80.9	60.7	49.9	44.2	40.7	43.7	49.3	54.4	58.1	62.6	68.9	78.7	92.2	97.3	100	100	100
	7	100	100	100	100	100	97.2	96.8	87.5	73.7	68.3	61.7	54.0	45.4	44.3	49.6	56.6	61.6	67.9	88.2	97.1	97.3	100	100	100
	8	100	100	100	100	100	95.8	95.8	94.3	79.4	71.2	60.2	48.0	40.2	41.8	52.9	66.7	74.8	79.2	91.6	95.8	95.8	100	100	100
	9	100	100	100	100	100	98.1	89.6	81.0	75.5	72.0	70.4	68.7	63.9	56.4	55.9	62.3	71.3	81.1	94.5	98.4	98.4	100	100	100
	10	100	100	100	100	100	96.8	96.7	96.8	96.2	96.1	96.5	96.2	95.7	95.5	94.7	95.4	95.5	96.7	96.8	96.9	96.9	100	100	100
	11	100	100	100	100	100	95.8	91.6	79.4	75.9	70.6	61.1	50.2	43.0	42.6	50.7	61.3	71.0	76.8	90.2	95.7	95.9	100	100	100
	12	100	100	100	100	100	98.3	98.4	94.2	87.1	82.1	84.1	85.3	85.2	87.4	87.8	86.2	87.5	90.6	92.5	98.4	99.2	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	13	100	100	100	100	100	97.3	97.1	96.7	96.2	95.9	95.0	95.7	95.6	95.7	96.4	96.3	96.2	96.2	96.6	97.0	97.1	100	100	100
	14	100	100	100	100	100	95.7	94.5	88.6	81.2	74.6	59.4	49.2	42.4	42.8	50.5	62.6	73.7	79.3	81.5	90.0	95.8	100	100	100
	15	100	100	100	100	100	95.6	85.1	82.5	79.2	69.8	56.9	43.9	36.7	42.2	56.1	70.3	76.7	79.8	84.6	87.8	95.7	100	100	100
	16	100	100	100	100	100	96.3	88.2	84.5	85.3	84.6	79.2	70.2	58.3	44.9	38.4	44.1	63.6	85.4	93.2	95.1	96.2	100	100	100
	17	100	100	100	100	100	95.8	89.7	79.4	75.0	72.9	67.6	56.8	44.0	39.6	47.5	61.4	71.7	76.1	84.9	95.6	95.7	100	100	100
	18	100	100	100	100	100	95.8	90.9	82.3	77.5	70.6	61.8	53.6	47.1	46.2	50.8	62.3	73.2	79.8	83.3	95.8	95.8	100	100	100
	19	100	100	100	100	100	93.9	83.3	56.9	37.6	34.2	30.9	27.4	23.3	22.0	26.2	32.0	36.3	41.0	71.0	93.7	94.3	100	100	100
	20	100	100	100	100	100	96.2	95.6	87.7	80.4	74.7	70.4	67.1	62.0	61.3	68.6	72.7	73.0	75.1	92.9	95.4	96.1	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	97.0	96.8	96.8	96.0	96.1	94.3	86.3	64.8	68.9	89.8	94.8	95.6	95.9	96.4	96.7	96.9	100	100	100
	23	100	100	100	100	100	96.1	90.2	82.2	78.2	74.4	68.4	57.9	47.3	42.3	46.4	57.8	70.3	78.4	85.0	95.7	95.8	100	100	100
	24	100	100	100	100	100	97.8	97.3	93.6	90.8	89.3	82.1	65.8	43.3	32.5	44.5	67.7	84.1	91.3	94.4	97.2	98.1	100	100	100
	25	100	100	100	100	100	96.7	96.3	85.8	75.7	63.6	39.5	17.9	9.5	13.3	33.3	54.9	63.6	67.8	92.5	96.1	96.5	100	100	100
	26	100	100	100	100	100	97.7	96.5	93.5	77.1	69.4	68.3	66.3	62.9	59.8	58.6	60.7	63.2	68.1	76.8	90.6	97.8	100	100	100
	27	100	100	100	100	100	96.9	96.8	96.4	95.8	95.3	93.4	87.3	92.0	95.5	93.8	93.9	95.6	96.2	97.2	97.8	98.3	100	100	100
	28	100	100	100	100	100	96.9	96.7	88.7	81.3	70.7	49.2	25.2	12.8	15.3	31.8	57.2	74.1	80.2	94.6	96.9	97.2	100	100	100
	29	100	100	100	100	100	96.6	96.4	95.0	82.4	69.1	44.8	19.7	9.5	12.4	24.3	44.0	60.0	70.1	86.5	96.1	96.5	100	100	100
	30	100	100	100	100	100	99.4	97.8	97.3	94.0	93.4	93.8	90.1	90.6	91.8	92.7	93.6	94.0	91.3	96.3	98.6	99.4	100	100	100
	31	100	100	100	100	100	99.5	98.6	96.6	95.4	94.9	94.5	94.6	94.0	94.2	93.6	95.2	97.2	97.9	99.1	99.4	99.5	100	100	100
	32	100	100	100	100	100	99.0	97.9	93.1	92.8	91.4	89.4	87.1	85.3	82.2	82.9	87.1	89.6	94.4	98.9	99.0	99.0	100	100	100
	33	100	100	100	100	100	96.6	96.5	96.2	95.9	95.9	96.1	95.7	93.7	87.9	86.1	91.6	94.5	96.1	96.5	96.5	96.5	100	100	100
	34	100	100	100	100	100	96.2	95.8	75.8	57.1	54.8	51.5	48.5	45.9	41.5	28.0	30.9	61.2	72.1	89.9	96.4	96.4	100	100	100
	35	100	100	100	100	100	97.1	96.9	89.0	70.0	51.9	25.6	11.9	11.3	22.7	43.4	60.8	67.2	70.0	84.7	96.2	96.6	100	100	100
	36	100	100	100	100	100	95.8	95.3	68.6	57.3	43.6	24.8	16.6	17.1	22.9	36.2	48.0	53.2	61.9	93.4	95.3	95.9	100	100	100
	37	100	100	100	100	100	99.0	98.9	98.3	93.0	81.6	72.1	68.3	76.7	83.4	85.0	86.5	89.1	91.5	95.7	98.0	99.1	100	100	100
	38	100	100	100	100	100	96.9	96.9	96.7	95.8	95.0	95.3	96.1	96.0	95.6	91.2	86.5	90.4	95.2	96.3	96.3	96.6	100	100	100
	39	100	100	100	100	100	95.9	96.1	88.0	65.5	62.8	60.2	61.8	62.2	62.3	61.7	60.6	59.5	56.4	59.0	84.8	95.8	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	40	100	100	100	100	100	96.5	96.5	95.8	91.6	90.7	93.7	93.3	94.3	95.6	95.0	94.0	94.7	93.6	95.8	96.5	96.6	100	100	100
	41	100	100	100	100	100	95.7	95.2	76.0	61.6	54.4	39.5	24.4	14.9	13.1	20.3	34.8	49.7	73.3	95.1	95.3	95.9	100	100	100
	42	100	100	100	100	100	98.4	92.6	88.0	83.8	81.5	80.0	78.2	76.1	72.0	62.7	67.6	75.1	87.2	96.2	98.5	98.6	100	100	100
	43	100	100	100	100	100	96.5	96.4	95.8	95.4	95.2	95.4	95.3	93.4	92.2	90.4	89.3	94.3	95.4	96.4	96.5	96.6	100	100	100
	44	100	100	100	100	100	95.7	95.3	92.7	58.0	54.5	43.3	28.0	17.0	12.2	16.1	25.0	42.8	54.1	84.5	95.5	96.2	100	100	100
Lower	1	100	100	100	100	100	93.7	87.7	37.7	29.4	25.4	22.4	19.8	17.1	15.1	13.0	8.8	12.3	26.1	56.0	93.4	93.9	100	100	100
	2	100	100	100	100	100	93.0	64.2	23.3	18.3	14.3	12.9	12.6	11.8	10.3	8.3	8.1	11.3	19.0	52.5	92.9	93.3	100	100	100
	3	100	100	100	100	100	98.9	95.5	91.3	89.9	83.9	79.0	77.0	71.8	61.5	64.9	77.1	83.9	92.0	96.8	98.9	99.0	100	100	100
	4	100	100	100	100	100	96.7	84.1	70.6	59.8	50.4	45.1	42.5	39.3	40.3	46.9	54.7	60.1	68.0	84.1	96.6	96.8	100	100	100
	5	100	100	100	100	100	99.6	99.4	98.0	97.6	96.9	95.6	93.5	92.9	93.5	89.3	86.8	88.7	93.4	97.5	99.6	99.6	100	100	100
	6	100	100	100	100	100	95.0	94.8	82.1	59.2	45.0	36.7	33.9	29.0	23.9	19.2	18.6	23.5	36.5	81.3	94.8	95.0	100	100	100
	7	100	100	100	100	100	94.8	94.4	73.4	58.7	45.1	42.0	40.1	37.0	30.8	25.2	22.4	23.2	37.5	73.9	94.7	95.0	100	100	100
	8	100	100	100	100	100	97.8	97.7	97.1	96.3	90.9	78.7	76.1	88.2	95.6	96.2	96.6	96.8	96.8	96.9	97.1	97.9	100	100	100
	9	100	100	100	100	100	99.0	98.8	96.2	89.8	80.8	74.7	74.7	83.6	89.6	91.5	93.0	94.1	95.9	97.1	98.5	99.0	100	100	100
	10	100	100	100	100	100	95.2	90.8	53.3	42.7	37.0	34.0	31.1	28.8	26.5	25.1	25.5	30.5	42.5	61.6	90.5	95.3	100	100	100
	11	100	100	100	100	100	96.2	95.6	82.9	69.7	65.3	40.0	13.5	6.4	11.3	31.0	52.9	59.0	59.3	74.2	95.3	96.1	100	100	100
	12	100	100	100	100	100	96.4	92.3	82.6	74.5	60.5	39.3	23.6	19.5	23.6	34.7	46.1	53.7	62.4	82.7	95.8	96.1	100	100	100
	13	100	100	100	100	100	95.2	93.5	86.5	48.8	21.6	13.3	12.1	15.6	22.5	30.2	39.0	51.5	68.4	82.5	95.0	95.2	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-45. Hourly Effective Shade (%) for Maximum Weekly Fall Conditions for EOY112 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	100	97.2	96.5	88.5	86.7	89.8	92.2	91.1	90.2	86.4	88.5	89.9	90.9	97.4	100	100	100	100	100
	2	100	100	100	100	100	100	96.5	91.7	79.8	72.1	70.7	68.9	66.4	63.9	62.3	55.8	68.3	91.7	96.5	100	100	100	100	100
	3	100	100	100	100	100	100	98.9	97.2	91.0	86.2	85.6	82.9	83.1	81.5	83.0	85.8	96.9	98.6	99.0	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	87.8	66.0	56.8	46.8	44.4	49.1	57.7	66.3	75.8	90.9	94.9	96.2	100	100	100	100	100
	5	100	100	100	100	100	100	97.2	96.7	83.0	73.7	67.8	66.2	68.0	70.7	75.0	82.4	89.5	94.5	97.1	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	6	100	100	100	100	100	100	96.1	93.0	79.1	61.3	57.1	56.8	59.9	64.5	68.6	72.2	77.8	88.3	96.4	100	100	100	100	100
	7	100	100	100	100	100	100	96.2	95.7	88.8	71.7	62.7	56.4	51.7	53.6	58.0	64.8	77.9	94.9	96.5	100	100	100	100	100
	8	100	100	100	100	100	100	94.4	94.4	93.9	78.7	73.1	68.1	63.6	65.3	71.9	77.1	84.2	94.2	94.5	100	100	100	100	100
	9	100	100	100	100	100	100	97.7	91.4	84.7	77.4	73.9	71.9	69.1	67.6	66.8	66.9	78.9	94.8	98.2	100	100	100	100	100
	10	100	100	100	100	100	100	95.8	95.8	95.7	95.7	95.6	95.4	95.4	95.3	95.1	95.0	95.5	95.9	95.9	100	100	100	100	100
	11	100	100	100	100	100	100	94.5	91.1	81.7	76.6	75.2	71.6	67.4	68.6	71.5	74.7	83.2	93.6	94.4	100	100	100	100	100
	12	100	100	100	100	100	100	98.8	91.6	91.1	92.1	91.8	89.1	89.5	90.5	91.2	93.1	93.8	97.5	98.9	100	100	100	100	100
	13	100	100	100	100	100	100	96.4	96.0	95.5	95.4	95.4	95.5	95.3	95.6	95.5	95.7	95.7	95.9	95.9	100	100	100	100	100
	14	100	100	100	100	100	100	94.5	93.2	88.9	79.6	71.7	69.9	69.4	70.2	71.3	74.0	79.5	83.5	94.4	100	100	100	100	100
	15	100	100	100	100	100	100	94.3	86.0	78.3	73.9	70.6	65.4	62.2	66.4	76.1	82.6	83.1	83.1	94.3	100	100	100	100	100
	16	100	100	100	100	100	100	95.3	91.3	87.6	86.5	84.7	81.8	77.1	73.1	69.7	68.8	79.5	89.3	95.0	100	100	100	100	100
	17	100	100	100	100	100	100	94.4	89.2	81.9	83.2	80.8	75.3	67.3	63.3	67.6	76.2	82.8	91.3	94.4	100	100	100	100	100
	18	100	100	100	100	100	100	94.5	88.7	79.4	78.3	76.3	75.9	73.1	70.6	72.7	75.0	77.3	89.6	94.5	100	100	100	100	100
	19	100	100	100	100	100	100	92.1	83.4	59.2	37.3	34.5	31.5	29.1	28.5	32.2	36.7	50.1	88.1	92.2	100	100	100	100	100
	20	100	100	100	100	100	100	95.1	94.1	87.1	78.7	76.6	73.1	70.6	68.5	72.2	75.6	83.9	93.9	94.3	100	100	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	100	95.9	96.0	95.9	94.0	94.4	85.5	75.9	81.8	92.1	94.2	95.1	95.3	95.8	100	100	100	100	100
	23	100	100	100	100	100	100	94.9	90.8	82.8	81.1	80.2	76.6	70.8	68.0	69.6	73.4	77.7	90.5	94.4	100	100	100	100	100
	24	100	100	100	100	100	100	97.7	96.8	93.5	89.9	85.6	79.9	65.6	55.8	63.0	76.6	85.5	96.0	96.7	100	100	100	100	100
	25	100	100	100	100	100	100	95.6	95.1	81.7	65.3	46.1	29.6	26.0	40.6	59.5	65.8	81.1	94.7	95.4	100	100	100	100	100
	26	100	100	100	100	100	100	97.0	95.8	94.3	86.0	77.1	73.4	70.5	66.8	66.5	71.5	78.1	84.1	93.8	100	100	100	100	100
	27	100	100	100	100	100	100	96.1	95.8	95.5	94.0	91.2	93.2	94.6	95.6	95.5	94.7	96.1	97.4	97.8	100	100	100	100	100
	28	100	100	100	100	100	100	95.9	95.7	88.9	74.3	59.9	42.2	34.7	38.5	57.4	71.0	85.5	95.8	96.2	100	100	100	100	100
	29	100	100	100	100	100	100	95.6	95.3	94.6	78.2	55.4	34.9	27.2	30.7	43.0	59.4	75.6	94.6	95.2	100	100	100	100	100
	30	100	100	100	100	100	100	99.1	98.2	97.6	95.3	93.3	93.6	93.0	94.5	95.0	95.8	97.5	99.0	99.2	100	100	100	100	100
	31	100	100	100	100	100	100	99.2	99.2	98.5	97.7	97.3	96.7	96.3	96.2	96.4	96.5	95.9	97.9	99.3	100	100	100	100	100
	32	100	100	100	100	100	100	98.7	98.6	96.0	93.9	93.6	91.7	89.0	86.6	86.5	88.8	97.1	98.5	98.7	100	100	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	33	100	100	100	100	100	100	95.4	95.4	95.3	95.2	95.0	95.2	93.8	91.1	92.1	90.8	94.9	95.3	95.5	100	100	100	100	100
	34	100	100	100	100	100	100	93.9	93.9	78.4	57.4	56.8	54.8	52.9	52.5	44.3	49.2	51.8	94.4	95.3	100	100	100	100	100
	35	100	100	100	100	100	100	96.0	95.7	85.4	58.5	35.7	31.4	41.6	59.7	71.0	75.9	81.9	95.0	95.3	100	100	100	100	100
	36	100	100	100	100	100	100	94.4	93.8	68.3	57.1	43.5	39.1	48.1	60.5	66.9	67.1	82.2	93.8	94.2	100	100	100	100	100
	37	100	100	100	100	100	100	98.6	98.2	96.7	90.4	78.0	77.4	84.6	87.0	89.3	92.8	96.6	98.6	98.8	100	100	100	100	100
	38	100	100	100	100	100	100	96.9	96.8	96.7	96.4	96.0	95.6	95.4	95.3	94.9	93.1	92.7	94.8	95.7	100	100	100	100	100
	39	100	100	100	100	100	100	95.3	95.4	90.4	65.3	65.1	65.6	66.5	67.0	67.4	67.2	66.0	72.7	95.1	100	100	100	100	100
	40	100	100	100	100	100	100	95.5	95.3	95.2	94.8	94.2	94.6	94.7	95.3	95.3	94.7	94.9	95.3	95.4	100	100	100	100	100
	41	100	100	100	100	100	100	94.5	93.7	80.7	63.5	55.8	47.2	43.3	42.5	46.2	55.4	90.5	93.6	94.2	100	100	100	100	100
	42	100	100	100	100	100	100	98.0	95.9	93.2	88.7	84.8	82.6	80.4	78.3	72.1	77.5	90.5	96.0	97.9	100	100	100	100	100
	43	100	100	100	100	100	100	95.5	95.3	94.9	95.2	95.0	94.7	93.7	94.3	92.9	94.3	95.2	95.3	95.5	100	100	100	100	100
	44	100	100	100	100	100	100	94.4	93.9	93.2	72.0	63.6	54.7	47.8	40.5	40.2	46.8	70.9	93.8	94.2	100	100	100	100	100
	1	100	100	100	100	100	100	92.2	92.1	77.4	54.0	40.4	32.2	26.8	23.4	19.5	15.9	13.6	66.0	91.5	100	100	100	100	100
	2	100	100	100	100	100	100	90.9	68.9	34.8	26.7	22.5	19.2	18.1	17.9	16.6	16.4	23.0	83.1	90.9	100	100	100	100	100
	3	100	100	100	100	100	100	98.6	96.8	93.0	89.7	81.4	77.0	72.9	69.0	74.3	80.3	92.0	98.2	98.7	100	100	100	100	100
	4	100	100	100	100	100	100	95.8	95.6	91.7	79.3	67.4	58.5	51.0	53.7	58.6	64.1	69.1	94.7	95.6	100	100	100	100	100
	5	100	100	100	100	100	100	99.5	99.2	98.3	97.9	96.9	96.0	94.7	93.8	92.6	89.3	94.2	99.0	99.2	100	100	100	100	100
	6	100	100	100	100	100	100	93.5	93.3	89.2	72.6	58.9	49.6	41.9	35.5	33.0	31.0	54.4	92.7	93.4	100	100	100	100	100
Lower	7	100	100	100	100	100	100	93.4	93.3	79.9	75.2	60.1	54.0	52.4	48.7	44.5	42.5	58.3	84.9	93.3	100	100	100	100	100
	8	100	100	100	100	100	100	97.3	96.7	95.2	95.3	87.3	86.3	94.2	95.5	95.8	95.8	96.1	96.7	97.2	100	100	100	100	100
	9	100	100	100	100	100	100	98.6	98.4	96.4	92.7	84.3	86.4	92.1	95.5	96.6	96.7	96.0	97.4	98.5	100	100	100	100	100
	10	100	100	100	100	100	100	93.7	90.9	66.9	56.5	49.8	45.8	43.3	42.1	42.6	46.1	53.0	70.0	93.6	100	100	100	100	100
	11	100	100	100	100	100	100	95.1	94.0	84.1	63.8	46.6	20.9	19.4	36.2	55.7	58.9	64.0	94.1	94.8	100	100	100	100	100
	12	100	100	100	100	100	100	95.2	92.0	82.8	75.2	50.8	36.8	37.9	46.0	54.1	61.6	78.6	94.3	94.9	100	100	100	100	100
	13	100	100	100	100	100	100	93.7	91.3	83.1	48.3	26.3	27.4	32.8	42.5	56.7	73.2	84.4	91.6	93.7	100	100	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Table B-46. Hourly Effective Shade (%) for Mean August Conditions for EOY112 Disturbance Condition for the ModPRO2

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Upper	1	100	100	100	100	100	99.0	97.5	91.0	82.1	79.8	83.0	85.1	84.7	82.5	80.7	84.3	86.0	85.3	88.9	94.1	98.9	100	100	100
	2	100	100	100	100	100	98.7	93.0	84.0	75.7	69.5	65.7	63.1	60.6	57.1	52.4	51.1	64.6	82.0	92.6	98.5	98.8	100	100	100
	3	100	100	100	100	100	99.6	98.3	94.7	89.8	85.9	84.6	82.8	80.9	79.3	81.9	84.3	91.4	94.9	98.9	99.6	99.7	100	100	100
	4	100	100	100	100	100	98.4	92.6	81.2	63.3	53.1	43.8	39.1	42.6	51.1	60.7	70.7	82.2	89.9	95.2	98.5	98.6	100	100	100
	5	100	100	100	100	100	99.0	96.8	90.4	78.5	68.6	61.4	59.2	60.7	64.7	68.4	75.7	84.7	90.7	93.6	97.7	98.9	100	100	100
	6	100	100	100	100	100	98.5	95.8	87.0	69.9	55.6	50.7	48.8	51.8	56.9	61.5	65.2	70.2	78.6	87.6	96.1	98.7	100	100	100
	7	100	100	100	100	100	98.6	96.5	91.6	81.2	70.0	62.2	55.2	48.6	48.9	53.8	60.7	69.7	81.4	92.3	98.5	98.7	100	100	100
	8	100	100	100	100	100	97.9	95.1	94.4	86.7	75.0	66.7	58.1	51.9	53.6	62.4	71.9	79.5	86.7	93.1	97.9	97.9	100	100	100
	9	100	100	100	100	100	99.1	93.7	86.2	80.1	74.7	72.2	70.3	66.5	62.0	61.3	64.6	75.1	88.0	96.3	99.2	99.2	100	100	100
	10	100	100	100	100	100	98.4	96.3	96.3	96.0	95.9	96.1	95.8	95.6	95.4	94.9	95.2	95.5	96.3	96.4	98.5	98.5	100	100	100
	11	100	100	100	100	100	97.9	93.1	85.3	78.8	73.6	68.2	60.9	55.2	55.6	61.1	68.0	77.1	85.2	92.3	97.9	98.0	100	100	100
	12	100	100	100	100	100	99.2	98.6	92.9	89.1	87.1	87.9	87.2	87.4	88.9	89.5	89.7	90.7	94.0	95.7	99.2	99.6	100	100	100
	13	100	100	100	100	100	98.7	96.8	96.4	95.9	95.7	95.2	95.6	95.5	95.7	96.0	96.0	96.0	96.1	96.3	98.5	98.6	100	100	100
	14	100	100	100	100	100	97.9	94.5	90.9	85.1	77.1	65.6	59.6	55.9	56.5	60.9	68.3	76.6	81.4	88.0	95.0	97.9	100	100	100
	15	100	100	100	100	100	97.8	89.7	84.3	78.8	71.9	63.8	54.7	49.5	54.3	66.1	76.5	79.9	81.5	89.5	93.9	97.9	100	100	100
	16	100	100	100	100	100	98.2	91.8	87.9	86.5	85.6	82.0	76.0	67.7	59.0	54.1	56.5	71.6	87.4	94.1	97.6	98.1	100	100	100
	17	100	100	100	100	100	97.9	92.1	84.3	78.5	78.1	74.2	66.1	55.7	51.5	57.6	68.8	77.3	83.7	89.7	97.8	97.9	100	100	100
	18	100	100	100	100	100	97.9	92.7	85.5	78.5	74.5	69.1	64.8	60.1	58.4	61.8	68.7	75.3	84.7	88.9	97.9	97.9	100	100	100
	19	100	100	100	100	100	97.0	87.7	70.2	48.4	35.8	32.7	29.5	26.2	25.3	29.2	34.4	43.2	64.6	81.6	96.9	97.2	100	100	100
	20	100	100	100	100	100	98.1	95.4	90.9	83.8	76.7	73.5	70.1	66.3	64.9	70.4	74.2	78.5	84.5	93.6	97.7	98.1	100	100	100
	21	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	98.5	96.4	96.4	96.0	95.1	94.4	85.9	70.4	75.4	91.0	94.5	95.4	95.6	96.1	98.4	98.5	100	100	100
	23	100	100	100	100	100	98.1	92.6	86.5	80.5	77.8	74.3	67.3	59.1	55.2	58.0	65.6	74.0	84.5	89.7	97.9	97.9	100	100	100
	24	100	100	100	100	100	98.9	97.5	95.2	92.2	89.6	83.9	72.9	54.5	44.2	53.8	72.2	84.8	93.7	95.6	98.6	99.1	100	100	100
	25	100	100	100	100	100	98.4	96.0	90.5	78.7	64.5	42.8	23.8	17.8	27.0	46.4	60.4	72.4	81.3	94.0	98.1	98.3	100	100	100
	26	100	100	100	100	100	98.9	96.8	94.7	85.7	77.7	72.7	69.9	66.7	63.3	62.6	66.1	70.7	76.1	85.3	95.3	98.9	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	27	100	100	100	100	100	98.5	96.5	96.1	95.7	94.7	92.3	90.3	93.3	95.6	94.7	94.3	95.9	96.8	97.5	98.9	99.2	100	100	100
	28	100	100	100	100	100	98.5	96.3	92.2	85.1	72.5	54.6	33.7	23.8	26.9	44.6	64.1	79.8	88.0	95.4	98.5	98.6	100	100	100
	29	100	100	100	100	100	98.3	96.0	95.2	88.5	73.7	50.1	27.3	18.4	21.6	33.7	51.7	67.8	82.4	90.9	98.1	98.3	100	100	100
	30	100	100	100	100	100	99.7	98.5	97.8	95.8	94.4	93.6	91.9	91.8	93.2	93.9	94.7	95.8	95.2	97.8	99.3	99.7	100	100	100
	31	100	100	100	100	100	99.8	98.9	97.9	97.0	96.3	95.9	95.7	95.2	95.2	95.0	95.9	96.6	97.9	99.2	99.7	99.8	100	100	100
	32	100	100	100	100	100	99.5	98.3	95.9	94.4	92.7	91.5	89.4	87.2	84.4	84.7	88.0	93.4	96.5	98.8	99.5	99.5	100	100	100
	33	100	100	100	100	100	98.3	96.0	95.8	95.6	95.6	95.6	95.5	93.8	89.5	89.1	91.2	94.7	95.7	96.0	98.3	98.3	100	100	100
	34	100	100	100	100	100	98.1	94.9	84.9	67.8	56.1	54.2	51.7	49.4	47.0	36.2	40.1	56.5	83.3	92.6	98.2	98.2	100	100	100
	35	100	100	100	100	100	98.6	96.5	92.4	77.7	55.2	30.7	21.7	26.5	41.2	57.2	68.4	74.6	82.5	90.0	98.1	98.3	100	100	100
	36	100	100	100	100	100	97.9	94.9	81.2	62.8	50.4	34.2	27.9	32.6	41.7	51.6	57.6	67.7	77.9	93.8	97.7	98.0	100	100	100
	37	100	100	100	100	100	99.5	98.8	98.3	94.9	86.0	75.1	72.9	80.7	85.2	87.2	89.7	92.9	95.1	97.3	99.0	99.6	100	100	100
	38	100	100	100	100	100	98.5	96.9	96.8	96.3	95.7	95.7	95.9	95.7	95.5	93.1	89.8	91.6	95.0	96.0	98.2	98.3	100	100	100
	39	100	100	100	100	100	98.0	95.7	91.7	78.0	64.1	62.7	63.7	64.4	64.7	64.6	63.9	62.8	64.6	77.1	92.4	97.9	100	100	100
	40	100	100	100	100	100	98.3	96.0	95.6	93.4	92.8	94.0	94.0	94.5	95.5	95.2	94.4	94.8	94.5	95.6	98.3	98.3	100	100	100
	41	100	100	100	100	100	97.9	94.9	84.9	71.2	59.0	47.7	35.8	29.1	27.8	33.3	45.1	70.1	83.5	94.7	97.7	98.0	100	100	100
	42	100	100	100	100	100	99.2	95.3	92.0	88.5	85.1	82.4	80.4	78.3	75.2	67.4	72.6	82.8	91.6	97.1	99.3	99.3	100	100	100
	43	100	100	100	100	100	98.3	96.0	95.6	95.2	95.2	95.2	95.0	93.6	93.3	91.7	91.8	94.8	95.4	96.0	98.3	98.3	100	100	100
	44	100	100	100	100	100	97.9	94.9	93.3	75.6	63.3	53.5	41.4	32.4	26.4	28.2	35.9	56.9	74.0	89.4	97.8	98.1	100	100	100
	1	100	100	100	100	100	96.9	90.0	64.9	53.4	39.7	31.4	26.0	22.0	19.3	16.3	12.4	13.0	46.1	73.8	96.7	97.0	100	100	100
	2	100	100	100	100	100	96.5	77.6	46.1	26.6	20.5	17.7	15.9	15.0	14.1	12.5	12.3	17.2	51.1	71.7	96.5	96.7	100	100	100
	3	100	100	100	100	100	99.5	97.1	94.1	91.5	86.8	80.2	77.0	72.4	65.3	69.6	78.7	88.0	95.1	97.8	99.5	99.5	100	100	100
	4	100	100	100	100	100	98.4	90.0	83.1	75.8	64.9	56.3	50.5	45.2	47.0	52.8	59.4	64.6	81.4	89.9	98.3	98.4	100	100	100
Lower	5	100	100	100	100	100	99.8	99.5	98.6	98.0	97.4	96.3	94.8	93.8	93.7	91.0	88.1	91.5	96.2	98.4	99.8	99.8	100	100	100
	6	100	100	100	100	100	97.5	94.2	87.7	74.2	58.8	47.8	41.8	35.5	29.7	26.1	24.8	39.0	64.6	87.4	97.4	97.5	100	100	100
	7	100	100	100	100	100	97.4	93.9	83.4	69.3	60.2	51.1	47.1	44.7	39.8	34.9	32.5	40.8	61.2	83.6	97.4	97.5	100	100	100
	8	100	100	100	100	100	98.9	97.5	96.9	95.8	93.1	83.0	81.2	91.2	95.6	96.0	96.2	96.5	96.8	97.1	98.6	99.0	100	100	100
	9	100	100	100	100	100	99.5	98.7	97.3	93.1	86.8	79.5	80.6	87.9	92.6	94.1	94.9	95.1	96.7	97.8	99.3	99.5	100	100	100

Model	Number	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
	10	100	100	100	100	100	97.6	92.3	72.1	54.8	46.8	41.9	38.5	36.1	34.3	33.9	35.8	41.8	56.3	77.6	95.3	97.7	100	100	100
	11	100	100	100	100	100	98.1	95.4	88.5	76.9	64.6	43.3	17.2	12.9	23.8	43.4	55.9	61.5	76.7	84.5	97.7	98.1	100	100	100
	12	100	100	100	100	100	98.2	93.8	87.3	78.7	67.9	45.1	30.2	28.7	34.8	44.4	53.9	66.2	78.4	88.8	97.9	98.1	100	100	100
	13	100	100	100	100	100	97.6	93.6	88.9	66.0	35.0	19.8	19.8	24.2	32.5	43.5	56.1	68.0	80.0	88.1	97.5	97.6	100	100	100

Abbreviations:

% = percent *EOY = end of year*

Section 6: Outputs for Post Closure for the ModPRO2

Table B-47. Simulated Reach Temperatures (°C) for Maximum Weekly Summer Conditions for ModPRO2 EOY18 through EOY22 Disturbance Conditions

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
Upper	1	0.50	13.54	13.54	9.86	9.86	7.12	7.12
	2	0.43	13.84	13.84	10.08	10.08	7.40	7.40
	3	0.63	11.66	11.66	8.66	8.65	6.36	6.36
	4	0.67	13.32	13.32	9.91	9.91	7.33	7.33
	5	0.86	13.37	13.37	10.13	10.13	7.53	7.53
	6	1.91	13.35	13.35	10.33	10.33	7.80	7.80
	7	1.40	14.83	14.83	11.47	11.47	9.00	9.00
	8	0.76	11.59	11.59	8.93	8.93	6.90	6.91
	9	1.30	11.53	11.53	9.02	9.02	7.14	7.14
	10	0.76	12.89	12.88	9.77	9.85	7.64	7.78
	11	1.40	11.79	11.80	9.24	9.28	7.32	7.37
	12	2.44	12.83	12.83	10.12	10.13	8.03	8.05
	13	0.31	12.73	12.73	10.04	10.05	7.97	7.99
	14	0.35	12.70	12.70	10.02	10.03	7.96	7.98
	15	0.61	13.16	13.15	10.58	10.56	8.59	8.57
	16	0.29	13.76	13.72	10.98	10.95	8.69	8.65
	17	2.76	13.73	13.72	10.41	10.42	8.08	8.09
	18	0.58	15.10	15.04	11.43	11.41	8.96	8.96
	19	0.41	14.85	14.81	11.44	11.41	9.12	9.09
	20	0.67	16.07	15.83	11.82	11.71	9.07	9.04
	21	1.33	16.04	15.84	11.75	11.66	8.65	8.62
	22	0.28	16.80	16.59	12.16	12.06	8.90	8.88
	23	0.63	15.31	15.39	11.42	11.72	8.34	8.79
	24	1.37	14.48	14.48	11.45	11.45	9.37	9.37
	25	0.46	15.28	14.89	11.91	11.74	9.29	9.29
	26	0.6	15.50	15.56	11.51	11.78	8.37	8.80
	27	1.22	16.03	16.08	11.68	11.93	8.35	8.76
	28	0.52	11.40	11.40	8.60	8.61	6.40	6.42
	29	0.33	11.10	11.11	8.81	8.82	7.06	7.07
	30	1.32	11.23	11.23	9.27	9.27	7.65	7.66
	31	0.42	11.27	11.28	9.39	9.39	7.76	7.77
	32	0.15	11.58	11.58	9.54	9.55	7.83	7.83

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
	33	0.36	16.01	16.05	11.62	11.85	8.30	8.67
	34	0.43	16.77	16.70	11.85	12.04	8.29	8.64
	35	1.53	12.62	12.62	10.87	10.87	9.38	9.38
	36	0.28	14.71	14.20	11.58	11.36	9.48	9.48
	37	0.7	15.24	14.80	11.72	11.54	9.23	9.25
	38	0.71	18.89	17.02	12.88	12.24	8.61	8.62
	39	0.38	17.89	17.64	12.20	12.30	8.21	8.54
	40	1.48	13.69	13.54	10.33	10.27	8.22	8.22
	41	0.45	17.03	16.04	11.33	11.00	8.29	8.29
	42	0.24	18.34	18.04	12.33	12.40	8.16	8.48
Lower	1	0.55	14.01	14.01	9.92	9.92	6.95	6.95
	2	0.58	14.59	14.58	10.21	10.21	7.29	7.29
	3	0.26	11.96	11.97	9.35	9.39	7.40	7.48
	4	0.17	14.55	14.55	10.22	10.22	7.32	7.32
	5	0.24	11.56	11.57	8.81	8.82	6.71	6.72
	6	0.71	14.75	14.75	10.32	10.32	7.35	7.35
	7	0.92	15.17	15.17	10.51	10.51	7.42	7.42
	8	0.23	20.85	20.85	15.00	15.00	11.03	11.03
	9	0.54	17.43	18.05	13.34	13.55	9.83	9.68
	10	1.19	15.66	15.65	10.82	10.82	7.56	7.57
	11	0.06	13.82	13.82	13.66	13.66	13.58	13.58
	12	1.13	14.48	14.47	13.75	13.74	13.41	13.41
	13	0.86	15.11	15.08	12.62	12.63	10.75	10.78

Abbreviations:
°C = degree Celsius
EOY = end of year

Table B-48. Simulated Reach Temperatures (°C) for Maximum Weekly Summer Conditions for ModPRO2 EOY27 through EOY112

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
Upper	1	0.5	13.53	13.53	13.53	13.53	9.85	9.85	9.85	9.85	7.11	7.11	7.11	7.11
	2	0.43	13.79	13.79	13.79	13.79	10.06	10.06	10.06	10.06	7.38	7.38	7.38	7.38
	3	0.63	11.64	11.64	11.64	11.64	8.65	8.65	8.65	8.65	6.35	6.35	6.35	6.35
	4	0.67	13.26	13.26	13.26	13.26	9.88	9.88	9.88	9.88	7.31	7.31	7.31	7.31
	5	0.86	13.30	13.30	13.30	13.30	10.09	10.09	10.09	10.09	7.52	7.52	7.52	7.52
	6	1.91	13.25	13.25	13.25	13.25	10.27	10.27	10.27	10.28	7.80	7.79	7.79	7.80

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
	7	1.4	14.85	14.85	14.85	14.85	11.41	11.41	11.41	11.41	8.87	8.87	8.87	8.87
	8	1.87	22.25	21.40	19.77	17.43	13.75	13.28	12.65	11.79	7.81	7.80	7.78	7.76
	9	0.76	12.82	12.80	12.81	12.82	9.73	9.99	9.80	9.67	7.60	8.07	7.72	7.50
	10	0.83	16.46	12.76	12.48	12.34	10.93	9.83	9.54	9.36	7.16	7.64	7.27	7.03
	11	0.91	24.24	21.62	19.77	16.97	14.34	13.19	12.37	11.21	6.97	7.04	6.88	6.75
	12	0.76	11.58	11.58	11.58	11.58	8.92	8.92	8.92	8.93	6.90	6.89	6.90	6.90
	13	1.33	14.18	11.31	11.19	11.15	10.06	8.80	8.74	8.72	6.76	6.73	6.73	6.74
	14	1.27	22.73	19.69	17.70	15.07	13.81	12.37	11.53	10.41	6.73	6.66	6.55	6.43
	15	0.56	24.14	21.49	18.97	15.68	14.68	13.23	12.17	10.73	6.88	6.70	6.55	6.37
	16	0.73	24.54	22.29	19.94	16.55	15.02	13.58	12.43	10.85	7.01	6.75	6.58	6.35
	17	0.8	20.53	19.35	17.87	15.74	14.67	13.79	13.04	12.05	9.67	9.45	9.36	9.24
	18	0.29	19.39	18.54	17.25	15.51	14.59	13.87	13.22	12.40	10.43	10.22	10.15	10.05
	19	2.76	13.66	13.66	13.66	13.66	10.30	10.29	10.29	10.29	7.93	7.92	7.92	7.92
	20	0.58	14.88	14.81	14.67	14.63	11.26	11.24	11.20	11.19	8.82	8.81	8.81	8.82
	21	0.41	14.62	14.53	14.37	14.34	11.27	11.24	11.19	11.18	8.98	8.97	8.97	8.97
	22	0.67	15.35	14.99	14.08	13.67	11.45	11.32	11.05	10.98	8.88	8.87	8.87	8.87
	23	1.33	18.47	17.86	16.56	15.20	13.86	13.31	12.68	12.03	10.00	9.79	9.68	9.58
	24	0.28	18.56	17.96	16.59	15.29	13.94	13.41	12.77	12.15	10.12	9.91	9.80	9.72
	25	0.63	16.10	15.78	15.08	14.47	12.28	12.03	11.70	11.41	8.99	8.88	8.82	8.79
	26	1.37	14.35	14.35	14.35	14.35	11.39	11.39	11.39	11.39	9.37	9.37	9.37	9.37
	27	0.46	14.38	14.23	13.79	13.67	11.47	11.39	11.23	11.20	9.28	9.30	9.29	9.28
	28	0.6	16.12	15.80	15.09	14.51	12.30	12.05	11.73	11.45	9.00	8.89	8.83	8.79
	29	1.22	16.39	16.06	15.35	14.85	12.40	12.15	11.83	11.56	8.98	8.87	8.80	8.77
	30	0.52	11.41	11.39	11.39	11.39	8.67	8.59	8.60	8.59	6.52	6.39	6.40	6.38
	31	0.33	11.12	11.09	11.10	11.09	8.87	8.80	8.80	8.79	7.17	7.06	7.06	7.04
	32	1.32	11.23	11.21	11.21	11.20	9.30	9.26	9.26	9.25	7.72	7.67	7.66	7.65
	33	0.42	11.44	11.36	11.27	11.26	9.56	9.51	9.46	9.45	7.94	7.89	7.88	7.88
	34	0.15	11.85	11.77	11.61	11.56	9.74	9.68	9.62	9.61	8.00	7.96	7.95	7.96
	35	0.36	16.24	15.92	15.26	14.85	12.27	12.04	11.74	11.49	8.91	8.79	8.73	8.69
	36	0.43	16.70	16.37	15.62	15.19	12.41	12.18	11.85	11.59	8.90	8.78	8.71	8.66
	37	1.53	12.54	12.54	12.54	12.54	10.84	10.84	10.84	10.84	9.38	9.38	9.38	9.38
	38	0.28	13.84	13.59	12.78	12.67	11.21	11.12	10.94	10.92	9.48	9.48	9.48	9.48
	39	0.7	14.47	14.28	13.69	13.60	11.40	11.32	11.18	11.18	9.25	9.24	9.25	9.29
	40	0.71	15.60	14.81	13.24	13.12	11.68	11.38	10.75	10.72	8.61	8.60	8.61	8.64
	41	0.38	17.38	17.01	16.13	15.70	12.57	12.34	11.96	11.70	8.84	8.72	8.64	8.58
	42	1.48	13.36	13.29	13.06	13.03	10.20	10.18	10.12	10.12	8.21	8.21	8.21	8.21

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
	43	0.45	15.48	15.06	14.06	13.77	10.78	10.64	10.35	10.32	8.29	8.29	8.29	8.28
	44	0.24	17.70	17.33	16.42	15.99	12.62	12.39	12.00	11.74	8.79	8.66	8.59	8.53
Lower	1	0.55	13.98	13.98	13.98	13.98	9.91	9.91	9.91	9.91	6.93	6.93	6.93	6.93
	2	0.58	14.53	14.53	14.53	14.53	10.18	10.18	10.18	10.18	7.25	7.25	7.25	7.25
	3	0.26	11.94	11.93	11.93	11.92	9.37	9.33	9.33	9.27	7.46	7.38	7.39	7.28
	4	0.17	14.49	14.49	14.49	14.49	10.19	10.19	10.19	10.19	7.28	7.28	7.28	7.28
	5	0.24	11.56	11.55	11.56	11.56	8.82	8.81	8.82	8.82	6.72	6.70	6.72	6.72
	6	0.71	14.67	14.67	14.67	14.67	10.28	10.28	10.28	10.28	7.32	7.31	7.32	7.32
	7	0.92	15.06	15.06	15.05	15.05	10.46	10.46	10.46	10.46	7.40	7.40	7.40	7.40
	8	0.23	20.55	20.10	16.59	14.28	14.84	14.21	12.58	12.20	11.02	10.99	10.94	10.93
	9	0.54	16.98	16.42	14.34	13.34	13.13	12.70	11.69	11.50	9.87	9.85	9.90	10.04
	10	1.19	15.50	15.49	15.45	15.44	10.75	10.75	10.74	10.74	7.55	7.54	7.56	7.56
	11	0.06	13.96	13.75	13.40	13.16	13.82	13.61	13.25	13.01	13.76	13.55	13.20	12.96
	12	1.13	14.54	14.34	14.00	13.76	13.88	13.68	13.33	13.10	13.58	13.38	13.04	12.81
	13	0.86	15.01	14.89	14.66	14.52	12.72	12.60	12.39	12.26	11.01	10.89	10.69	10.56

Abbreviations:
°C = degree Celsius
EOY = end of year

Table B-49. Simulated Reach Temperatures (°C) for Maximum Weekly Fall Conditions for ModPRO2 EOY18 through EOY22

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
Upper	1	0.5	10.07	10.07	8.69	8.69	7.57	7.57
	2	0.43	10.59	10.59	8.75	8.75	7.56	7.56
	3	0.63	9.66	9.66	8.09	8.09	6.95	6.95
	4	0.67	10.67	10.67	8.71	8.71	7.45	7.45
	5	0.86	10.88	10.88	8.82	8.82	7.48	7.48
	6	1.91	10.97	10.97	8.85	8.86	7.46	7.47
	7	1.4	11.76	11.76	9.34	9.34	7.97	7.97
	8	0.76	9.65	9.67	8.30	8.35	7.29	7.37
	9	1.3	9.73	9.76	8.27	8.34	7.23	7.32
	10	0.76	10.96	10.96	8.90	8.91	7.69	7.70
	11	1.4	10.11	10.13	8.38	8.42	7.19	7.26
	12	2.44	10.76	10.76	8.66	8.68	7.30	7.33
	13	0.31	10.63	10.63	8.55	8.57	7.17	7.20
	14	0.35	10.59	10.60	8.52	8.55	7.13	7.17
	15	0.61	11.17	11.14	9.23	9.09	7.96	7.74

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
	16	0.29	11.75	11.71	9.47	9.29	8.00	7.73
	17	2.76	11.85	11.85	9.43	9.44	8.15	8.17
	18	0.58	12.85	12.80	9.98	9.98	8.54	8.56
	19	0.41	12.62	12.57	9.97	9.96	8.61	8.63
	20	0.67	13.20	12.98	9.99	9.94	8.27	8.28
	21	1.33	13.10	12.94	9.76	9.63	7.76	7.62
	22	0.28	13.36	13.19	9.95	9.83	7.89	7.78
	23	0.63	12.22	12.11	9.40	9.39	7.54	7.57
	24	1.37	11.93	11.93	9.29	9.29	7.75	7.75
	25	0.46	12.55	12.08	9.36	9.19	7.21	7.21
	26	0.6	12.35	12.22	9.41	9.40	7.49	7.52
	27	1.22	12.68	12.54	9.47	9.45	7.41	7.44
	28	0.52	9.35	9.35	8.03	8.02	6.95	6.94
	29	0.33	9.43	9.42	8.08	8.07	7.09	7.07
	30	1.32	9.87	9.86	8.18	8.16	7.02	7.00
	31	0.42	10.01	10.00	8.15	8.14	6.88	6.87
	32	0.15	10.30	10.29	8.23	8.22	6.87	6.85
	33	0.36	12.70	12.56	9.42	9.40	7.31	7.34
	34	0.43	13.10	12.81	9.49	9.44	7.20	7.22
	35	1.53	10.84	10.84	9.21	9.21	8.07	8.07
	36	0.28	12.08	11.52	9.47	9.31	7.89	7.89
	37	0.7	12.41	12.00	9.40	9.32	7.47	7.55
	38	0.71	14.32	13.05	9.59	9.20	6.50	6.58
	39	0.38	13.80	13.37	9.61	9.50	7.02	7.04
	40	1.48	11.31	11.17	8.76	8.72	7.36	7.36
	41	0.45	13.58	12.50	9.03	8.82	6.89	6.89
	42	0.24	14.12	13.63	9.65	9.53	6.94	6.96
Lower	1	0.55	10.35	10.35	8.80	8.80	7.55	7.55
	2	0.58	11.09	11.09	8.96	8.96	7.61	7.61
	3	0.26	10.34	10.34	8.78	8.79	7.84	7.84
	4	0.17	11.14	11.14	8.96	8.96	7.61	7.61
	5	0.24	9.47	9.47	8.12	8.13	7.08	7.09
	6	0.71	11.44	11.44	8.99	8.99	7.57	7.57
	7	0.92	11.83	11.83	9.04	9.04	7.52	7.53
	8	0.23	16.19	16.19	11.96	11.96	9.67	9.67
	9	0.54	13.76	13.56	10.62	10.59	8.33	8.44

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
	10	1.19	12.24	12.23	9.15	9.15	7.44	7.45
	11	0.06	10.39	10.27	10.21	10.09	10.14	10.03
	12	1.13	10.90	10.78	10.24	10.12	9.99	9.89
	13	0.86	11.60	11.52	9.82	9.76	8.81	8.76

Abbreviations:
°C = degree Celsius
EOY = end of year

Table B-50. Simulated Reach Temperatures (°C) for Maximum Weekly Fall Conditions for ModPRO2 EOY27 through EOY112

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
Upper	1	0.5	10.07	10.07	10.07	10.07	8.69	8.69	8.69	8.69	7.57	7.57	7.57	7.57
	2	0.43	10.59	10.59	10.59	10.59	8.75	8.75	8.75	8.75	7.56	7.56	7.56	7.56
	3	0.63	9.66	9.66	9.66	9.66	8.09	8.09	8.09	8.09	6.95	6.95	6.95	6.95
	4	0.67	10.67	10.67	10.67	10.67	8.71	8.71	8.71	8.71	7.45	7.45	7.45	7.45
	5	0.86	10.88	10.88	10.88	10.88	8.82	8.82	8.82	8.82	7.48	7.48	7.48	7.48
	6	1.91	10.97	10.97	10.97	10.97	8.85	8.85	8.83	8.86	7.47	7.47	7.43	7.47
	7	1.4	11.78	11.78	11.78	11.78	9.29	9.29	9.29	9.29	7.87	7.87	7.87	7.87
	8	1.87	17.33	15.83	14.38	12.71	10.26	9.74	9.26	8.70	5.98	5.96	5.94	5.92
	9	0.76	10.94	10.96	10.93	10.93	8.75	8.92	8.74	8.71	7.46	7.71	7.44	7.38
	10	0.83	13.73	10.84	10.61	10.52	9.05	8.31	8.04	7.98	6.21	6.52	6.17	6.10
	11	0.91	17.92	15.46	13.90	12.01	10.35	9.41	8.77	8.03	5.11	5.15	4.98	4.89
	12	0.76	9.60	9.60	9.60	9.60	8.21	8.21	8.21	8.21	7.17	7.16	7.17	7.17
	13	1.33	12.55	9.84	9.74	9.68	8.64	7.74	7.70	7.68	6.15	6.13	6.14	6.14
	14	1.27	17.23	14.53	13.02	11.27	10.23	9.08	8.44	7.73	5.10	5.01	4.91	4.82
	15	0.56	17.74	15.17	13.32	11.20	10.68	9.47	8.67	7.74	5.08	4.89	4.75	4.61
	16	0.73	17.69	15.49	13.61	11.43	10.74	9.54	8.70	7.71	5.12	4.86	4.69	4.53
	17	0.8	15.13	13.99	12.84	11.55	11.09	10.39	9.89	9.31	7.80	7.60	7.54	7.43
	18	0.29	14.48	13.63	12.62	11.58	11.15	10.60	10.18	9.71	8.49	8.30	8.25	8.16
	19	2.76	11.88	11.88	11.88	11.88	9.37	9.37	9.37	9.37	8.04	8.04	8.04	8.05
	20	0.58	12.86	12.81	12.74	12.73	9.90	9.88	9.87	9.86	8.39	8.39	8.39	8.39
	21	0.41	12.64	12.58	12.50	12.48	9.87	9.85	9.83	9.83	8.43	8.43	8.43	8.43
	22	0.67	12.76	12.45	11.82	11.67	9.79	9.70	9.55	9.52	8.11	8.10	8.10	8.11
	23	1.33	13.91	13.32	12.37	11.62	10.68	10.28	9.87	9.51	8.27	8.08	7.97	7.90
	24	0.28	13.85	13.31	12.34	11.64	10.70	10.33	9.92	9.58	8.35	8.16	8.06	7.98
	25	0.63	12.41	12.17	11.77	11.48	9.76	9.59	9.39	9.26	7.79	7.70	7.62	7.62
	26	1.37	11.93	11.93	11.93	11.93	9.29	9.29	9.29	9.29	7.75	7.75	7.75	7.75

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
	27	0.46	11.73	11.60	11.29	11.23	9.06	9.01	8.92	8.91	7.21	7.22	7.21	7.21
	28	0.6	12.42	12.18	11.78	11.51	9.75	9.58	9.38	9.26	7.74	7.66	7.58	7.57
	29	1.22	12.59	12.37	11.99	11.76	9.78	9.62	9.42	9.29	7.67	7.59	7.51	7.50
	30	0.52	9.35	9.35	9.35	9.35	8.03	8.03	8.03	8.01	6.95	6.95	6.95	6.93
	31	0.33	9.43	9.43	9.43	9.42	8.08	8.08	8.08	8.06	7.09	7.10	7.09	7.06
	32	1.32	9.87	9.87	9.87	9.86	8.18	8.19	8.18	8.17	7.02	7.03	7.02	7.00
	33	0.42	10.26	10.19	10.07	10.04	8.26	8.24	8.20	8.19	6.94	6.96	6.94	6.94
	34	0.15	10.63	10.54	10.37	10.34	8.36	8.34	8.29	8.28	6.94	6.95	6.94	6.93
	35	0.36	12.59	12.38	12.03	11.83	9.70	9.55	9.36	9.24	7.58	7.50	7.42	7.41
	36	0.43	12.76	12.55	12.15	11.95	9.72	9.57	9.36	9.23	7.49	7.41	7.32	7.31
	37	1.53	10.84	10.84	10.84	10.84	9.21	9.21	9.21	9.21	8.07	8.07	8.07	8.07
	38	0.28	11.31	11.10	10.81	10.79	9.25	9.19	9.12	9.12	7.89	7.89	7.89	7.89
	39	0.7	11.87	11.76	11.56	11.55	9.26	9.16	9.19	9.19	7.52	7.40	7.58	7.57
	40	0.71	12.18	11.58	10.87	10.82	8.89	8.63	8.48	8.47	6.53	6.39	6.59	6.58
	41	0.38	13.19	12.95	12.41	12.18	9.74	9.58	9.34	9.21	7.33	7.24	7.16	7.14
	42	1.48	11.11	11.04	10.93	10.92	8.71	8.69	8.67	8.67	7.36	7.36	7.36	7.36
	43	0.45	12.07	11.74	11.19	11.10	8.74	8.65	8.54	8.53	6.89	6.89	6.89	6.89
	44	0.24	13.42	13.17	12.58	12.35	9.75	9.59	9.33	9.20	7.25	7.16	7.08	7.06
Lower	1	0.55	10.35	10.35	10.35	10.35	8.80	8.80	8.80	8.80	7.55	7.55	7.55	7.55
	2	0.58	11.09	11.09	11.09	11.09	8.96	8.96	8.96	8.96	7.61	7.61	7.61	7.61
	3	0.26	10.34	10.34	10.34	10.34	8.78	8.78	8.79	8.79	7.84	7.84	7.84	7.84
	4	0.17	11.14	11.14	11.14	11.14	8.96	8.96	8.96	8.96	7.61	7.61	7.61	7.61
	5	0.24	9.47	9.47	9.47	9.47	8.13	8.13	8.13	8.13	7.09	7.09	7.09	7.09
	6	0.71	11.44	11.44	11.44	11.44	8.99	8.99	8.99	8.99	7.57	7.57	7.57	7.57
	7	0.92	11.83	11.83	11.83	11.83	9.04	9.04	9.05	9.05	7.53	7.53	7.53	7.54
	8	0.23	16.19	14.75	12.09	11.67	11.96	11.46	10.61	10.55	9.67	9.65	9.64	9.63
	9	0.54	13.64	12.76	11.15	10.97	10.60	10.26	9.76	9.77	8.39	8.31	8.57	8.69
	10	1.19	12.24	12.22	12.20	12.19	9.15	9.15	9.14	9.15	7.45	7.45	7.46	7.47
	11	0.06	10.42	10.28	10.05	9.91	10.26	10.12	9.89	9.76	10.21	10.07	9.84	9.71
	12	1.13	10.90	10.76	10.52	10.38	10.28	10.14	9.92	9.79	10.06	9.92	9.70	9.58
	13	0.86	11.56	11.48	11.34	11.25	9.87	9.78	9.65	9.57	8.90	8.82	8.68	8.61

Abbreviations:

°C = degree Celsius

EOY = end of year

Table B-51. Simulated Reach Temperatures (°C) for Maximum Weekly Mean August Conditions for ModPRO2 EOY18 through EOY22

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
Upper	1	0.5	11.34	11.34	8.83	8.83	6.53	6.53
	2	0.43	11.95	11.95	9.03	9.03	6.63	6.63
	3	0.63	10.68	10.68	8.06	8.06	5.79	5.79
	4	0.67	11.91	11.91	8.98	8.98	6.60	6.60
	5	0.86	12.10	12.10	9.18	9.18	6.78	6.78
	6	1.91	12.18	12.18	9.34	9.34	7.03	7.03
	7	1.4	13.04	13.04	10.10	10.10	8.01	8.01
	8	0.76	10.59	10.59	8.30	8.30	6.29	6.30
	9	1.3	10.60	10.60	8.39	8.40	6.52	6.53
	10	0.76	11.92	11.91	9.03	9.10	6.97	7.10
	11	1.4	10.97	10.99	8.59	8.62	6.68	6.73
	12	2.44	11.79	11.79	9.23	9.25	7.25	7.27
	13	0.31	11.70	11.71	9.17	9.18	7.18	7.21
	14	0.35	11.68	11.68	9.15	9.16	7.17	7.19
	15	0.61	12.09	12.09	9.59	9.58	7.65	7.64
	16	0.29	12.67	12.64	9.88	9.85	7.71	7.68
	17	2.76	12.69	12.69	9.54	9.54	7.36	7.37
	18	0.58	13.90	13.85	10.38	10.37	8.21	8.21
	19	0.41	13.65	13.62	10.39	10.37	8.36	8.33
	20	0.67	14.45	14.23	10.66	10.57	8.30	8.27
	21	1.33	14.36	14.18	10.47	10.39	7.76	7.74
	22	0.28	14.86	14.67	10.75	10.67	7.96	7.94
	23	0.63	13.74	13.78	10.17	10.38	7.47	7.78
	24	1.37	13.07	13.07	10.35	10.35	8.62	8.62
	25	0.46	13.67	13.32	10.67	10.52	8.56	8.55
	26	0.6	13.86	13.87	10.24	10.43	7.50	7.80
	27	1.22	14.24	14.23	10.37	10.54	7.48	7.77
	28	0.52	10.34	10.34	7.99	8.00	5.81	5.83
	29	0.33	10.15	10.16	8.17	8.18	6.40	6.42
	30	1.32	10.42	10.42	8.55	8.56	6.97	6.98
	31	0.42	10.52	10.53	8.65	8.65	7.06	7.07
	32	0.15	10.86	10.86	8.77	8.78	7.11	7.12
	33	0.36	14.20	14.18	10.32	10.47	7.44	7.70
	34	0.43	14.74	14.61	10.48	10.59	7.41	7.65
	35	1.53	11.50	11.50	9.92	9.92	8.63	8.63

Model	Number	Length	Maximum Temperature for EOY:		Average Temperature for EOY:		Minimum Temperature for EOY:	
			18	22	18	22	18	22
	36	0.28	13.13	12.63	10.44	10.26	8.74	8.74
	37	0.7	13.58	13.17	10.52	10.39	8.51	8.53
	38	0.71	16.19	14.78	11.21	10.73	7.92	7.94
	39	0.38	15.60	15.28	10.72	10.77	7.35	7.58
	40	1.48	12.37	12.24	9.41	9.36	7.51	7.51
	41	0.45	15.88	14.40	10.11	9.85	7.58	7.58
	42	0.24	16.00	15.61	10.82	10.83	7.32	7.54
Lower	1	0.55	11.63	11.63	8.87	8.87	6.44	6.44
	2	0.58	12.33	12.33	9.10	9.10	6.51	6.51
	3	0.26	11.08	11.08	8.65	8.69	6.70	6.78
	4	0.17	12.36	12.35	9.12	9.12	6.53	6.53
	5	0.24	10.51	10.51	8.18	8.19	6.12	6.13
	6	0.71	12.67	12.66	9.20	9.20	6.55	6.55
	7	0.92	13.11	13.11	9.34	9.34	6.60	6.60
	8	0.23	18.81	18.81	13.70	13.70	10.55	10.55
	9	0.54	15.59	16.12	12.07	12.24	9.31	9.20
	10	1.19	13.64	13.63	9.57	9.57	6.69	6.70
	11	0.06	12.40	12.34	12.24	12.19	12.18	12.13
	12	1.13	12.93	12.87	12.28	12.23	12.01	11.96
	13	0.86	13.41	13.36	11.18	11.16	9.59	9.59

Abbreviations:

°C = degree Celsius

EOY = end of year

Table B-52. Simulated Reach Temperatures (°C) for Maximum Weekly Mean August Conditions for ModPRO2 EOY27 through EOY112

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
Upper	1	0.5	11.30	11.30	11.30	11.30	8.81	8.81	8.81	8.81	6.52	6.52	6.52	6.52
	2	0.43	11.86	11.86	11.86	11.86	8.99	8.99	8.99	8.99	6.61	6.61	6.61	6.61
	3	0.63	10.62	10.62	10.62	10.62	8.03	8.03	8.03	8.03	5.74	5.74	5.74	5.74
	4	0.67	11.80	11.80	11.80	11.80	8.93	8.93	8.93	8.93	6.58	6.58	6.58	6.58
	5	0.86	11.96	11.96	11.96	11.96	9.11	9.11	9.11	9.11	6.77	6.77	6.77	6.77
	6	1.91	12.02	12.02	12.02	12.02	9.26	9.26	9.26	9.27	7.03	7.02	7.03	7.03
	7	1.4	12.98	12.98	12.98	12.98	10.00	10.00	10.00	10.00	7.87	7.87	7.87	7.87
	8	1.87	19.74	18.54	17.00	15.01	11.92	11.43	10.89	10.21	6.90	6.89	6.88	6.86
	9	0.76	11.81	11.80	11.80	11.81	8.97	9.21	9.03	8.91	6.92	7.37	7.04	6.82

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
	10	0.83	15.03	11.81	11.57	11.45	9.87	9.03	8.77	8.61	6.50	6.97	6.62	6.38
	11	0.91	21.40	18.59	16.87	14.49	12.40	11.34	10.63	9.69	6.14	6.23	6.08	5.97
	12	0.76	10.52	10.51	10.52	10.52	8.27	8.26	8.27	8.27	6.26	6.25	6.25	6.26
	13	1.33	13.16	10.45	10.34	10.29	9.16	8.14	8.09	8.07	6.11	6.09	6.09	6.10
	14	1.27	20.22	17.16	15.38	13.17	12.05	10.75	10.02	9.12	5.92	5.89	5.80	5.70
	15	0.56	21.29	18.42	16.18	13.41	12.76	11.40	10.47	9.31	6.02	5.90	5.77	5.63
	16	0.73	21.48	19.01	16.80	13.92	13.01	11.63	10.64	9.36	6.10	5.91	5.77	5.60
	17	0.8	17.95	16.61	15.18	13.38	12.75	11.91	11.26	10.46	8.45	8.27	8.21	8.12
	18	0.29	16.98	15.96	14.71	13.23	12.68	12.00	11.44	10.78	9.11	8.95	8.90	8.82
	19	2.76	12.72	12.72	12.72	12.72	9.48	9.48	9.47	9.48	7.23	7.23	7.22	7.23
	20	0.58	13.85	13.80	13.69	13.66	10.30	10.28	10.25	10.24	8.08	8.07	8.07	8.08
	21	0.41	13.59	13.52	13.40	13.37	10.31	10.28	10.25	10.24	8.23	8.22	8.22	8.22
	22	0.67	13.98	13.64	12.86	12.61	10.42	10.31	10.09	10.04	8.12	8.11	8.11	8.11
	23	1.33	16.29	15.55	14.33	13.19	12.17	11.64	11.08	10.56	8.86	8.68	8.57	8.50
	24	0.28	16.29	15.58	14.32	13.24	12.21	11.70	11.14	10.64	8.95	8.77	8.66	8.61
	25	0.63	14.35	14.01	13.39	12.90	10.87	10.63	10.35	10.12	8.01	7.91	7.85	7.84
	26	1.37	13.07	13.07	13.07	13.07	10.35	10.35	10.35	10.35	8.62	8.62	8.62	8.62
	27	0.46	13.01	12.87	12.53	12.45	10.38	10.32	10.21	10.19	8.55	8.57	8.55	8.55
	28	0.6	14.35	14.02	13.41	12.94	10.89	10.65	10.37	10.15	8.03	7.93	7.87	7.85
	29	1.22	14.53	14.20	13.61	13.19	10.97	10.73	10.46	10.24	8.01	7.91	7.85	7.83
	30	0.52	10.36	10.34	10.34	10.34	8.06	7.99	7.99	7.98	5.92	5.80	5.81	5.79
	31	0.33	10.18	10.15	10.15	10.15	8.23	8.17	8.17	8.16	6.51	6.41	6.41	6.39
	32	1.32	10.44	10.42	10.42	10.42	8.60	8.56	8.56	8.55	7.04	6.98	6.98	6.97
	33	0.42	10.75	10.69	10.58	10.55	8.81	8.76	8.73	8.72	7.23	7.18	7.17	7.18
	34	0.15	11.15	11.07	10.93	10.90	8.96	8.91	8.86	8.86	7.29	7.24	7.24	7.24
	35	0.36	14.38	14.08	13.54	13.20	10.87	10.65	10.39	10.19	7.96	7.86	7.80	7.77
	36	0.43	14.69	14.38	13.79	13.43	10.96	10.74	10.46	10.25	7.93	7.83	7.76	7.73
	37	1.53	11.50	11.50	11.50	11.50	9.92	9.92	9.92	9.92	8.63	8.63	8.63	8.63
	38	0.28	12.41	12.19	11.66	11.59	10.19	10.12	10.00	9.99	8.74	8.74	8.74	8.74
	39	0.7	13.01	12.84	12.48	12.43	10.33	10.27	10.19	10.19	8.53	8.52	8.53	8.57
	40	0.71	13.82	13.18	12.09	12.01	10.40	10.18	9.78	9.77	7.93	7.92	7.93	7.97
	41	0.38	15.20	14.87	14.16	13.80	11.07	10.85	10.53	10.32	7.88	7.77	7.71	7.67
	42	1.48	12.17	12.11	11.94	11.91	9.34	9.32	9.28	9.28	7.51	7.51	7.51	7.51
	43	0.45	13.82	13.47	12.56	12.37	9.74	9.64	9.44	9.42	7.58	7.58	7.58	7.58
	44	0.24	15.47	15.13	14.39	14.03	11.10	10.88	10.55	10.34	7.84	7.73	7.67	7.63
Lower	1	0.55	11.63	11.63	11.63	11.63	8.87	8.87	8.87	8.87	6.44	6.44	6.44	6.44

Model	Number	Length	Maximum Temperature for EOY:				Average Temperature for EOY:				Minimum Temperature for EOY:			
			27	32	52	112	27	32	52	112	27	32	52	112
	2	0.58	12.33	12.33	12.33	12.33	9.10	9.10	9.10	9.10	6.51	6.51	6.51	6.51
	3	0.26	11.08	11.08	11.08	11.07	8.68	8.64	8.65	8.59	6.77	6.69	6.70	6.60
	4	0.17	12.35	12.36	12.35	12.36	9.12	9.12	9.12	9.12	6.53	6.53	6.53	6.52
	5	0.24	10.51	10.51	10.51	10.51	8.19	8.18	8.19	8.19	6.13	6.12	6.13	6.13
	6	0.71	12.66	12.66	12.66	12.66	9.20	9.20	9.20	9.20	6.55	6.55	6.55	6.55
	7	0.92	13.11	13.11	13.11	13.11	9.34	9.34	9.34	9.34	6.60	6.60	6.61	6.61
	8	0.23	18.81	17.73	13.43	13.14	13.70	13.08	11.60	11.55	10.55	10.53	10.49	10.48
	9	0.54	15.39	14.51	12.30	12.11	12.00	11.59	10.70	10.68	9.35	9.34	9.38	9.49
	10	1.19	13.63	13.62	13.59	13.58	9.57	9.57	9.56	9.56	6.71	6.71	6.72	6.73
	11	0.06	12.53	12.33	12.02	11.82	12.39	12.19	11.88	11.68	12.34	12.14	11.83	11.63
	12	1.13	13.02	12.83	12.51	12.32	12.42	12.23	11.92	11.72	12.18	11.98	11.68	11.49
	13	0.86	13.41	13.30	13.10	12.99	11.33	11.21	11.03	10.92	9.83	9.72	9.54	9.44

Abbreviations:
°C = degree Celsius
EOY = end of year

Table B-53. Simulated Reach Flows (cms) for Maximum Weekly Summer Conditions for the ModPRO2 EOY18 through EOY22

Model	Number	Length (km)	EOY	
			18	22
Upper	1	0.50	0.0975	0.0975
	2	0.43	0.1028	0.1028
	3	0.63	0.0488	0.0488
	4	0.67	0.1604	0.1604
	5	0.86	0.1698	0.1698
	6	1.91	0.2000	0.1999
	7	1.40	0.0228	0.0227
	8	0.76	0.0272	0.0272
	9	1.30	0.0289	0.0290
	10	0.76	0.0108	0.0112
	11	1.40	0.0410	0.0416
	12	2.44	0.0690	0.0696
	13	0.31	0.0690	0.0696
	14	0.35	0.0690	0.0696
	15	0.61	0.0769	0.0769
	16	0.29	0.0796	0.0794
	17	2.76	0.0278	0.0278
	18	0.58	0.0392	0.0393

Model	Number	Length (km)	EOY	
			18	22
	19	0.41	0.0430	0.0425
	20	0.67	0.0514	0.0508
	21	1.33	0.1334	0.1327
	22	0.28	0.1439	0.1432
	23	0.63	0.3605	0.3753
	24	1.37	0.0063	0.0063
	25	0.46	0.0116	0.0116
	26	0.60	0.3760	0.3908
	27	1.22	0.3810	0.3959
	28	0.52	0.0213	0.0214
	29	0.33	0.0257	0.0258
	30	1.32	0.0317	0.0318
	31	0.42	0.0342	0.0343
	32	0.15	0.0352	0.0353
	33	0.36	0.4201	0.4352
	34	0.43	0.4206	0.4356
	35	1.53	0.0066	0.0066
	36	0.28	0.0120	0.0120
	37	0.70	0.0137	0.0138
	38	0.71	0.0175	0.0177
	39	0.38	0.4390	0.4545
	40	1.48	0.0106	0.0106
	41	0.45	0.0140	0.0140
	42	0.24	0.4530	0.4685
Lower	1	0.55	0.3107	0.3107
	2	0.58	0.3170	0.3170
	3	0.26	0.0072	0.0074
	4	0.17	0.3261	0.3263
	5	0.24	0.0117	0.0118
	6	0.71	0.3429	0.3431
	7	0.92	0.3495	0.3500
	8	0.23	0.0033	0.0033
	9	0.54	0.0039	0.0034
	10	1.19	0.3620	0.3626
	11	0.06	0.4516	0.4611
	12	1.13	0.4619	0.4714

Model	Number	Length (km)	EOY	
			18	22
	13	0.86	0.8355	0.8457

Abbreviations:

cms = cubic meter per second

EOY = end of year

km = kilometer

Table B-54. Simulated Reach Flows (cms) for Maximum Weekly Summer Conditions for the ModPRO2 EOY27 through EOY112

Model	Number	Length (km)	EOY			
			27	32	52	112
Upper	1	0.50	0.0975	0.0975	0.0975	0.0975
	2	0.43	0.1028	0.1028	0.1028	0.1028
	3	0.63	0.0488	0.0488	0.0488	0.0488
	4	0.67	0.1604	0.1604	0.1604	0.1604
	5	0.86	0.1698	0.1699	0.1698	0.1698
	6	1.91	0.2002	0.1999	0.2001	0.2004
	7	1.40	0.0215	0.0215	0.0215	0.0215
	8	1.87	0.0260	0.0260	0.0260	0.0260
	9	0.76	0.0107	0.0124	0.0111	0.0104
	10	0.83	0.0120	0.0142	0.0125	0.0115
	11	0.91	0.0380	0.0402	0.0385	0.0375
	12	0.76	0.0272	0.0272	0.0272	0.0272
	13	1.33	0.0290	0.0289	0.0289	0.0290
	14	1.27	0.0669	0.0690	0.0674	0.0665
	15	0.56	0.0669	0.0690	0.0674	0.0665
	16	0.73	0.0669	0.0690	0.0674	0.0665
	17	0.80	0.1116	0.1137	0.1121	0.1112
	18	0.29	0.1339	0.1360	0.1344	0.1335
	19	2.76	0.0266	0.0265	0.0265	0.0265
	20	0.58	0.0371	0.0369	0.0370	0.0370
	21	0.41	0.0404	0.0402	0.0402	0.0403
	22	0.67	0.0471	0.0469	0.0470	0.0470
	23	1.33	0.1887	0.1879	0.1834	0.1825
	24	0.28	0.1985	0.1976	0.1931	0.1938
	25	0.63	0.4146	0.4131	0.4089	0.4107
	26	1.37	0.0063	0.0063	0.0063	0.0063
	27	0.46	0.0116	0.0117	0.0116	0.0116
	28	0.60	0.4301	0.4287	0.4244	0.4261

Model	Number	Length (km)	EOY			
			27	32	52	112
	29	1.22	0.4352	0.4338	0.4296	0.4314
	30	0.52	0.0218	0.0213	0.0213	0.0212
	31	0.33	0.0264	0.0258	0.0258	0.0256
	32	1.32	0.0325	0.0318	0.0318	0.0317
	33	0.42	0.0360	0.0353	0.0353	0.0353
	34	0.15	0.0372	0.0365	0.0365	0.0365
	35	0.36	0.4764	0.4742	0.4701	0.4718
	36	0.43	0.4768	0.4747	0.4706	0.4723
	37	1.53	0.0066	0.0066	0.0066	0.0066
	38	0.28	0.0120	0.0120	0.0120	0.0120
	39	0.70	0.0138	0.0138	0.0138	0.0141
	40	0.71	0.0177	0.0177	0.0178	0.0181
	41	0.38	0.4957	0.4936	0.4896	0.4916
	42	1.48	0.0106	0.0106	0.0106	0.0106
	43	0.45	0.0140	0.0140	0.0140	0.0140
	44	0.24	0.5097	0.5076	0.5036	0.5056
Lower	1	0.55	0.3107	0.3107	0.3107	0.3108
	2	0.58	0.3170	0.3170	0.3170	0.3170
	3	0.26	0.0073	0.0072	0.0072	0.0070
	4	0.17	0.3263	0.3261	0.3262	0.3260
	5	0.24	0.0118	0.0117	0.0118	0.0118
	6	0.71	0.3431	0.3429	0.3431	0.3429
	7	0.92	0.3501	0.3498	0.3504	0.3504
	8	0.23	0.0033	0.0033	0.0033	0.0033
	9	0.54	0.0041	0.0042	0.0048	0.0055
	10	1.19	0.3634	0.3631	0.3643	0.3652
	11	0.06	0.5100	0.5070	0.5030	0.5050
	12	1.13	0.5203	0.5173	0.5133	0.5153
	13	0.86	0.8954	0.8921	0.8892	0.8921

Abbreviations:

cms = cubic meter per second

EOY = end of year

km = kilometer

Table B-55. Simulated Reach Flows (cms) for Maximum Weekly Fall Conditions for the ModPRO2 EOY18 through EOY22

Model	Number	Length (km)	EOY	
			18	22
Upper	1	0.50	0.0798	0.0798
	2	0.43	0.0840	0.0840
	3	0.63	0.0401	0.0401
	4	0.67	0.1317	0.1317
	5	0.86	0.1395	0.1395
	6	1.91	0.1630	0.1637
	7	1.40	0.0130	0.0130
	8	0.76	0.0167	0.0172
	9	1.30	0.0179	0.0185
	10	0.76	0.0070	0.0070
	11	1.40	0.0259	0.0266
	12	2.44	0.0419	0.0425
	13	0.31	0.0419	0.0425
	14	0.35	0.0419	0.0425
	15	0.61	0.0526	0.0499
	16	0.29	0.0562	0.0523
	17	2.76	0.0205	0.0206
	18	0.58	0.0310	0.0312
	19	0.41	0.0342	0.0345
	20	0.67	0.0409	0.0412
	21	1.33	0.0991	0.0956
	22	0.28	0.1089	0.1053
	23	0.63	0.2834	0.2853
	24	1.37	0.0037	0.0037
	25	0.46	0.0059	0.0059
	26	0.60	0.2911	0.2930
	27	1.22	0.2939	0.2958
	28	0.52	0.0155	0.0155
	29	0.33	0.0179	0.0178
	30	1.32	0.0209	0.0208
	31	0.42	0.0222	0.0221
	32	0.15	0.0227	0.0226
	33	0.36	0.3186	0.3205
	34	0.43	0.3189	0.3207
	35	1.53	0.0036	0.0036

Model	Number	Length (km)	EOY	
			18	22
	36	0.28	0.0065	0.0065
	37	0.70	0.0071	0.0073
	38	0.71	0.0089	0.0092
	39	0.38	0.3283	0.3304
	40	1.48	0.0071	0.0071
	41	0.45	0.0090	0.0090
	42	0.24	0.3373	0.3394
Lower	1	0.55	0.2022	0.2022
	2	0.58	0.2070	0.2070
	3	0.26	0.0054	0.0054
	4	0.17	0.2133	0.2134
	5	0.24	0.0073	0.0073
	6	0.71	0.2234	0.2235
	7	0.92	0.2275	0.2280
	8	0.23	0.0031	0.0031
	9	0.54	0.0031	0.0034
	10	1.19	0.2360	0.2370
	11	0.06	0.3369	0.3407
	12	1.13	0.3420	0.3458
	13	0.86	0.5846	0.5895

Abbreviations:
cms = cubic meter per second
EOY = end of year
km = kilometer

Table B-56. Simulated Reach Flows (cms) for Maximum Weekly Fall Conditions for the ModPRO2 EOY27 through EOY112

Model	Number	Length (km)	EOY			
			27	32	52	112
Upper	1	0.50	0.0798	0.0798	0.0798	0.0798
	2	0.43	0.0840	0.0840	0.0840	0.0840
	3	0.63	0.0401	0.0401	0.0401	0.0401
	4	0.67	0.1317	0.1317	0.1317	0.1317
	5	0.86	0.1395	0.1395	0.1395	0.1395
	6	1.91	0.1636	0.1636	0.1614	0.1637
	7	1.40	0.0124	0.0124	0.0124	0.0124
	8	1.87	0.0150	0.0150	0.0150	0.0150
	9	0.76	0.0063	0.0070	0.0062	0.0061
	10	0.83	0.0071	0.0081	0.0070	0.0068

Model	Number	Length (km)	EOY			
			27	32	52	112
	11	0.91	0.0221	0.0231	0.0220	0.0218
	12	0.76	0.0160	0.0159	0.0160	0.0160
	13	1.33	0.0170	0.0169	0.0170	0.0170
	14	1.27	0.0390	0.0400	0.0389	0.0388
	15	0.56	0.0390	0.0400	0.0389	0.0388
	16	0.73	0.0390	0.0400	0.0389	0.0388
	17	0.80	0.0690	0.0700	0.0689	0.0688
	18	0.29	0.0840	0.0850	0.0839	0.0838
	19	2.76	0.0193	0.0193	0.0193	0.0193
	20	0.58	0.0282	0.0282	0.0282	0.0282
	21	0.41	0.0305	0.0304	0.0305	0.0305
	22	0.67	0.0370	0.0369	0.0370	0.0370
	23	1.33	0.1285	0.1267	0.1229	0.1228
	24	0.28	0.1375	0.1357	0.1319	0.1318
	25	0.63	0.3128	0.3110	0.3034	0.3074
	26	1.37	0.0037	0.0037	0.0037	0.0037
	27	0.46	0.0059	0.0059	0.0059	0.0059
	28	0.60	0.3205	0.3187	0.3111	0.3150
	29	1.22	0.3234	0.3215	0.3139	0.3179
	30	0.52	0.0155	0.0155	0.0155	0.0154
	31	0.33	0.0179	0.0179	0.0179	0.0178
	32	1.32	0.0209	0.0210	0.0210	0.0208
	33	0.42	0.0226	0.0227	0.0226	0.0225
	34	0.15	0.0232	0.0233	0.0232	0.0231
	35	0.36	0.3486	0.3468	0.3392	0.3432
	36	0.43	0.3489	0.3471	0.3395	0.3434
	37	1.53	0.0036	0.0036	0.0036	0.0036
	38	0.28	0.0065	0.0065	0.0065	0.0065
	39	0.70	0.0072	0.0069	0.0074	0.0074
	40	0.71	0.0091	0.0086	0.0093	0.0093
	41	0.38	0.3586	0.3563	0.3494	0.3533
	42	1.48	0.0071	0.0071	0.0071	0.0071
	43	0.45	0.0090	0.0090	0.0090	0.0090
	44	0.24	0.3676	0.3653	0.3584	0.3623
Lower	1	0.55	0.2023	0.2023	0.2023	0.2023
	2	0.58	0.2070	0.2070	0.2070	0.2070
	3	0.26	0.0054	0.0054	0.0054	0.0054

Model	Number	Length (km)	EOY			
			27	32	52	112
	4	0.17	0.2134	0.2134	0.2134	0.2134
	5	0.24	0.0073	0.0073	0.0073	0.0073
	6	0.71	0.2235	0.2235	0.2236	0.2236
	7	0.92	0.2278	0.2279	0.2283	0.2284
	8	0.23	0.0031	0.0031	0.0031	0.0031
	9	0.54	0.0033	0.0031	0.0040	0.0045
	10	1.19	0.2368	0.2368	0.2382	0.2389
	11	0.06	0.3670	0.3650	0.3580	0.3620
	12	1.13	0.3721	0.3701	0.3631	0.3671
	13	0.86	0.6156	0.6136	0.6080	0.6127

Abbreviations:

cms = cubic meter per second

EOY = end of year

km = kilometer

Table B-57. Simulated Reach Flows (cms) for Maximum Weekly Mean August Conditions for the ModPRO2 EOY18 through EOY22

Model	Number	Length (km)	EOY	
			18	22
Upper	1	0.50	0.0975	0.0975
	2	0.43	0.1028	0.1028
	3	0.63	0.0488	0.0488
	4	0.67	0.1604	0.1604
	5	0.86	0.1698	0.1698
	6	1.91	0.2000	0.1999
	7	1.40	0.0228	0.0227
	8	0.76	0.0272	0.0272
	9	1.30	0.0289	0.0290
	10	0.76	0.0108	0.0112
	11	1.40	0.0410	0.0416
	12	2.44	0.0690	0.0696
	13	0.31	0.0690	0.0696
	14	0.35	0.0690	0.0696
	15	0.61	0.0769	0.0769
	16	0.29	0.0796	0.0794
	17	2.76	0.0278	0.0278
	18	0.58	0.0392	0.0393
	19	0.41	0.0430	0.0425
	20	0.67	0.0514	0.0508
	21	1.33	0.1334	0.1327

Model	Number	Length (km)	EOY	
			18	22
	22	0.28	0.1439	0.1432
	23	0.63	0.3598	0.3712
	24	1.37	0.0063	0.0063
	25	0.46	0.0116	0.0116
	26	0.60	0.3753	0.3867
	27	1.22	0.3803	0.3918
	28	0.52	0.0213	0.0214
	29	0.33	0.0257	0.0258
	30	1.32	0.0317	0.0318
	31	0.42	0.0342	0.0343
	32	0.15	0.0352	0.0353
	33	0.36	0.4194	0.4311
	34	0.43	0.4199	0.4315
	35	1.53	0.0066	0.0066
	36	0.28	0.0120	0.0120
	37	0.70	0.0137	0.0138
	38	0.71	0.0175	0.0177
	39	0.38	0.4383	0.4504
	40	1.48	0.0106	0.0106
	41	0.45	0.0140	0.0140
	42	0.24	0.4523	0.4644
Lower	1	0.55	0.3107	0.3107
	2	0.58	0.3170	0.3170
	3	0.26	0.0072	0.0074
	4	0.17	0.3261	0.3263
	5	0.24	0.0117	0.0118
	6	0.71	0.3429	0.3431
	7	0.92	0.3495	0.3500
	8	0.23	0.0033	0.0033
	9	0.54	0.0039	0.0034
	10	1.19	0.3620	0.3626
	11	0.06	0.4516	0.4611
	12	1.13	0.4619	0.4714
	13	0.86	0.8355	0.8457

Abbreviations:

cms = cubic meter per second

EOY = end of year

km = kilometer

Table B-58. Simulated Reach Flows (cms) for Maximum Weekly Mean August Conditions for the ModPRO2 EOY27 through EOY112

Model	Number	Length (km)	EOY			
			27	32	52	112
Upper	1	0.50	0.0975	0.0975	0.0975	0.0975
	2	0.43	0.1028	0.1028	0.1028	0.1028
	3	0.63	0.0488	0.0488	0.0488	0.0488
	4	0.67	0.1604	0.1604	0.1604	0.1604
	5	0.86	0.1698	0.1699	0.1698	0.1698
	6	1.91	0.2002	0.1999	0.2001	0.2004
	7	1.40	0.0215	0.0215	0.0215	0.0215
	8	1.87	0.0260	0.0260	0.0260	0.0260
	9	0.76	0.0107	0.0124	0.0111	0.0104
	10	0.83	0.0120	0.0142	0.0125	0.0115
	11	0.91	0.0380	0.0402	0.0385	0.0375
	12	0.76	0.0272	0.0272	0.0272	0.0272
	13	1.33	0.0290	0.0289	0.0289	0.0290
	14	1.27	0.0669	0.0690	0.0674	0.0665
	15	0.56	0.0669	0.0690	0.0674	0.0665
	16	0.73	0.0669	0.0690	0.0674	0.0665
	17	0.80	0.1116	0.1137	0.1121	0.1112
	18	0.29	0.1339	0.1360	0.1344	0.1335
	19	2.76	0.0266	0.0265	0.0265	0.0265
	20	0.58	0.0371	0.0369	0.0370	0.0370
	21	0.41	0.0404	0.0402	0.0402	0.0403
	22	0.67	0.0471	0.0469	0.0470	0.0470
	23	1.33	0.1886	0.1880	0.1834	0.1825
	24	0.28	0.1984	0.1977	0.1931	0.1938
	25	0.63	0.4145	0.4132	0.4089	0.4107
	26	1.37	0.0063	0.0063	0.0063	0.0063
	27	0.46	0.0116	0.0117	0.0116	0.0116
	28	0.60	0.4300	0.4288	0.4244	0.4261
	29	1.22	0.4351	0.4339	0.4296	0.4314
	30	0.52	0.0218	0.0213	0.0213	0.0212
	31	0.33	0.0264	0.0258	0.0258	0.0256
	32	1.32	0.0325	0.0318	0.0318	0.0317
	33	0.42	0.0360	0.0353	0.0353	0.0353
	34	0.15	0.0372	0.0365	0.0365	0.0365
	35	0.36	0.4763	0.4743	0.4701	0.4718
	36	0.43	0.4767	0.4748	0.4706	0.4723

Model	Number	Length (km)	EOY			
			27	32	52	112
	37	1.53	0.0066	0.0066	0.0066	0.0066
	38	0.28	0.0120	0.0120	0.0120	0.0120
	39	0.70	0.0138	0.0138	0.0138	0.0141
	40	0.71	0.0177	0.0177	0.0178	0.0181
	41	0.38	0.4956	0.4937	0.4896	0.4916
	42	1.48	0.0106	0.0106	0.0106	0.0106
	43	0.45	0.0140	0.0140	0.0140	0.0140
	44	0.24	0.5096	0.5077	0.5036	0.5056
Lower	1	0.55	0.3107	0.3107	0.3107	0.3108
	2	0.58	0.3170	0.3170	0.3170	0.3170
	3	0.26	0.0073	0.0072	0.0072	0.0070
	4	0.17	0.3263	0.3261	0.3262	0.3260
	5	0.24	0.0118	0.0117	0.0118	0.0118
	6	0.71	0.3431	0.3429	0.3431	0.3429
	7	0.92	0.3501	0.3498	0.3504	0.3504
	8	0.23	0.0033	0.0033	0.0033	0.0033
	9	0.54	0.0041	0.0042	0.0048	0.0055
	10	1.19	0.3634	0.3631	0.3643	0.3652
	11	0.06	0.5100	0.5070	0.5030	0.5050
	12	1.13	0.5203	0.5173	0.5133	0.5153
	13	0.86	0.8954	0.8921	0.8892	0.8921

Abbreviations:

cms = cubic meter per second

EOY = end of year

km = kilometer

Section 7: Simulated Warmest Temperatures for the Comparison of No Action and ModPRO2 Alternative

This section provides the warmest simulated temperatures for the No Action and the ModPRO2 alternative for each simulated mine year. These tables address the maximum weekly summer condition and the maximum weekly fall condition, and simulated maximums and averages are provided. The main report compares the warmest simulated temperatures for a particular mine year (EOY6, EOY12, EOY18, and EOY112). The tables in this section provide the data for each simulation year.

Table B-59. Highest Simulated Temperatures (°C) across Model Scenarios and Mine Years for Different Parts of the Study Area for the ModPRO2

Area	Simulated Daily Temperature Statistic	No Action	EOY6 ModPRO2	EOY12 ModPRO2	EOY18 ModPRO2	EOY22 ModPRO2	EOY27 ModPRO2	EOY32 ModPRO2	EOY52 ModPRO2	EOY112 ModPRO2
Upper EFSFSR (above Meadow Creek)	Summer Max:	13.7	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
	Fall Max:	11.1	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
	Summer Avg:	10.3	10.2	10.3	10.3	10.3	10.3	10.3	10.3	10.3
	Fall Avg:	8.8	8.8	8.9	8.8	8.9	8.9	8.9	8.8	8.9
Meadow Creek above East Fork Meadow Creek	Summer Max:	17.9	14.9	14.7	14.8	14.8	24.5	22.3	19.9	17.4
	Fall Max:	15.1	12.4	11.8	11.8	11.8	17.9	15.8	14.4	12.7
	Summer Avg:	12.7	12.3	11.4	11.5	11.5	15.0	13.9	13.2	12.4
	Fall Avg:	10.4	9.3	9.3	9.5	9.3	11.2	10.6	10.2	9.7
Meadow Creek below East Fork Meadow Creek	Summer Max:	19.8	18.2	17.0	16.8	16.6	18.6	18.0	16.6	15.3
	Fall Max:	16.2	15.9	13.8	13.4	13.2	13.9	13.3	12.4	11.6
	Summer Avg:	13.4	13.1	12.1	12.2	12.1	13.9	13.4	12.8	12.2
	Fall Avg:	10.8	10.2	10.0	10.0	9.9	10.7	10.4	9.9	9.6
Middle EFSFSR (between Meadow and Fiddle Creeks)	Summer Max:	17.4	16.4	15.8	16.0	16.1	16.4	16.1	15.4	14.8
	Fall Max:	14.0	13.6	12.7	12.7	12.5	12.6	12.4	12.0	11.8
	Summer Avg:	12.3	11.9	11.5	11.7	11.9	12.4	12.2	11.8	11.6
	Fall Avg:	9.9	9.6	9.4	9.5	9.4	9.8	9.6	9.4	9.3
Fiddle Creek	Summer Max:	11.5	11.9	11.5	11.6	11.6	11.9	11.8	11.6	11.6
	Fall Max:	10.1	10.4	10.3	10.3	10.3	10.6	10.5	10.4	10.3
	Summer Avg:	9.5	9.7	9.6	9.5	9.5	9.7	9.7	9.6	9.6
	Fall Avg:	8.3	8.3	8.3	8.2	8.2	8.4	8.3	8.3	8.3
Lower EFSFSR (between Fiddle and Sugar Creek)	Summer Max:	17.4	16.3	18.1	18.3	18.0	17.7	17.3	16.4	16.0
	Fall Max:	14.0	13.3	14.7	14.1	13.6	13.4	13.2	12.6	12.4
	Summer Avg:	13.5	11.8	13.7	13.8	13.7	13.9	13.7	13.3	13.1
	Fall Avg:	10.6	9.4	10.3	10.2	10.1	10.3	10.1	9.9	9.8
West End Creek	Summer Max:	12.9	21.7	19.1	20.9	20.9	20.6	20.1	16.8	16.8
	Fall Max:	11.0	17.1	17.3	16.2	16.2	16.2	14.7	13.2	13.2
	Summer Avg:	11.1	13.7	12.7	16.8	16.8	16.8	16.8	16.8	16.8
	Fall Avg:	9.6	10.4	10.3	13.2	13.2	13.2	13.2	13.2	13.2
Lower Sugar Creek	Summer Max:	15.4	15.7	15.6	15.7	15.7	15.5	15.5	15.5	15.4

Area	Simulated Daily Temperature Statistic	No Action	EOY6 ModPRO2	EOY12 ModPRO2	EOY18 ModPRO2	EOY22 ModPRO2	EOY27 ModPRO2	EOY32 ModPRO2	EOY52 ModPRO2	EOY112 ModPRO2
	Fall Max:	12.2	12.3	12.3	12.2	12.2	12.2	12.2	12.2	12.2
	Summer Avg:	10.7	10.8	10.7	10.8	10.8	10.8	10.7	10.7	10.7
	Fall Avg:	9.1	9.1	9.1	9.1	9.2	9.1	9.1	9.1	9.1
EFSFSR downstream of Sugar Creek	Summer Max:	14.9	16.0	15.0	15.1	15.1	15.0	14.9	14.7	14.5
	Fall Max:	11.9	12.5	11.6	11.6	11.5	11.6	11.5	11.3	11.3
	Summer Avg:	13.0	11.4	13.1	13.2	13.2	13.3	13.2	12.9	12.7
	Fall Avg:	10.3	9.2	10.1	10.0	10.0	10.1	10.0	9.8	9.7

Abbreviations:

℃ = degree Celsius

Avg = average

EFSFSR = East Fork of the South Fork of the Salmon River

EOY = end of year

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BEFORE THE DEPARTMENT OF WATER RESOURCES
OF THE STATE OF IDAHO

IN THE MATTER OF APPLICATION FOR PERMIT NOS. 77-14378, APPLICATIONS FOR TRANSFER NOS. 85396, 85397, AND 85398, AND APPLICATION FOR EXCHANGE 85538 IN THE NAME OF PERPETUA RESOURCES IDAHO, INC.	))))))))	**PROTESTANTS' JOINT RESPONSE IN OPPOSITION TO TO PERPETUA RESOURCES' PETITION FOR RECONSIDERATION**

ACRONYMS

cfs	cubic feet per second
EFSFSR	East Fork South Fork Salmon River
ESA	Endangered Species Act
Ex.	Exhibit
IDFG	Idaho Department of Fish and Game
IDWR or Department	Idaho Department of Water Resources
OSC	Office of Species Conservation
Perpetua or company	Perpetua Resources Idaho, Inc.
Petition	Petition for Reconsideration filed April 24, 2024
Preliminary Order	Preliminary Order Approving Applications filed on April 10, 2024
Project	Stibnite Gold Project
Protestants	Protestants Nez Perce Tribe, Save the South Fork Salmon, Inc., and Idaho Conservation League
SHSM	Stibnite Hydrologic Site Model
Test.	Testimony
Tr.	Transcript of December 11-15, 2023, Hearing, attached as Exhibit A to the Declaration of Michael A. Lopez filed on January 31, 2024
USGS	United States Geological Survey

I. INTRODUCTION

On April 24, 2024, Applicant Perpetua Resources ("Perpetua" or "company") filed a Petition for Reconsideration ("Petition") with the Idaho Department of Water Resources ("IDWR" or "Department") requesting that Conditions 9, 10, and 14 be deleted and Conditions 13 and 15 be modified in Officer Cefalo's April 10, 2024, Preliminary Order Approving Applications ("Preliminary Order") and accompanying water right permits for the proposed Stibnite Gold Project ("Project").

According to IDWR Proposed Rule 45.01.e, "[t]he Director [of IDWR] will deny an application [for acquisition, transfer or exchange of a water right] that conflicts with the local public interest unless the project can be approved with conditions to resolve the local public interest conflict."[1] Officer Cefalo's Preliminary Order makes clear that he used his broad discretion and affirmative duty under Idaho law to assess and protect the local public interest by imposing limited, reasonable, and workable conditions that are based on substantial evidence in the record.[2] The Preliminary Order reflects that Officer Cefalo weighed and balanced the information he learned through a five-day hearing to develop water right conditions that comply with Idaho Department of Fish and Game's ("IDFG") and Office of Species Conservation's ("OSC") recommendation that IDWR develop conditions <u>in addition</u> to the 20% condition proposed by Perpetua in order to ensure "[s]urface water diversions and infrastructure will not at any time

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[1] Proposed Rule Text of Docket No. 37-0308-2301, 37-03-08-045.e.v., Idaho Department of Water Resources, https://idwr.idaho.gov/wp-content/uploads/sites/2/legal/Rule-37-03-08/20231004-370308-PROPOSED-RULE-FINAL.pdf; The Idaho Legislature has defined the local public interest as "the interests that the people in the area directly affected by a proposed water use have in the effects of such use on the public water resource." Idaho Code § 42-202B(3). The local public interest includes the public's interest in the protection of fish and wildlife habitat. *Shokal v. Dunn*, 109 Idaho 330, 338, 707 P.2d 441, 449 (1985).

[2] *Shokal v. Dunn*, 109 Idaho 330, 337, 339, 707 P.2d 441, 448, 450 (1985); *Hardy v. Higginson*, 123 Idaho 485, 492, 849 P.2d 946, 953 (1993).

impede the passage of any life stage of Chinook Salmon, Steelhead, Bull Trout, or Cutthroat Trout from the confluence of the EFSFSR and Sugar Creek upstream past the Point of Diversion."[3] Officer Cefalo also developed water right conditions that provide baseline habitat protections for fish, including for Endangered Species Act ("ESA")-listed fish, based on substantial information in the record. Officer Cefalo's conditions provide these protections while still affording Perpetua sufficient operational flexibility to meet the company's individual peak, industrial, and mining water demands.

In an attempt to access more water, Perpetua is seeking to roll back Officer Cefalo's protections for fish by recasting its representations at the hearing and information it submitted in the record regarding its operational groundwater needs from the Meadow Creek drainage, its tunnel modeling and design, its low flow modeling for the East Fork South Fork Salmon River ("EFSFSR"), and even the size of its River Pump.[4] But to justify its proposed changes, Perpetua points to no facts or evidence not already considered by Officer Cefalo, raises no legal error, and makes no claim that the conditions are untenable or will prevent implementation of its Project. And, contrary to Perpetua's assertions, the company's proposed modifications would result in water right permits that are inadequately protective of fish habitat and passage.

Now is simply not the appropriate time for Perpetua to seek to modify its water right permits. Without a final mine plan, Perpetua is continuing to speculate in its Petition, as apparently it did at the hearing, regarding its ultimate operational water needs. Once Perpetua has a final mine plan, Perpetua can file an application for amended water rights, as contemplated by Officer Cefalo's Condition 11.[5]

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[3] Ex. 206 at 1.
[4] Petition at 4, 9-11, 13-14.
[5] Preliminary Order at 20.

Protestants Nez Perce Tribe, Save the South Fork Salmon, Inc., and Idaho Conservation League ("Protestants"), therefore, oppose Perpetua's Petition and respectfully request that it be denied in full.

II. ARGUMENT

A. Condition 10 and Condition 15 Both Provide Needed Protection for ESA-Listed Chinook Salmon and Bull Trout.

Protestants oppose the elimination of Condition 10 and the modification of Condition 15. Protestants disagree with Perpetua's assertion that the flow protections provided by Conditions 10 and 15 are duplicative. Although Condition 10 provides some flow protection that overlaps with Condition 15 for the downstream reach of Meadow Creek, Condition 10's primary purpose is to protect flows in Meadow Creek for ESA-listed bull trout above the reach protected by Condition 15.

With respect to Condition 15, Protestants strongly disagree with Perpetua's contention that the flow protections Condition 15 provides for fish habitat can be reduced. Protestants also note that were IDWR to modify Condition 15 as Perpetua proposes, the Meadow Creek flow protections provided by Condition 10 would be necessary, yet not sufficient, to check the precipitous flow and fish habitat declines possible in the downstream reach of Meadow Creek under a three-day rolling average flow regime.

With Officer Cefalo's Conditions 10 and 15 in place, Perpetua will have flexibility to meet its operational water demands. Perpetua's peak mill diversion demand is 4.5 cfs,[6] which can be satisfied with the permit conditions. With Perpetua's plans for water storage and the treatment and reuse of dewatering and contact water,[7] Perpetua has the capability to supplement its water needs

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[6] Ex. 1g at 16.
[7] Ex. 1g at 16; Ex. 25b at 2-2, 2-5, 3-8 to 3-10.

during restrictive periods under Conditions 10 and 15. Additionally, Perpetua's own analysis of its industrial water needs[8] shows that each peak industrial water demand[9] can be met during the restrictive periods imposed in Conditions 10 and 15, affording Perpetua operational flexibility.

Condition 10 Should Not Be Eliminated

Officer Cefalo imposed Condition 10 to "attenuate the effects of ground water pumping on areas outside of the lined section [of Meadow Creek]" and to protect the local public interest in ESA-listed fish habitat.[10] His decision is supported by substantial information in the record.

At the hearing, one of Perpetua's expert witnesses, Daniel Stanaway, testified that the company intends to minimize flow depletions in Meadow Creek from groundwater diversions by installing a geosynthetic liner under Meadow Creek.[11] The liner will stretch from "just above Blow-Out Creek all the way through to near the confluence with the East Fork, South Fork."[12] Mr. Stanaway explained that even with the liner, however, there will still be flow depletions occurring in Meadow Creek due to diversions from the industrial supply wells in the Meadow Creek drainage and from dewatering the Hangar Flats Pit.[13] According to Mr. Stanaway, "even with the liner, a cone [of] depression [from groundwater pumping] can extend up-gradient of that, and because the industri[al] supply wells are further up in the drainage then you can have that cone [of] depression extend essentially upgradient of the head of that liner," which could deplete flows in Meadow

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[8] Ex. 25b at 3-9 to 3-10.

[9] Ex. 1g at 16.

[10] Preliminary Order at 10, 24.

[11] Stanaway Test., Tr. at 257-260, 270-271. "Approximately 3,800 feet of geosynthetic liner will be installed under [Meadow Creek and its] floodplain to minimize streamflow reduction caused by groundwater pumping that occurs between the TSF Buttress and the confluence of the EFSFSR. Groundwater pumping wells are the only diversions in the Meadow Creek valley and therefore the only source of streamflow depletions caused by water withdrawal considered in the water right application for permit." Ex. 63 at 3-11, 3-12.

[12] Stanaway Test., Tr. at 257.

[13] Stanaway Test., Tr. at 260; *See* Preliminary Order at 10.

Creek.[14] Wesley Keller, a fisheries biologist for Protestant Nez Perce Tribe, later testified that ESA-listed bull trout occupy areas of Meadow Creek beyond the portion Perpetua intends to line and, in fact, "occupy almost the entire reach and really high up into Meadow Creek."[15]

Officer Cefalo based Condition 10's maximum monthly diversion rate of 31 acre-feet from the industrial supply wells in the Meadow Creek drainage on Perpetua's own modeling. Mr. Stanaway testified that when the modeling team attempted to model the Project's full freshwater demand from the proposed industrial supply wells[16] in the Meadow Creek drainage, the "model crashed, the system tanked."[17] According to Mr. Stanaway, the model crashed because "the model can't find [a] solution because there's essentially no more water there . . . . That was a situation that would essentially lead to the stream drying up."[18] As a result, the modeling team tested "what would be a safe yield from the supply wells, and it came out to be that that 0.5 cfs [of groundwater diversion] was an acceptable combination of reducing stream flow impacts and still obtaining a quantity of water that was needed by the project."[19] At one point during his testimony Mr. Stanaway remarked "you can see that . . . a decision that was made that supply wells here would be limited to a 0.5 cfs."[20] Perpetua input a maximum monthly diversion rate of 0.5 cfs of groundwater into its other hydraulic modeling for the Project.[21]

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[14] Stanaway Test, Tr. at 558-260.
[15] Keller Test., Tr. at 902-903.
[16] Protestants note that eleven industrial supply wells were proposed in the modeling report, yet thirteen industrial supply wells were proposed in the application for water right 77-14378. The impact of this change is unknown.
[17] Stanaway Test., Tr. at 225.
[18] Stanaway Test., Tr. at 272, 274.
[19] Stanaway Test., Tr. at 226; Ex. 27a at 6-21.
[20] Stanaway Test., Tr. at 224.
[21] Ex. 25b at 3-9. Perpetua's Hydrologic Site Model Refined Proposed Action (ModPRO2) Report states that "[t]he maximum pumping rate for the water supply well system is limited [to] 0.5 cfs in the Mining [Stibnite Hydrologic Site Model ("SHSM")] simulation. When the mill demand exceeds 0.5 cfs, additional water is obtained from the surface water supply intake. In the Mining SHSM the surface water supply is diverted from the EFSFSR at the upstream (south) end of the EFSFSR tunnel." *Id.*

An average monthly withdrawal rate of 0.5 cfs equals a volume of 31 acre-feet per month—the limit found in Condition 10.[22] Condition 10 is, therefore, based on the substantial evidence of Perpetua's own modeling that it will afford flow protection to ESA-listed bull trout habitat in Meadow Creek. Without the limit found in Condition 10, Perpetua could potentially divert more groundwater within the Meadow Creek drainage than can be safely withdrawn without significantly affecting Meadow Creek stream flows.

In addition to protecting Meadow Creek flows for ESA-listed bull trout, Condition 10 also provides a reporting benefit. Under Condition 16, Perpetua "shall provide the Department with an annual report summarizing the diversion amounts and flow rates for the previous calendar year."[23] Consequently, with Condition 10 in place, IDWR and other interested parties will be able to track withdrawals from Perpetua's proposed industrial supply wells in the Meadow Creek drainage to assess effects on Meadow Creek flows and aquatic resources.

Protestants additionally note that Condition 10 incentivizes the conservation of water at the Project site. Given the local public interest in fish habitat in Meadow Creek, Perpetua should be using the water it obtains from the Hangar Flats Pit dewatering wells (and other excess mine-impacted water collected from other site dewatering operations and contact water collection) for beneficial use—such as for milling or to supplement Meadow Creek stream flows—rather than simply releasing treated water downstream and pumping fresh groundwater from the industrial supply wells in the Meadow Creek drainage to satisfy industrial water needs.[24] By restricting the industrial supply wells located in the Meadow Creek drainage to a safe withdrawal rate, Condition

[22] Preliminary Order at 10.
[23] Preliminary Order at 26.
[24] Scanlan Test., Tr. at 132, 139; Bosley Test., Tr. at 392.

10 incentivizes Perpetua to conserve the water already impacted by mining operations from the Hangar Flat Pit and other site operations during mining.[25]

Protestants oppose Perpetua's proposed elimination of Condition 10.

Condition 15 Should Not Be Modified

Unlike the broad protections of Condition 10, Condition 15 is specifically intended to protect the local public interest in the downstream reach of Meadow Creek, the portion Perpetua proposes to line with a geosynthetic liner. This reach begins slightly above the confluence of Blowout Creek and Meadow Creek and stretches downstream to the confluence of Meadow Creek and the EFSFSR.[26]

Protestants provided substantial evidence at hearing that protecting fish habitat in Meadow Creek is in the local public interest. Meadow Creek is home to ESA-listed Chinook salmon, ESA-listed bull trout, rainbow trout, and west slope cutthroat trout[27] and provides critical spawning and rearing habitat for ESA-listed bull trout and Chinook salmon,[28] which the Nez Perce Tribe has been outplanting in Meadow Creek since 2000.[29] As noted earlier, bull trout occupy almost all of Meadow Creek.[30]

Ryan Kinzer and Mike Ackerman's September 11, 2023, expert fisheries report established that the quantity and timing of water diversions in Meadow Creek has the potential to impact

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25 Such an incentive appears appropriate in light of Terry Scanlan's testimony regarding Perpetua's dewatering wells and mill diversion demand: "[T]here's times where you've got a lot more water being pumped than can be used, and so you have to discharge that. Treat it and discharge it, which is costly. So you don't want to do that if you can avoid it." Scanlan Test, Tr. at 158.

26 Stanaway Test., Tr. at 257-260, 270-271; Ex. 63 at 3-11.

27 Keller Test., Tr. at 902-904; Kinzer Test., Tr. at 1071.

28 Ex. 201 at 4.

29 Keller Test., Tr. at 898-900, 917-18, 921. "[W]e out-plant adult Chinook Salmon up there because it is a -- it is a quality habitat that those fish used to have access to, and we want to make sure that it's being fully utilized." Kinzer Test., Tr. at 1086.

30 Keller Test., Tr. at 902-903.

spawning and rearing of Chinook salmon and bull trout there.[31] Mr. Kinzer articulated the potential effects as follows:

> A primary concern . . . is reduction in fish habitat. Fish obviously require water, so as we -- as we lower the water levels we also, you know, lower fish habitat.[32] There's some secondary concerns that impact fish survival. Stream temperatures can definitely impact fish survival.[33] There's been shown in the literature [a] relationship between flow and productivity [defined as the number of offspring per adult spawner]. Productivity seems to decrease as flows decrease specifically along this reach upstream of the Yellow Pine Pit where we are out-planting the fish[.] [T]here's a concern of red[d] dewatering. Fish do have the ability to move and go into different areas to seek out refuge and can withstand some impacts. Red[ds]s do not. Red[d]s are very static and as the water decreases it can affect them and the survival of the eggs inside the red[d].[34]

Mr. Keller testified that when Chinook salmon spawn, they lay their eggs in redds they construct "high in the water column so they're very close to the surface of the water. You know, and so you just have to have good consistent flow over those red[d]s in order to have those eggs survive."[35]

Based on the local public interest in fish habitat in Meadow Creek, Officer Cefalo found that a primary concern for Meadow Creek is flow depletion resulting from Project-related groundwater pumping.[36] He explicitly declined, however, to include a condition "requiring

[31] Ex. 201 at 5-8.

[32] Mr. Kinzer's expert report states: "Reductions in flow have been found to reduce foraging opportunities and growth, increase mortality by reducing available habitat, alter feeding behaviors and associated food webs, and often change stream temperatures from optimal conditions (NOAA 2021b). Additional effects to fish include, but are not limited to, changes in water quality and chemistry (NOAA 2017), hindered fish passage (Thompson 1972), increased mortality from density dependence, scouring of redds from increased anchor ice during winter low-flow months, and/or dewatering of redds during critical egg incubation months." Ex. 201 at 4.

[33] "The concern that I have is that the water -- the water withdrawals would drive temperatures up and, you know, consequently kind of push these lines up higher up onto that Y axis and into that red level where fish are going to have a harder time surviving out there. . . . [I]t's established in the literature that generally water withdrawals will drive temperatures up. So I think that's a pretty common, common thing." Kinzer Test., Tr. at 1128.

[34] Kinzer Test., Tr. at 1072-73.

[35] Keller Test., Tr. at 896.

[36] Preliminary Order at 24.

Perpetua to construct a new Meadow Creek channel with a liner" as the company proposes to do.[37] Noting that stream channel alteration is governed by a separate part of Idaho Code, Officer Cefalo elected to instead preserve fish habitat through the downstream reach of Meadow Creek by requiring a minimum stream flow of 3.0 cfs whenever Perpetua is diverting groundwater from wells in the Meadow Creek drainage.[38]

Officer Cefalo derived a minimum streamflow of 3.0 cfs from his finding that "[b]ase flows in Meadow Creek range between 2.0 cfs and 3.0 cfs in low to average water years."[39] For this finding, Officer Cefalo cited Protestant Nez Perce Tribe's Expert Witness Report, prepared by Mr. Kinzer and Mr. Ackerman. The report provides a table with the 5%, 50%, and 95% exceedance flows for Meadow Creek[40] and concludes that "[t]he median monthly flow, calculated from a 3-day rolling mean of daily averages (using the historical record and downloading from USGS), in Meadow Creek ranges from 2 to 40 cfs."[41] The 95% exceedance flows depicted in Mr. Kinzer and Mr. Ackerman's table are under 2.0 cfs for six months of the year.[42]

Although Officer Cefalo's Condition 15 is based on substantial evidence in the record, Perpetua proposes that various components of the Condition be changed, namely: 1) Officer Cefalo's decision to impose a 3.0 cfs minimum flow when groundwater diversions are occurring in Meadow Creek instead of 95% exceedance flows; 2) Officer Cefalo's decision to impose a continuous minimum stream flow as opposed to a three-day average; 3) Officer Cefalo's starting point in Meadow Creek for Condition 15; and 4) Officer Cefalo's decision to apply Condition 15

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[37] Preliminary Order at 24.
[38] Preliminary Order at 24.
[39] Preliminary Order at 9.
[40] Ex. 201 at 5.
[41] Ex. 201 at 5.
[42] Ex. 201 at 5.

to Permit 77-7285 in addition to Permit 77-14378. Protestants address Perpetua's arguments in turn below.

3.0 cfs v. 95% Exceedance Flows

Perpetua argues that that 95% exceedance flows (1.6 to 2.3 during low flow periods of August to April) are "historical baseflows" for Meadow Creek and, thus, represent a "more appropriate" minimum flow in Meadow Creek when groundwater diversions are occurring than 3.0 cfs.[43] Protestants note that this characterization of 95% exceedance flows by Perpetua varies from the company's characterization of 95% exceedance flows in its own expert hydrology rebuttal report where they referred to such flows as "a very rare occurrence with the vast majority of flows exceeding this value."[44] Regardless, Perpetua provides no explanation as to why 95% exceedance flows would protect the local public interest in fish habitat in Meadow Creek.

Protestants also note that the 95% exceedance flows that Perpetua proposes be incorporated into Condition 15—those referenced by Mr. Kinzer and Mr. Ackerman in Table 1 of their expert report—are not the 95% exceedance flows for the reach of Meadow Creek covered by Condition 15.[45] Mr. Kinzer and Mr. Ackerman's Table 1 summarizes flows at USGS gage site #13310850. Gage site #13310850 is upstream of the partial fish passage barrier and does not include the additional flows of Blowout Creek and one other unnamed tributary to Meadow Creek.[46] Protestants do not believe the 95% exceedance flows for the reach of Meadow Creek covered by Condition 15 can be found in the record.

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[43] Petition at 4.

[44] Ex. 64 at 2-2; *See* Stanaway Test., Tr. at 327.

[45] Ex. 201 at 5; Petition at 5. *See* Petition at 8 for location of USGS gage site #13310850.

[46] Petition, Figure 1 at 8.

Officer Cefalo clearly decided, when he mandated a minimum flow of 3.0 cfs in Meadow Creek, that he was not going to mandate the lowest historical flows.[47] Instead he chose to impose a more average low flow condition, which also included the additional water from Blowout Creek. This was an eminently reasonable decision and one justified by the substantial local public interest in maintaining a healthy fishery and successful Chinook salmon spawning in Meadow Creek.

Continuous Flows vs. Three-Day Average

Perpetua proposes that Condition 15 only require the company to maintain 95% exceedance flows over a "three-day average."[48] Perpetua does not explain this proposal, but the proposal could significantly affect flow rates in Meadow Creek. Under a rolling average flow regime, flows can drop well below the average for periods of time and rise well above the average, so long as the rolling average is met. Should very low flows occur for a period of time under a three-day rolling average, it could affect fish and dewater Chinook salmon redds in Meadow Creek. As Mr. Keller testified, redds need "good consistent flow… in order to have those eggs survive."[49]

IPDES Outfall v. Partial Fish Passage Barrier

Perpetua proposes that IDWR move the upper compliance point for Condition 15 slightly downstream. Condition 15 currently applies from the "existing fish passage barrier" location above the confluence of Meadow Creek and Blowout Creek to the confluence of Meadow Creek and the EFSFSR.[50] Perpetua proposes that IDWR move the upper point of the Condition 15 downstream

47 Petition at 4, 6.
48 Preliminary Order at 21.
49 Keller Test., Tr. at 896.
50 Preliminary Order at 24.

to the IPDES outfall "which is located less than 100 yards downstream of the existing fish passage barrier and is the upstream-most point that Perpetua can feasibly augment streamflow."[51]

Although 100 yards downstream sounds minor, ensuring streamflow at the "fish passage barrier" is important because it is actually just a partial fish passage barrier. As Mr. Keller testified, "the fish passage barrier" is only a barrier for Chinook salmon. Bull trout can make it past the barrier.[52] Protestants acknowledge that Perpetua has deemed augmenting streamflow at the "fish passage barrier" infeasible—presumably based on its current draft mine plan—but omitting the 100 yards between the IPDES outfall and the partial fish passage barrier from Condition 15 could allow flows in this section of reach to get very low or even dry up. Were this to happen, it could prevent bull trout from utilizing the full extent of their habitat in Meadow Creek.

Removing Condition 15 From Permit 77-7285

Finally, Perpetua proposes that Condition 15 be eliminated from permit 77-7285. Were IDWR to agree, Perpetua would be able to pump up to 0.5 cfs or 30.2 acre-feet per year of groundwater in the Meadow Creek drainage under permit 77-7285 without any flow protections for fish habitat in Meadow Creek.

Perpetua's Petition tacitly concedes that Condition 15 streamflow protections should apply, albeit in a modified form, to the 0.5 cfs of groundwater pumping authorized under Permit 77-14378. The company then proposes, however, that 0.5 cfs of groundwater pumping from the Meadow Creek drainage under Permit 77-7285 be exempted from Condition 15. This proposal ignores Officer Cefalo's finding that a "primary area of concern for ground water pumping affecting stream flow is in the Meadow Creek drainage"[53] and Mr. Stanaway's own testimony on

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[51] Petition at 3, 6.
[52] Keller Test., Tr. at 902-903.
[53] Petition at 24.

behalf of Perpetua that there will still be flow depletions in Meadow Creek due to diversions from the industrial supply wells in the Meadow Creek drainage, even after Perpetua installs a liner under Meadow Creek.[54] Perpetua's proposal also fails to take into account that, without Condition 10, without Condition 15 for Permit 77-7285, and with only a modified Condition 15 for Permit 77-14378, Perpetua could potentially take up to 9.6 cfs in a given month from groundwater wells in the Meadow Creek drainage.[55]

Allowing Perpetua to divert groundwater in the Meadow Creek drainage without any flow protections for Meadow Creek would require IDWR to ignore the substantial information in the record regarding groundwater diversions' effects on Meadow Creek and the importance of flow protections for ESA-listed fish in Meadow Creek. By retaining Condition 15 for permit 77-7285, IDWR will help ensure there are baseline flow protections for fish habitat in Meadow Creek.

Officer Cefalo's Condition 15 is supported by substantial evidence in the record. Protestants oppose Perpetua's proposed modifications.

B. Condition 13 Ensures Volitional Passage at the Project Site and Should Not Be Modified.

Condition 13, which requires Perpetua to allow at least 7.25 cfs of water past the EFSFSR river pump point of diversion during times of adult Chinook salmon and bull trout passage, is fully supported by the record. Condition 13 provides the minimum flow necessary to allow volitional fish passage through Perpetua's chosen tunnel design based on Perpetua's own flow modeling.[56] As Officer Cefalo found, volitional passage is the "preferred means for ESA-listed species to access the available habitat in the upper reaches of the EFSFSR,"[57] and accords with IDFG and

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[54] Stanaway Test., Tr. at 260; *See* Preliminary Order at 10.
[55] Scanlan Test., Tr. at 154, 168-169.
[56] Ex. 47 at 12.
[57] Preliminary Order at 6.

OSC's request that IDWR condition its water right approvals to ensure the passage of any life stage of Chinook salmon, steelhead, bull trout, and cutthroat trout in the EFSFSR from the confluence of Sugar Creek through the proposed tunnel.[58] It also provides an important backstop to Perpetua's proposed 20% condition—Condition 12—for which "[e]vidence in the record confirms . . . is not sufficient to preserve fish passage in Perpetua's fishway under all flow scenarios."[59]

Perpetua now argues that the flow criteria in Condition 13 for fish passage should be replaced with a 1-foot depth requirement, derived from NOAA's fish passage criteria for adult Chinook salmon.[60] According to Perpetua, this "flow depth is the fundamental criteria required for successful fish passage, not a particular flow rate."[61]

Perpetua's argument should be rejected, and Condition 13 maintained as drafted, for at least four reasons.

First, a depth requirement alone will not ensure volitional fish passage through the proposed tunnel. Depth represents just one criterion for fish passage; other criteria such as weir length, hydraulic drop, and water velocity are no less important.[62] All criteria, for all relevant species, must be met. The 2022 McMillen Jacobs Report—Perpetua's hydraulic modeling—supports the use of 7.25 cfs as the minimum flow to ensure the tunnel meets all passage criteria:

> 7.25 [cfs] of volumetric flow rate will meet the minimum flow depth of 1 ft as well as the other design criteria such as velocity and hydraulic drop. Lower flow rates will meet velocity and hydraulic drop criteria, but will have less than 1 foot of depth over the weir.[63]

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[58] Preliminary Order at 21.
[59] Preliminary Order at 22.
[60] Petition at 9.
[61] Petition at 10.
[62] *See* Ex. 46 at 5-7.
[63] Ex. 47 at 12.

Were IDWR to modify Condition 13, it risks undermining volitional fish passage at the Project. Even assuming Perpetua's assertion that "alternate geometries, such as a 'U'-shaped weir design" can achieve the 1-foot depth criteria at flows lower than 7.25 cfs,[64] a redesign would also need to meet other design criteria for volitional passage. Yet Perpetua has provided no evidence from the record that it will. Instead, Perpetua points to "appurtenances to facilitate trap and haul operations should fish fail to ascend the tunnel for any reason"[65] (e.g., because its tunnel meets only NOAA's depth criterion for fish passage without meeting NOAA's criteria for weir length, hydraulic drop, and water velocity).

As it stands, the record supports the use of 7.25 cfs as a minimum flow from June 30 to September 30 to ensure volitional fish passage. According to the 2022 McMillen Jacobs Report, 7.25 cfs represents a reliable floor—the result of modeling Perpetua's current tunnel design for the minimum flow using the minimum weir width for adult Chinook.[66] Conversely, there is no information in the record to support Perpetua's claim that "the protection of fish passage sought by Condition 13 is best achieved by a water depth specification" rather than a flow rate.[67]

Second, Perpetua provides no support for its tacit contention that IDWR has authority to mandate water depths in the tunnel's weirs.[68] While an open question, Protestants have reason to believe IDWR lacks this authority: in his Preliminary Order, Officer Cefalo declined to require that Perpetua line Meadow Creek to insulate it from the effects of groundwater pumping in the area, citing a separate legal process and authority governing the alteration of stream channels in

[64] Petition at 10.
[65] Petition at 10.
[66] Ex. 47 at 9 ("The fishway weir crest is 2 ft from the channel bottom, and its width is 1.25 ft (15 inches). The width was established initially as 2 ft . . . but is modified here to help identify the lowest possible fishway flow that still meets the fish passage design criteria").
[67] Petition at 10.
[68] Petition at 10.

Idaho.[69] Officer Cefalo further remarked that "Protestants correctly note that there are elements of the [Project] that may fall outside the jurisdiction of the Department. For example, the Department might not have the authority to require Perpetua to construct a stream channel and tunnel around the Yellow Pine Pit."[70] If IDWR lacks the authority to require Perpetua to construct a tunnel, IDWR may also lack the authority to require that the tunnel's weirs have a 1.0-foot water depth.

Ultimately, IDWR need not reach this question. Setting a minimum flow rate of at least 7.25 cfs between June 30 and September 30 to ensure volitional fish passage—without reference to Perpetua's proposed tunnel—is well supported by the record and well within IDWR's authority.

Third, the 7.25 cfs minimum flow also protects volitional fish passage in the downstream reach of the EFSFSR between the tunnel outlet and Sugar Creek. As noted in the Preliminary Order, "IDFG and OSC requested that the Department condition [Perpetua's] water right approvals to ensure that '[s]urface water diversions and infrastructure [at the [Project]] will not at any time impede the passage of any life stage of Chinook Salmon, Steelhead, Bull Trout, or Cutthroat Trout from the confluence of the EFSFSR and Sugar Creek upstream past the Point of Diversion [River Pump].'"[71] The request covers two reaches of the EFSFSR: 1) the confluence of the EFSFSR Salmon River and Sugar Creek to the base of Perpetua's proposed tunnel, and 2) through Perpetua's proposed tunnel.

While the minimum flow rate of 7.25 cfs derives from Perpetua's tunnel modeling, it provides a measure of protection for volitional fish passage through the lower reach as well. Even under existing average base flows during times of adult Chinook and bull trout passage (modeled

[69] Preliminary Order at 24.
[70] Preliminary Order at 20.
[71] Preliminary Order at 21 (emphasis added) (quoting Ex. 206 at 1).

at 9.9 cfs), stream cross-sections from this lower reach fall below applicable fish passage criteria.[72] As flows drop, the proportion of out-of-compliance cross-sections increases.[73] Condition 13 as drafted provides a minimum flow—at least some measure of protection above Condition 12, the 20% condition—to the downstream reach during key migration periods.[74] Perpetua's requested change to a depth criteria would only apply to the proposed tunnel.

Fourth, the basis for Perpetua's proposed change to Condition 13—its ability to conduct significant anticipated changes to the tunnel design—would require re-evaluation of the local public interest factors. Currently, the tunnel is central to the Project as proposed, central to Perpetua's representations that the Project will protect the local public interest, and central to IDWR's evaluation of "the local public interest to restore volitional fish passage to the upper reaches of the EFSFSR."[75] By requesting changes to Condition 13 that open the door to unspecified modifications to the tunnel design with trap-and-haul as a backstop, Perpetua is essentially walking back material representations about its design of the Project, which IDWR used to evaluate the local public interest.[76]

IDWR included Condition 11 to address the types of material changes Perpetua now seeks. It provides:

> The approval of this permit is in the local public interest based on the elements and actions described in the Modified Plan of Restoration and Operations, dated October 15, 2021. If the final plan of operations approved by the U.S. Forest Service differs substantially from the Modified Plan of Restoration and Operations, the permit holder shall file an application for amendment, updating the elements of the permit to reflect the final plan of operations and

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[72] Ex. 219 at 44.
[73] Ex. 219 at 44-45.
[74] *See* Preliminary Order at 23.
[75] Preliminary Order at 21.
[76] *See* Ex. 219A at 9-10; Ex. 47 at 1-4; Ex. 34 at 13-15, 26-27; Bosley Test., Tr. at 385.

asking the Department to reevaluate the local public interest of the project.[77]

Perpetua should avail itself of Condition 11 if and when it needs to redesign its tunnel.[78] Substantial changes to the tunnel design will demand reevaluation of the local public interest factors. For example, while Perpetua asserts in its Petition that trap and haul operations can be implemented should the weir design fail, there is no evidence in the record to support Perpetua's assertion (and Officer Cefalo made no such alternative finding) that trap and haul is an acceptable public interest alternative to volitional passage. For now, Condition 13 reflects carefully made local public interest findings based on Perpetua's current plans and modeling.

In sum, Perpetua's proposed change to Condition 13 should be rejected because it will not ensure volitional fish passage and lacks support in the record. Moreover, Condition 13 provides exactly what Perpetua seeks in its Petition—operational flexibility—while still protecting the local public interest.

C. Condition 14 Ensures that Surface Water Diversions and Infrastructure Do Not at Any Time Impede Passage of Any Life Stage of Chinook Salmon, Steelhead, Bull Trout, and Cutthroat Trout.

Perpetua proposes eliminating Condition 14, contending that Condition 12 provides adequate streamflow and fish habitat protection downstream of its EFSFSR River Pump between October 1 and June 29 when juvenile anadromous fish are out-migrating and resident fish are overwintering in pools.[79] There is no information in the record to support this contention.

In its Petition, "Perpetua recognizes the [P]rotestants' concern…that Condition 12 may mask impacts to the fishery" but reasons that "[w]hile [the condition's] masking effect is

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77 Preliminary Order at 20.

78 While Perpetua's witness Mr. Bosley endorsed the current tunnel design, he testified that Perpetua would if necessary "redesign the fishway so that it worked." Bosley Test., Tr. at 385.

79 Petition at 11.

theoretically possible, there is no biological data or hydrologic and hydraulic modeling to suggest that 5.0 cfs is a minimum flow requirement to protect the fishery from October 1 to June 29."[80] Perpetua points out that its own 2022 McMillen Jacobs Report "did not make a finding that 5.0 cfs was the minimum flow to protect cutthroat trout"[81] and argues that there is no other information in the record to show that 5.0 cfs is the appropriate minimum streamflow to protect cutthroat trout. Finally, Perpetua argues that the depth criteria (0.3 feet) used by the McMillen Jacobs Report to model downstream fish passage of juveniles of all species can "likely be met with streamflow much lower than 5.0 cfs."[82]

Perpetua's arguments are unavailing. The fact of the matter is the 2022 McMillen Jacobs Report is the <u>only</u> information in the record regarding acceptable low flows for downstream passage outside of the adult anadromous migration period, and it demonstrates that 5.0 cfs <u>would</u> pass juveniles of all species downstream through the tunnel.[83] Perpetua's secondary contention that downstream passage can likely occur at flows below 5.0 cfs is pure conjecture. IDWR simply has no information in the record to impose a minimum flow of less than 5.0 cfs to protect juveniles, as IDFG and OSC recommended in their August 2, 2022, letter, downstream passage for "<u>of any life stage</u> of Chinook Salmon, Steelhead, Bull Trout, or Cutthroat Trout from the confluence of the EFSFSR and Sugar Creek upstream past the Point of Diversion."[84]

Perpetua further contends that Condition 14 is unnecessary because Table 3 in Dr. Kendra Kaiser's Expert Hydrology Report shows that Condition 12 already maintains EFSFSR flows

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[80] Petition at 11. *See also* Preliminary Order at 28.
[81] Petition at 11.
[82] Petition at 11 (emphasis added).
[83] Ex. 47 at 15 (emphasis added).
[84] Petition at 11 (emphasis added); Ex. 206 at 1; Preliminary Order at 8 (emphasis added).

above 5.0 cfs at 95% exceedance flows from October 1 to June 29. This conclusion cannot be drawn from Table 3.

Dr. Kaiser's Table 3 assumes the EFSFSR is contributing an average of 60% flow to the point of quantification for Condition 12.[85] As a result, Table 3 does not account for variability in percent contributions from the EFSFSR to Condition 12's point of quantification, which can range from 45-67% of total flow.[86] Thus, although Condition 12 may keep the EFSFSR's flows above 5.0 cfs at 95% exceedance flows when the EFSFSR's is contributing 60% of the flow at the point of quantification, the Condition may not when the EFSFSR is contributing less percent flow to the point of quantification. And, even assuming a 60% contribution from the EFSFSR, Condition 12 does not protect EFSFSR from going below the historical minimum when the flow at the point of quantification is up to or above 31.0 cfs.[87] Perpetua's conclusion that Table 3 confirms that Condition 12 will keep the EFSFSR above 5.0 cfs at 95% exceedance flows is, therefore, not accurate. Protestants do not believe there is any other information in the record analyzing flow depletions in the EFSFSR under all flow scenarios with Condition 12 in place.

Officer Cefalo's inclusion of Condition 14 is supported by substantial evidence in the record.[88] To start, it was reasonable for Officer Cefalo to impose conditions, in addition to Condition 12 to protect fisheries resources, given the recommendation contained in IDFG and OSC's August 2, 2022, letter and information with respect to the local public interest in fish habitat

[85] Kaiser Test., Tr. at 1028.

[86] Kaiser Test., Tr. at 1027.

[87] Kaiser Test., Tr. at 1030; Ex. 261.

[88] USGS flow records going back to 2011 show the lowest flows in the EFSFSR above the confluence of Sugar Creek occur from September through March. Ex. 261; Ex. 215 at 13. According to these records, average monthly discharge values range from 13.44 to 15.66. Ex. 261; Ex. 215 at 13; Petition at 12, Table 3. Furthermore, observed historic minimum flows between September and March range from 6.9 to 9.4 cfs. Based on these numbers, Condition 14 allows Perpetua to divert 34-52% of the observed monthly flows from September through March, which would subject the EFSFSR to even lower flows than the observed historic minimums without conditions 9, 12, and 14 in place. Ex. 261; Ex. 215 at 13. These percentages can be inferred by dividing the "Full Water Right with Condition" column in Ex. 215 at 13 by the monthly average flows from September through March shown in Ex. 261.

presented at the hearing.[89] Officer Cefalo also reasonably relied on Perpetua's own modeling to set a minimum flow rate of 5.0 cfs from October 1 to June 29, since there is no other information in the record indicating that all fish at any life stage will be able to pass downstream in lower flows.[90] And, finally, Officer Cefalo's imposition of Condition 14 was reasonable because it places very little, if any, burden on Perpetua. According to the company's own (albeit flawed) analysis, Condition 14 will place no additional limitation on its water rights. If true, no burdens of Condition 14 accrue to Perpetua and all the benefits accrue to the local public interest.

D. Perpetua's Request That Condition 9 Be Eliminated to Allow the Company to Divert More than 4.5 cfs From the EFSFSR Should Be Rejected Because It Contradicts Record Evidence and Lacks Merit.

Perpetua's request to eliminate Condition 9, which limits the diversion rate of the River Pump at the EFSFSR to 4.5 cfs, should be rejected for two main reasons. The first is straightforward but important: Condition 9 reflects representations Perpetua itself made in documentary evidence and through sworn testimony, and upon which Officer Cefalo properly relied to craft permit conditions protective of the local public interest. As Perpetua acknowledges in its Petition, the 4.5 cfs pump capacity "has been used by Perpetua for planning and design."[91] It underlies key documents in the record, including the Fishway Operations and Management Plan[92] and hydraulic modeling,[93] which in turn underlie Officer Cefalo's finding of fact that "[t]he River Pump will have a capacity of approximately 4.5 cfs."[94] Perpetua's own witnesses referenced and confirmed the 4.5 cfs pump capacity in hearing testimony.[95] For instance, Perpetua's Senior

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[89] Ex. 206 at 1; Preliminary Order at 8 (emphasis added).
[90] Preliminary Order at 22 (emphasis added); Ex. 47 at 15.
[91] Petition at 13.
[92] Ex. 34 at 124, 139.
[93] Ex. 47 at 2.
[94] Preliminary Order at 5.
[95] Scanlan Test., Tr. at 138; Bosley Test., Tr. at 538.

Engineer, Gene Bosley, testified that Perpetua does not have any use for a continuous diversion of 9.6 cfs from the EFSFSR point of diversion and that the River Pump intake as designed would not be able to handle more than 4.5 cfs.

> Q. . . . when you were referring to the 9.6 cfs water right application, you provided testimony that you have no use for that amount of water; is that correct?
> A. Yeah, not continuously.
>
> Q. And you provided testimony that the East Fork, South Fork Salmon River point of diversion intake cannot even handle more than 4.5 cfs; is that correct?
>
> A. That's right. You wouldn't get it all from there.[96]

Mr. Stanaway corroborated this testimony when he said that Perpetua looked to the EFSFSR as a diversion source to meet its full freshwater demand for the Project, which Mr. Stanaway estimated at 4 to 4.5 cfs, after modeling determined that the full freshwater demand couldn't be pulled from ground wells in the Meadow Creek drainage.[97] All told, the record is replete with Perpetua's representations denying the need to divert more than 4.5 cfs from the EFSFSR except under the most unlikely operating scenarios.[98]

The Petition's claim that "[t]he 4.5 cfs pump capacity is not a proposal by Perpetua to set a limit for surface water diversions" looks past the far larger point that Perpetua has represented the 4.5 cfs pump capacity to IDWR and the Protestants as an accurate and material component of the current Project design. It now seems clear from Perpetua's Petition that the company has not

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[96] Bosley Test., Tr. at 538. *See also* Ex. 34 at 124, 139 (stating a maximum withdrawal rate from the River Pump at 4.5 cfs); Ex. 47 at 2 ("Perpetua intends to supplement the site water balance with as much as 4.5 cfs of raw water from the EFSFSR.").
[97] Stanaway Test., Tr. at 226, 274; Ex. 27a at 6-21; Stanaway Test., Tr. at 274.
[98] Bosley Test., Tr. at 538; Scanlan Test., Tr. at 140; Stanaway Test., Tr. at 226, 274.

yet developed "final pump station designs."[99] Nonetheless, Perpetua made representations about pump capacity and surface water diversions in the record. Those representations serve as valid bases for Condition 9. As with Condition 13, Perpetua's appropriate course of action will be to file an application for amendment pursuant to Condition 11 once it has developed a final pump station design.[100]

Second, and separate from Perpetua's representations regarding River Pump capacity, Perpetua's rationales for striking Condition 9 lack merit. To start, Perpetua's contention that evolving restrictions as the water right permitting process has progressed "from the time of application through the Preliminary Order…including (1) the 20% of unimpaired streamflow diversion limit of Condition 12, and (2) the Meadow Creek groundwater pumping limitations imposed by Conditions 10 and 15" have "significantly reduce[d] the times when Perpetua can divert the full 4.5 cfs from the EFSFSR" is nonsensical.[101] Perpetua proposed Condition 12 based on its own modeling. Condition 10 is also based on the company's own modeling and representations at hearing regarding the maximum diversion rate from the industrial supply wells in the Meadow Creek drainage.[102] Only Condition 15, which applies to Meadow Creek, represents new information for the company to assimilate into its water management plan.[103]

Perpetua further argues that Condition 9 can be eliminated because Condition 12 and Perpetua's proposed revised Condition 13 would be sufficient to protect streamflow, fish habitat, and fish passage.[104] There is no reliable information in the record regarding how low flows in the

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[99] Petition at 14.
[100] *See* Bosley Test., Tr. at 539 ("Q. So could Perpetua potentially replace intake to handle more in the future should the mine operations change? A. It could. It would be permitted just like anything else.").
[101] Petition at 13.
[102] Stanaway Test., Tr. at 224-226, 272, 274; Ex. 27a at 6-21.
[103] Preliminary Order at 24.
[104] Petition at 11.

EFSFSR above the confluence with Sugar Creek can drop with Condition 12 in place under the full range of possible flow scenarios. And Perpetua's argument ignores Officer Cefalo's findings that "evidence in the record confirms that Perpetua's proposed condition, alone, is not sufficient to present fish passage in the fishway under all flow scenarios."[105] Furthermore, Protestants are not convinced Perpetua's proposed modifications to Condition 13 will provide any meaningful flow protections for the EFSFSR either. And, Perpetua proposes eliminating Condition 14, another important backstop for preventing super low flows in the EFSFSR.

Condition 9 provides a needed check for the other conditions limiting flow depletions in the EFSFSR downstream of Perpetua's River Pump for fish passage. Capping the maximum diversion rate at 4.5 cfs provides another safeguard for ensuring fish passage. Capping the maximum diversion rate also prevents impacts to fish and fish habitat from large, instantaneous changes in streamflow. As Mr. Kinzer and Mr. Ackerman explained in their expert report, large changes in flow in either direction can either strand fish in flow scenarios, or flush fish downstream when flows suddenly increase.[106] Limiting the instantaneous diversion rate to 4.5 cfs decreases the risk of impeding passage or stranding fish as a result of significant and fast changes in flows.[107]

Condition 9 was based on material representations made by Perpetua at the hearing, including that Perpetua did not need to divert more than 4.5 cfs from the EFSFSR. The Condition should remain undisturbed.

III. CONCLUSION

For the reasons above, the Protestants request that Hearing Officer Cefalo deny Perpetua's Petition for Reconsideration.

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[105] Preliminary Order at 22.
[106] Ex. 201 at 13.
[107] Ex. 201 at 3, 13.

DATED this 8th day of May, 2024.

/s/ Michael A. Lopez
Michael A. Lopez
Attorney for Nez Perce Tribe

/s/ Amanda W. Rogerson
Amanda W. Rogerson
Attorney for Nez Perce Tribe

/s/ Julia S. Thrower
Julia S. Thrower
Attorney for Save the South Fork Salmon, Inc. and Idaho Conservation League

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that on this 8th day of May, 2024, I caused a true and correct copy of the foregoing document to be served by email, addressed to the following:

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Brown AND Caldwell

Prepared for

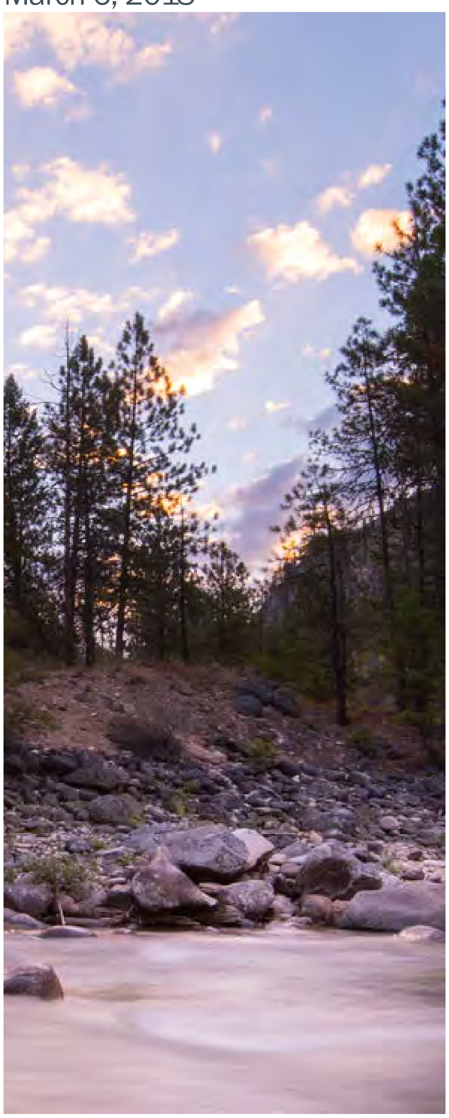
Midas Gold Idaho, Inc., Valley County, Idaho

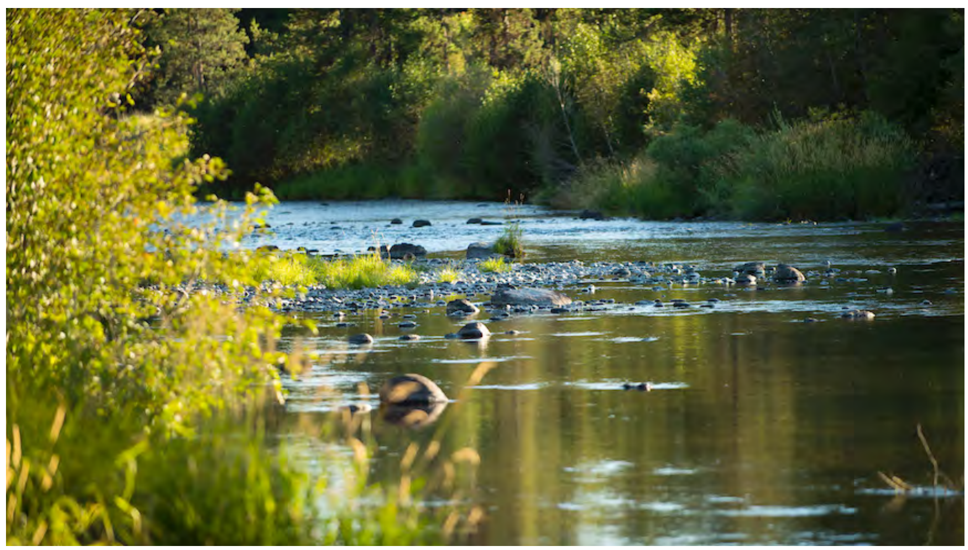
MIDAS GOLD

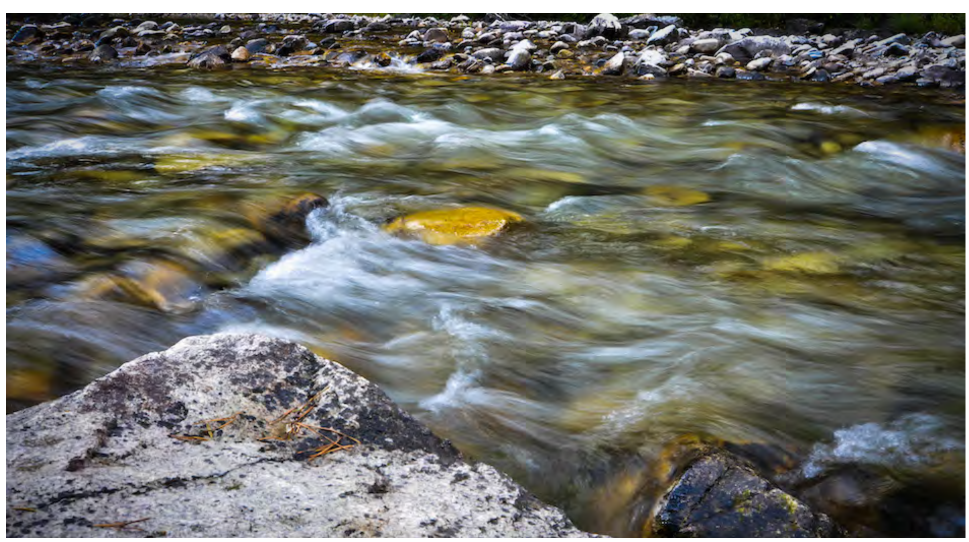
Final Stibnite Gold Project
Stream and Pit Lake Network Temperature Model

Existing Conditions Report

March 6, 2018







FINAL

Stibnite Gold Project
Stream and Pit Lake Network Temperature Model
Existing Conditions Report

Prepared for
Midas Gold Idaho, Inc.
Valley County, Idaho
March 6, 2018

Brown AND Caldwell
950 West Bannock Street, Suite 350
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Table of Contents

List of Figures

List of Graphs

List of Tables

List of Abbreviations

°C	degrees Celsius
BC	Brown and Caldwell
cm	centimeter
cms	cubic meter per second
DO	dissolved oxygen
DYRESM	Dynamic Reservoir Simulation Model
EFSFSR	East Fork of the South Fork of the Salmon River
EIS	environmental impact statement
EPA	United States Environmental Protection Agency
ft	foot
GLM	General Lake Model
HDR	HDR Engineering, Inc.
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
ISS	inorganic suspended sediment
LiDAR	light detection and ranging
m	meter
MDAT	maximum daily average temperature
MDMT	maximum daily maximum temperature
mg/l	milligram per liter
Midas Gold	Midas Gold Idaho, Inc.
MWH	MWH Americas, Inc.
MWMT	maximum weekly (7-day average) maximum temperature
N/A	not applicable
NED	National Elevation Dataset
ODEQ	Oregon Department of Environmental Quality
PRO	Plan of Restoration and Operations
Rio ASE	Rio Applied Science and Engineering
SGP	Stibnite Gold Project
SPLNT	stream and pit lake temperature
TMDL	total maximum daily load
USFS	United States Forest Service
USGS	United States Geological Survey
YPP	Yellow Pine pit

Executive Summary

Midas Gold Idaho, Inc. (Midas Gold), proposes to redevelop portions of the Stibnite Mining District in the headwaters of the East Fork of the South Fork of the Salmon River (EFSFSR), Valley County, central Idaho, as outlined in the Plan of Restoration and Operations (PRO) (Midas Gold 2016) for the Stibnite Gold Project (SGP or Project). The PRO was submitted to the United States Forest Service (USFS) and the Idaho Department of Lands in September 2016 and deemed complete by the USFS in December 2016. Concurrent with preparing the Environmental Impact Statement (EIS), federal and state permitting, and agency and stakeholder consultations, Midas Gold is advancing the Project's engineering design to the Feasibility Study level.

Midas Gold is currently conducting extensive modeling studies to assess future hydrology, water temperatures, and water quality associated with the Project. Broadly, the objectives of the modeling efforts are to predict the potential for groundwater and surface water impacts from the proposed open pits, development rock storage facilities, tailings storage facility, and related features described in the PRO. Numerical predictions are necessary to support analyses of the Proposed Action and alternatives in the SGP EIS currently being prepared by the USFS.

Because the proposed Project has the potential to affect instream conditions such as stream flows, groundwater interaction, and stream shading, the stream water temperature regime may also be altered. In addition, the PRO identifies two pit lakes that will remain after reclamation. This report describes the model that Brown and Caldwell (BC) has developed to address these potential effects and the use of the model to simulate existing conditions. Using widely accepted stream temperature and shading models and a general lake model applicable to mining, the Stream and Pit Lake Network Temperature (SPLNT) model was developed to predict the following:

- Stream temperature changes that would occur during and after mining and restoration activities
- Pit lake water temperature and dissolved oxygen (DO) profiles that would occur in the Hangar Flats and West End pit lakes after mining and reclamation

The SPLNT model is integrated with the other ongoing SGP modeling efforts. SPLNT will use outputs from the hydrologic model and the site-wide water balance model to describe the Proposed Action. For existing conditions, the model incorporates extensive site-specific meteorological, hydrologic, and stream data. Output from the SPLNT model will support development of the site-wide water chemistry model by SRK Consulting, Inc., by providing temperature and DO profiles for the proposed pit lakes.

This report describes the development of the existing conditions SPLNT model, including the following:

- Conceptual model
- Data types and sources
- Methods and generation of model input
- Results
- Summary

The SPLNT model has been developed and calibrated to existing conditions using the considerable available information on the stream network, the Yellow Pine pit (YPP) lake bathymetry, United States Geological Survey (USGS) streamflow records, stream temperature data, and other data available from Midas Gold's SGP baseline studies. BC submitted a SPLNT Model Work Plan to the agencies on

November 15, 2017. The work plan describes the extensive data and studies that are available to describe existing conditions for the SGP.

The SPLNT model domain represents the existing perennial stream network of the upper EFSFSR and tributaries downstream to the confluence with the first perennial tributary downstream of the study area, including the existing YPP lake. The SPLNT model was developed using the following models:

- QUAL2K for stream temperature modeling with Shade.xls for stream shading and TTools to conduct spatial analyses
- General Lake Model (GLM) for pit lake temperature and DO modeling

QUAL2K is a one-dimensional river and stream water quality model that simulates water temperature over a 24-hour period under steady-state flow conditions and outputs minimum, maximum, and average daily temperature. This model has been widely applied to temperature evaluations in the Pacific Northwest and is used by the United States Environmental Protection Agency. The latest version of the model is maintained and distributed by Tufts University and is available for download.

A key input for the QUAL2K model is hourly stream shading, which is specified for each modeling reach. The Washington State Department of Ecology developed a spreadsheet-based model to predict stream shading by reach at an hourly time step as needed for QUAL2K. The Shade.xls model accounts for latitude, longitude, topography, vegetation (height, density, and overhang), and solar radiation in its calculations. The Shade.xls model and documentation are also available for download.

TTools is an ArcMap script that processes spatial coverages of topographic and vegetative data and outputs aspect, topographic angles, canopy height, and canopy density. Outputs from TTools are entered into the Shade.xls model along with estimates of canopy overhang. Outputs from the Shade.xls model are then entered into QUAL2K as hourly shade estimates by reach.

Pit lakes are simulated using a dynamic model that predicts a daily time series of temperature and DO profiles and outlet water temperatures reflective of the fulltime series of modeled scenarios. Outputs from the pit lake models serve as inputs to downstream reaches for stream temperature modeling. GLM is a one-dimensional lake model that dynamically simulates water balance and vertical stratification. The model produces a time series of temperature profiles that account for surface water and groundwater inflows and outflows, surface heating and cooling (using local weather conditions), and subsequent vertical mixing within the lake. GLM is open-source and freely available under a General Public License.

Several types of raw data were used to develop the SPLNT model. This report details each of these data types and their sources, including the following types:

- Topographic data (elevation, aspect angles, and the direction of stream flows)
- Meteorological data (hourly values for air temperature, dew point temperature, wind speed, and cloud cover for the QUAL2K model and time series inputs for solar radiation, air temperature, relative humidity, wind speed, rainfall, and snowfall for the GLM)
- Stream hydraulic data (cross sections)
- Pit lake bathymetry data (morphological characteristics)
- Stream flow and water temperature data
- Pit lake temperature data

In addition to the raw data listed above, additional work was necessary to generate model input for the SPLNT model and the underlying models that include TTools, Shade.xls, QUAL2K, and GLM. Topographic shading was created using both near-field and far-field features and the degree of shading changes with the position of the sun. The Shade.xls model uses the maximum of the near-field (banks, local hills) and far-field (ridgelines) topographic angles in each of the east, south, and west directions to drive topographic shading. BC then delineated the drainage areas to each model reach using the topographic coverage. Separate components of the SPLNT model required characterizing stream channel dimensions including bankfull width and wetted depth, velocity, and width. To evaluate potential impacts of mining and restoration, simulation dates representative of thermal criteria were selected as the calibration and validation periods. Evaluation of 15-minute flow and temperature data available at multiple USGS gages and temperature monitoring stations in the study area led to the selection of July 29, 2016, for calibration and September 24, 2014, for validation. Finally, estimations of hourly shade values for reaches simulated in QUAL2K were developed using the TTools and Shade.xls models.

QUAL2K defines a model reach as one where average conditions are similar over the length of the reach. Recent work by BC to refine the SGP hydrologic model was used as the starting point for defining the stream network for consistency across models. Reaches were then split into separate modeling reaches at tributary confluences, distinct changes in shade (shadebreaks), and the upper extent of proposed mine features. Because the YPP is in the model domain and is being simulated dynamically using the GLM, it was necessary to simulate the existing conditions upstream and downstream of the YPP using two separate QUAL2K models.

The GLM dynamically simulates the heat and water balance of the pit lake over depth and through time and therefore requires time series inputs of model drivers and boundary conditions. Existing bathymetric data were used to quantify the relationship between water depth, surface area, and water volume. Daily inflow volume was obtained from a continuous record of flow from USGS Gage 13311000 EFSFSR at Stibnite, which is the nearest gage upstream of the YPP. The volume of water entering the YPP is high relative to the size of the lake. The record of water temperature at USGS Gage 13311000 EFSFSR at Stibnite is not as complete as the flow record, so linear relationships with water temperatures from nearby sites were used to develop a complete time series of temperatures for the water entering YPP. The GLM model requires at least daily values of air temperature, relative humidity, incoming solar radiation, wind speed, and precipitation. These datasets were primarily compiled from Midas Gold's on-site weather station record. For periods of missing data, values were obtained through the best available statistical relationships with other data sources, including the National Climatic Data Center dataset from McCall, Idaho, and grid-based data sets including PRISM and Daymet.

The calibration and validation of the SPLNT existing conditions models provide a relatively accurate tool that is considered sufficient for simulating water temperatures. For the calibration date, the mean error of simulated stream water temperatures is less than 0.1 degrees Celsius (°C) for daily average and maximum temperatures and less than 0.5 °C for daily minimum temperatures. For the validation date, the mean error of simulated stream water temperatures is less than 0.4 °C for daily average and maximum temperatures and less than 0.6 °C for daily minimum temperatures. The mean error of the calibrated model indicates that the calibration is not biased in predictions of daily average and daily maximum temperatures and is slightly conservative in predicting the daily minimum temperatures by an average of 0.43 °C. The validated model errors are small but are slightly conservative in that the model overestimates average, maximum, and minimum temperatures by 0.26, 0.35, and 0.58 °C respectively. The mean absolute error for the daily average outflow temperatures for the pit lake is 0.7 °C, which is less than one third of the average daily range in observed temperatures of 2.4 °C. For both the streams and the pit lake, the model sometimes over predicts and sometimes under predicts water temperature, indicating the differences are random rather than biased. Based on simulated DO and pit lake temperatures, the model shows the lake beginning to stratify during periods of low flow and warm weather, but stratification often appears to be weak and easily disturbed by moderate flow events during its onset.

The sensitivity analyses of the stream temperature model indicated that the model is most sensitive to shade values, followed by maximum cloud cover. The model was least sensitive to the sediment thermal depth and air temperatures. Alterations to diffuse flow rates and temperatures and stream flows caused moderate changes to stream temperatures. GLM sensitivity analyses were conducted for light extinction, wind speed, and sediment oxygen demand parameters with little impact on simulated results due to the extremely short residence times of the YPP. Sensitivity analyses for the YPP GLM are not included in this report.

Model output for the Proposed Action and alternatives will be compared to criteria established by the USFS and Idaho Department of Environmental Quality in the subsequent SGP SPLNT Model Proposed Action Report and, if appropriate, SGP SPLNT Model Alternatives Report.

Section 1

Background and Purpose

1.1 Background

Midas Gold Idaho, Inc. (Midas Gold) proposes to redevelop portions of the Stibnite Mining District in the headwaters of the East Fork of the South Fork of the Salmon River (EFSFSR), Valley County, central Idaho, as outlined in the Plan of Restoration and Operations (PRO) (Midas Gold 2016) for the Stibnite Gold Project (SGP or Project). The PRO was submitted to the United States Forest Service (USFS) and the Idaho Department of Lands in September 2016 and deemed complete by the USFS in December 2016. Concurrent with preparing the Environmental Impact Statement (EIS), federal and state permitting, and agency and stakeholder consultations, Midas Gold is advancing the Project's engineering design to the Feasibility Study level.

Midas Gold is currently conducting extensive modeling studies to assess existing and future hydrology, water temperatures, and water quality associated with the Project. Broadly, the objectives of the modeling efforts shown in Figure 1 are to predict the potential for groundwater and surface water impacts from the proposed open pits, development rock storage facilities, and tailings storage facility described in the PRO. Numerical predictions are necessary to support analyses of the Proposed Action and alternatives in the SGP EIS currently being prepared by the USFS.

1.2 Purpose and Scope

Because the proposed Project has the potential to affect instream conditions such as stream flows, groundwater interaction, and stream shading, the stream water temperature regime may also be altered. This report describes the modeling that Brown and Caldwell (BC) performed to address these potential effects. Using widely accepted stream temperature and shading models and a general lake model applicable to mining, the stream and pit lake network temperature (SPLNT) model was developed to predict the following:

- Stream temperature changes that would occur during and after mining and restoration activities
- Pit lake water temperature and dissolved oxygen (DO) profiles that would occur in the Hangar Flats and West End pit lakes after mining and reclamation

As shown in Figure 1, the SPLNT model is integrated with the other ongoing SGP modeling efforts. SPLNT modeling will use outputs from the hydrologic model and the site-wide water balance model to describe the Proposed Action. For existing conditions, the model incorporates extensive site-specific meteorological, hydrologic, and stream data. Output from the SPLNT model will support development of the site-wide water chemistry model developed by SRK Consulting, Inc., by providing temperature and DO profiles for the pit lakes. Specifically, the SPLNT model output will be used to evaluate the following:

- Achievement of USFS and Idaho Department of Environmental Quality (IDEQ) stream temperature criteria
- Potential effects on changes in water temperature on federally listed salmonid species' life stages present in Project streams using appropriate species-specific thermal criteria
- Depth-dependent temperature and DO concentration in the Hangar Flats and West End pit lakes
- National Pollutant Discharge Elimination System considerations for water temperature

The SPLNT modeling results are expected to provide important inputs to the environmental analyses being completed for the SGP EIS and the preparation of the biological assessment for the Section 7 consultation under the Endangered Species Act for Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), Snake River Basin steelhead (*O. mykiss*), and Columbia River bull trout (*Salvelinus confluentus*).

This report describes the development of the existing conditions SPLNT model, consisting of the conceptual model (Section 2), data types and sources (Section 3), methods and generation of model input (Section 4), results (Section 5), and summary (Section 6).

1.3 Pacific Northwest Temperature Evaluation Examples

Water temperature affects biological activity of aquatic organisms such as fish. For example, higher temperatures increase metabolic rates and decrease the solubility of DO, reducing its availability to aquatic organisms (Forney et al. 2013). Because of this effect, a stream's peak temperature in the summer is often a critical characteristic of habitat quality for various aquatic life (Forney et al. 2013). Previous water temperature studies in the Pacific Northwest have specifically focused on analyzing flow and temperature data observed during summer months (David Duncan and Associates 2002; Tetra Tech 2014).

In 2011, Tetra Tech used the QUAL2K model to evaluate the effects of different management practices for Nemote Creek in Montana (Tetra Tech 2014). The scenarios they evaluated included baseline conditions (i.e., low flow and warm weather), improved riparian vegetation conditions, and conditions of reduced surface water withdrawals (Tetra Tech 2014). In QUAL2K (Chapra et al. 2008), the heat budget and water temperatures are simulated as a function of meteorology, point and non-point loads, and withdrawals from a stream network. The model outputs minimum, maximum, and average daily water temperature.

Other studies in the Pacific Northwest have combined empirical data with spatial analyses to model water temperatures under various climate and flow conditions using a linear regression approach (David Duncan and Associates 2002; Forney et al. 2013). For example, a study initiated by the Columbia River Federal Caucus was conducted in the John Day River Basin in Oregon to evaluate the resiliency of salmon habitat to climate change and used a regional database to support development of a summer stream temperature model called NorWeST (Scranton et al. 2015). The NorWeST model database contains stream temperature data and model output for different climate scenarios for various streams and rivers in the western United States.

To evaluate stream temperatures for a given site, several metrics are commonly used (Scranton et al. 2015):

- Maximum weekly high temperature
  - Identifies abnormal baseline temperatures for a given site
  - Identifies habitats susceptible to extreme temperatures
- Mean weekly maximum temperature (MWMT; 7-day average of daily maximums)
  - Quantifies weekly maximum stream temperature while limiting the influence of an individual measurement from a single day
- Average weekly high temperature
  - Identifies the expected normal baseline temperatures for a given stream network
- Modeled mean August temperature reported by NorWeST database
  - Converts to MWMT and vice versa

Thermal criteria can also be established to describe the temperature thresholds and frequencies that aquatic life can tolerate without suffering adverse effects during different life stages. Specific thermal criteria are often established for different seasons and life stages. Previous stream temperature studies recommend prioritizing life stages in selected streams for a month or period of concern. For example, for small tributary streams of the upper Salmon River Basin, this recommended priority ranking would be (from high to low) passage → spawning → adult → juvenile (Maret et al. 2005). Therefore, the months of April through September (when migration and spawning activities most often occur) would represent a critical period within the Salmon River Basin.

Previously collected temperature data from the region have also shown that temperature criteria violations can occur during the late spring spawning period for salmonids (April through June), during the peak summer (July and August), and during early fall spawning (September) (Shumar and de Varona 2009). Outside of this period, stream temperatures are rarely a problem for spawning and migration activities; however, winter temperature thresholds have the potential to impact spawning adults and rearing juveniles (Scranton et al. 2015).

Simulated water temperatures derived from the SPLNT model will be compared to the temperature criteria listed in Section 2.3 for both the existing conditions and Proposed Action. These comparisons will be provided in the forthcoming SGP SPLNT Model Proposed Action Report.

Section 2

Conceptual Model

The SPLNT model has been developed and calibrated to existing conditions using the considerable available information on the stream network, the Yellow Pine pit (YPP) lake bathymetry, United States Geological Survey (USGS) streamflow records, stream temperature data, and other data available from Midas Gold's SGP baseline studies. BC submitted a SPLNT Model Work Plan to the agencies on November 15, 2017 (BC 2017). The work plan describes the extensive data and studies that are available to describe existing conditions for the SGP. This report focuses on data and information that was directly used to build the existing conditions model.

Developing the existing conditions model includes evaluating model performance for the calibration and validation periods described in Section 5.1. Model performance has been evaluated to ensure the acceptability of the existing conditions model before proceeding with Proposed Action or alternative evaluations. The modeling represents conditions identified as high priority for aquatic resources in the Pacific Northwest (April–September) that coincide with passage and spawning periods (Maret et al. 2005; Shumar and de Varona 2009). The model has been calibrated to low-flow/baseflow conditions to ensure its applicability when the potential impacts of mining could be more pronounced. The model has been validated for a period with slightly higher flows and slightly cooler temperatures that corresponds to the spawning period of two species of concern (Chinook salmon and bull trout). One species of concern (steelhead) spawns in the spring when stream flows are dominated by snowmelt runoff. Spring was not used as a calibration or validation period because potential impacts on water temperatures due to the Proposed Action would likely be mitigated by the dominance of flows from snowmelt runoff. The stream model has been developed as a steady-state model representing diurnal variability. Average, minimum, and maximum daily temperature statistics are the essential output. Varying conditions (different monthly or seasonal stream flows and meteorology) are simulated by changing the inputs to the model (i.e., stream flows, air temperature, cloud cover, etc.).

In the next phase of work, the SPLNT model will be used to address the potential impacts of physical changes to the stream network and watershed and the resulting changes in stream flows, groundwater contributions, withdrawals and discharges; diverting the EFSFSR through the tunnel around the YPP during mining activities; and the post-closure effects of Hangar Flats and West End pit lakes and other reclamation features. The results of these analyses will be documented in the forthcoming SGP SPLNT Model Proposed Action Report, and if appropriate, an SGP SPLNT Model Alternatives Report.

2.1 Model Domain and Extent

The SPLNT model domain represents the existing perennial stream network of the upper EFSFSR and tributaries downstream to the confluence with the first perennial tributary downstream of the study area (unnamed tributary with confluence at latitude 44.94121, longitude 115.3457), including the existing YPP lake. Figure 2 shows the boundary of the PRO (which includes the proposed pits and other disturbances), the study area (which includes the watershed and the SPLNT model domain) and existing stream network. A subset of perennial streams in the study area that may be affected by the PRO and pit lakes are explicitly simulated in the SPLNT model. Figure 3 shows the extent of the SPLNT model domain and which streams are explicitly simulated. The circles designate the upper extent of each perennial tributary to be explicitly modeled. Areas upstream of these locations (designated by varying colors) are simulated as headwater inputs to the model. Stream flows and water temperatures are assigned to headwater inputs using available information, as described in Section 4.6.2.

Pit lakes are simulated using a dynamic model that predicts a daily time series of temperature and DO profiles and outlet water temperatures reflective of the fulltime series of modeled scenarios. Outputs from the pit lake models serve as inputs to downstream reaches for stream temperature modeling. Current and future pit lakes are within the model domain shown in Figure 3.

2.2 Modeling Approach

The SPLNT model was developed using the following models:

- QUAL2K for stream temperature modeling with Shade.xls for stream shading (provides inputs to QUAL2K) and TTools to conduct spatial analyses (provides inputs to Shade.xls)
- General Lake Model (GLM) for pit lake temperature and DO modeling

2.2.1 Stream Network Temperature Model

QUAL2K is a one-dimensional river and stream water quality model that simulates water temperature over a 24-hour period under steady-state flow conditions. This model has been widely applied to temperature evaluations in the Pacific Northwest and is used by the United States Environmental Protection Agency (EPA) (Montana DEQ and EPA Region 8 2014; Tetra Tech 2013, 2014). The modeled stream network can consist of a mainstem river and branched tributaries. The streams are represented by a series of reaches, each of which is represented using constant hydraulic characteristics (e.g., slope, width). The heat budget and water temperatures are simulated as a function of meteorology, point and non-point loads, and withdrawals from each reach. QUAL2K is a freely available update to the older QUAL2E model. Both versions use Fortran for numerical computations, but QUAL2K has an enhanced user interface implemented within a Microsoft Excel spreadsheet. The latest version of the model is maintained and distributed by Tufts University and is available for download at http://www.qual2k.com/. The model outputs minimum, maximum, and average daily temperature.

A key input for the QUAL2K model is hourly stream shading, which is specified for each modeling reach. The Washington State Department of Ecology developed a spreadsheet-based model to predict stream shading by reach at an hourly time step as needed for QUAL2K. The Shade.xls model accounts for latitude, longitude, topography, vegetation (height, density, and overhang), and solar radiation in its calculations. The Shade.xls model and documentation are available at http://www.ecy.wa.gov/programs/eap/models.html. The Shade.xls model was adapted from a Fortran-based program called HeatSource developed by the Oregon Department of Environmental Quality (ODEQ 2001 and 2009). The ODEQ also developed an ArcGIS extension called TTools to process geospatial data for input into these models. This extension and supporting documentation are available at http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Tools.aspx.

2.2.2 Pit Lake Model

GLM is a one-dimensional lake model which dynamically simulates water balance and vertical stratification (Hipsey et al. 2014). The model produces a time series of temperature profiles that account for surface water and groundwater inflows and outflows, surface heating and cooling (using local weather conditions), and subsequent vertical mixing within the lake. GLM provides a modernized code structure around the same underlying equations of the older Dynamic Reservoir Simulation Model (DYRESM) (Imberger and Patterson 1981; Antenucci and Imerito 2001), which has a long history of use for mining applications (Castendyk 2009). Both programs were developed at the University of Western Australia and are based on the same underlying models and equations, but GLM was updated to produce greater computational efficiency and ease of use. Like DYRESM, GLM can be paired with modules for simulating water quality, including a module capable of simulating DO dynamics. The model can be run as a standalone executable (programmed using C++) or through an R-project interface that was developed by the USGS (glmtools). GLM is open-source and freely available under the GNU General Public License (GPLv3, https://www.gnu.org/licenses/gpl.html).

2.3 Thermal Criteria for Comparison

The SPLNT model simulates water temperatures in the streams and pit lakes and DO in the pit lakes. This section describes the thermal criteria that are available to evaluate effects on stream temperature regimes. The pit lake DO simulations were conducted to provide information for the pit lake water quality and site-wide water chemistry modeling currently being performed by SRK Consulting, Inc. (2017).

Thermal criteria describe the temperature thresholds and frequencies that aquatic species can tolerate without suffering adverse effects. Thermal criteria are often specified for different seasons and life stages. Published literature, USFS criteria, and IDEQ water temperature standards have been used to develop the thermal criteria for this evaluation. Thermal criteria may be revised relative to these recommendations based on discussion with agencies. Some potential temperature criteria being considered are presented below.

IDEQ's water quality standards (Idaho Administrative Policy Act [IDAPA] 58.01.02) include relatively complex criteria for temperature, based in part upon seasonal spawning and rearing requirements for salmonids. Idaho first adopted bull trout temperature criteria in 1998. These criteria were revised in 2001 and submitted to EPA for approval. EPA has not taken action, so the bull trout temperature criterion effective for Clean Water Act purposes is the 1997 federally promulgated temperature criterion of 10 degrees Celsius (°C) for 7-day average maximum daily temperatures from June through September for waters specified in the federal rule (40 Code of Federal Regulations 131.33).

Various thermal criteria are available for Chinook salmon, steelhead, and bull trout spawning, incubation, and rearing/migration (Dunham et al. 2001; EPA 2003; USFS 2003), including salmon temperature guilds (EPA n.d.).

Table 2-1 shows the temperature criteria from the *Watershed Indicators and Pathways in the Payette National Forest Land and Resource Management Plan* (USFS 2003). Thermal criteria applied by the IDEQ are listed in Table 2-2. These temperature criteria will be used for federally listed salmonids.

The QUAL2K model outputs minimum, maximum, and average daily temperatures, which can then be post-processed to evaluate various temperature statistics for comparison to these criteria.

Table 2-1. USFS Thermal Criteria Based on Indicators for Chinook Salmon, Steelhead, and Bull Trout Based on the MWMT

Species/Life Stage	Months	Functioning Acceptably (°C)	Functioning at Risk (°C)	Functioning of Unacceptable Risk (°C)
Chinook Salmon				
Spawning	Mid-August–September	10–13.9	13.9–15.5	>15.5
Rearing/migration	Year-round	10–13.9	13.9–17.7	>17.7
Steelhead				
Spawning	March–May	10–13.9	13.9–15.5	>15.5
Rearing/migration	Year-round	10–13.9	13.9–17.7	>17.7
Bull Trout				
Spawning	Mid-August–September	4–9	<4, 10	<4, >10
Incubation	Mid-August–early February	2–5	<2, 6	<1, >6
Rearing	Year-round	4–12	<4, 13–15	>15

Source: USFS 2003.

MWMT = maximum weekly (7-day average) maximum temperature.

Table 2-2. Idaho Thermal Criteria

Criteria	Warm Water	Seasonal Cold	Cold Water	Salmonid Spawning	Bull Trout
MDMT	33°C (91°F)	26°C (79°F)	22°C (72°F)	13°C (55°F)	N/A
MWMT	N/A	N/A	N/A	N/A	13°C (55°F)
MDAT	29°C (84°F)	23°C (73°F)	19°C (66°F)	9°C (48°F)	N/A

Source: http://www.deq.idaho.gov/water-quality/surface-water/temperature/
MDMT = maximum daily maximum temperature.

MWMT = maximum weekly (7-day average) maximum temperature.

MDAT = maximum daily average temperature.

Section 3

Data Types and Sources

This section describes the raw data that was used to develop the SPLNT model. Data processing to generate model inputs is described in Section 4.

3.1 Topographic Data

Topographic data describes the changes in elevation, aspect angles, and the direction of stream flows. There are two main sources of topographic data for the study area. Midas Gold collected light detection and ranging (LiDAR) data for most of the study area. Contours created from the LiDAR data are shown in Figure 4. The USGS National Elevation Dataset (NED) are available to fill holes in LiDAR coverage or extent beyond the study area as required by TTools.

3.2 Meteorological Data

The QUAL2K model requires the user to input hourly values for air temperature, dew point temperature, wind speed, and cloud cover. The GLM requires times series inputs for solar radiation, air temperature, relative humidity, wind speed, rainfall, and snowfall.

Available data were compiled for the MesoWest Midas Gold station, which is located in Meadow Creek valley. Figure 5 shows the raw data available for 2014 through 2017 for this site. Inputs to the QUAL2K model and GLM are described in Sections 4.6.4 and 4.7, respectively.

3.3 Stream Hydraulic Data

Cross section data were collected along 15 reaches in the study area for the aquatic resource baseline study (MWH Americas Inc. [MWH] 2017) and for field studies completed by Rio Applied Science and Engineering (Rio ASE) for stream restoration design (report in progress). Figure 6 shows the location of the 12 cross sections measured as part of the PACFISH/INFISH Biological Opinion surveys by MWH (2017). The location of the nine cross section surveys by Rio ASE to support restoration design are shown in Figure 7. The cross section data were used along with stream flow and hydraulic data collected by the USGS at the five gages in the study area (also shown on Figure 6 and Figure 7 and discussed in Section 3.5) to develop the rating curves described in Section 4.3.

3.4 Pit Lake Bathymetry Data

Bathymetry for the YPP (Figure 8) is available from Quadrant Consulting, Inc. (2016) and was used to define the morphological characteristics for the GLM existing conditions modeling. Midas Gold's pit design and optimization data representing the final contours of the Hangar Flats pit and the West End pit will be used to define the post-mining morphometry of these pits.

3.5 Stream Flow and Water Temperature Data

Water temperature and stream flow measurements are used to set initial conditions and develop and calibrate the SPLNT model. There are five active USGS stations in the watershed that measure flow and water temperature (https://waterdata.usgs.gov/nwisl). In addition, Midas Gold has measured water temperature during the summer period between 2013 and 2016 for the surface water quality baseline study (HDR Engineering, Inc. [HDR] 2017) and the aquatic resources baseline study (MWH 2017). Figure 9 shows the locations of the USGS gages and HDR monitoring stations (32 of these stations monitor streams). Figure 6 shows the location of the MWH stations where temperature was monitored (denoted by a “T” in the center of the station label). Table 3-1 through Table 3-3 summarize the flow and the temperature data available in the study area. Figure 10 through Figure 13 display the data available from these gages and monitoring stations.

Table 3-1. USGS 15-Minute Streamflow and Temperature Monitoring Gages in the Study Area

Gage Number	Tributary Name and Location	Drainage Area (sq. mi.)	Period of Record	Count of Measurements				
				Discharge	Water Temperature	Velocity (at point in stream)	Width	Gage Height
13310800	EFSFSR above Meadow Creek	9	2011-09-19 to 2017-08-23	2,208	2,238	25	32	103
13310850	Meadow Creek near Stibnite	5.6	2011-09-19 to 2017-08-23	2,209	2,197	26	33	76
13311000	EFSFSR at Stibnite	19.3	1983-01-25 to 2017-08-24	11,361	2,384	26	32	136
13311250	EFSFSR above Sugar Creek	25	2011-09-19 to 2017-08-24	2,246	2,052	26	33	136
13311450	Sugar Creek near Stibnite	18	2011-09-21 to 2017-08-24	2,244	2,052	26	33	137

Table 3-2. Midas Gold Temperature Monitoring Stations (15-Minute Data)

Station Number	Tributary Name and Location	Period of Record*
MWH-001	Headwaters—EFSFSR	2013–2016
MWH-003	Headwaters—EFSFSR	2013–2016
MWH-004	Headwaters—EFSFSR	2014–2016
MWH-005	Deadman Creek—EFSFSR	2013–2016
MWH-006	Headwaters—EFSFSR	2013–2016
MWH-007	Headwaters—EFSFSR	2013–2016
MWH-008	Sugar Creek	2013–2016
MWH-021	Sugar Creek	2014–2016
MWH-033	No Mans Creek—EFSFSR	N/A
MWH-034	Headwaters—EFSFSR	2013–2016
MWH-051	Burntlog Creek	2014–2016
MWH-054	Trapper Creek—Johnson Creek	2014–2016
MWH-055	Riordan Creek	2016
MWH-056	Fourmile Creek—SFSR	2014–2016
MWH-057	Goat Creek—SFSR	2014–2016

**Records have various gaps due to equipment failures.*

Source: Aquatic Resources Baseline Report (MWH 2017).

See Figure 6 for map of locations.

N/A = Not available.

Table 3-3. Midas Gold Stream, Seep, and Adit Temperature Monitoring Stations (Q=Quarterly, M=Monthly)

Station Number	Station Name	Drainage	Sample Count	Frequency Type
4	YP-AS-1	Sugar Creek	29	M, Q
5	YP-AS-2	Sugar Creek	37	M, Q
6	YP-AS-3	EFSFSR	35	M, Q
7	YP-AS-4	EFSFSR	36	M, Q
8	YP-AS-5	EFSFSR	1	Q
9	YP-AS-6	EFSFSR	34	M, Q
10	YP-AS-7	Meadow Creek	17	M, Q
11	YP-S-1	Sugar Creek	27	M, Q
12	YP-S-2	Meadow Creek	17	M, Q
13	YP-S-3	EFSFSR	24	M, Q
14	YP-S-5	Meadow Creek	16	M, Q
15	YP-S-6	Meadow Creek	34	M, Q
16	YP-S-7	Meadow Creek	33	M, Q
17	YP-S-8	Meadow Creek	34	M, Q
18	YP-S-9	EFSFSR	23	M, Q
19	YP-S-10	Meadow Creek	37	M, Q
20	YP-SEBS-1	EFSFSR	24	M, Q

Station Number	Station Name	Drainage	Sample Count	Frequency Type
21	YP-SEBS-2	EFSFSR	24	M, Q
22	YP-SR-2	EFSFSR	38	M, Q
23	YP-SR-4	EFSFSR	38	M, Q
24	YP-SR-6	EFSFSR	38	M, Q
25	YP-SR-8	EFSFSR	38	M, Q
26	YP-SR-10	EFSFSR	38	M, Q
27	YP-SR-11	EFSFSR	38	M, Q
28	YP-SR-13	EFSFSR	38	M, Q
29	YP-T-1	Sugar Creek	38	M, Q
30	YP-T-6	Sugar Creek	37	M, Q
31	YP-T-7	Sugar Creek	38	M, Q
32	YP-T-8A	Sugar Creek	31	M, Q
33	YP-T-10	EFSFSR	37	M, Q
34	YP-T-11	EFSFSR	38	M, Q
35	YP-T-12	EFSFSR	27	M, Q
36	YP-T-17	EFSFSR	37	M, Q
37	YP-T-21	EFSFSR	38	M, Q
38	YP-T-22	Meadow Creek	38	M, Q
39	YP-T-23A	Meadow Creek	23	M, Q
40	YP-T-27	Meadow Creek	38	M, Q
41	YP-T-29	Meadow Creek	38	M, Q
42	YP-T-33	Meadow Creek	38	M, Q
43	YP-T-35	EFSFSR	34	M, Q
44	YP-T-37	Sugar Creek	21	M, Q
45	YP-T-40	EFSFSR	38	M, Q
46	YP-T-41	EFSFSR	38	M, Q
47	YP-T-42	EFSFSR	23	M, Q
48	YP-T-43	Meadow Creek	35	M, Q
49	YP-M-3	Meadow Creek	35	M, Q
50	YP-HP-S1	Sugar Creek	30	M, Q
51	YP-T-15	EFSFSR	38	M, Q
52	Keyway Input	Meadow Creek	4	Q
53	YP-M-4	EFSFSR	24	M, Q
54	GM-MN-192	EFSFSR	1	Q
55	GM-GC-56	EFSFSR	1	Q
56	GM-GC-60	EFSFSR	1	Q
57	Rabbit Adit	EFSFSR	1	Q
58	GM-RC-220	EFSFSR	1	Q

Station Number	Station Name	Drainage	Sample Count	Frequency Type
59	GM-RC-216	EFSFSR	1	Q
60	YP-T-44	EFSFSR	23	M, Q
61	YP-SR-14	EFSFSR	26	M, Q
62	YP-T-45	Meadow Creek	17	M, Q
63	YP-T-46	Meadow Creek	10	M, Q
64	YP-T-47	EFSFSR	1	Q
65	YP-T-48	EFSFSR	19	M, Q
136	YP-HD-BLDG2-2014	EFSFSR	1	Q
138	YP-T-49	Sugar Creek	5	Q

Source: Surface Water Quality Baseline Report (HDR 2017).

See Figure 9 for map of locations.

3.6 Pit Lake Temperature Data

BC measured water temperature and DO in the YPP lake on October 3, 2017, between 12:11 p.m. and 12:36 p.m. This pit lake is shallow (35 feet [ft] maximum depth at normal pool) relative to the proposed West End and Hangar Flats pit lakes. Data were collected by boat at the center of the lake (0631346E, 4976250N UTM). Temperature and DO profile data were collected approximately every 1.5 ft from the surface to 6.5 ft and every 3.2 ft from 6.5 ft to 33 ft using a YSI 556 Meter. The DO meter was calibrated to the 100 percent saturation concentration before sampling, and a post-sampling drift check was conducted to verify that the meter was operating within 10 percent of the known calibration values. Secchi depth, a measure of water clarity, was also measured and was found to be 21 feet.

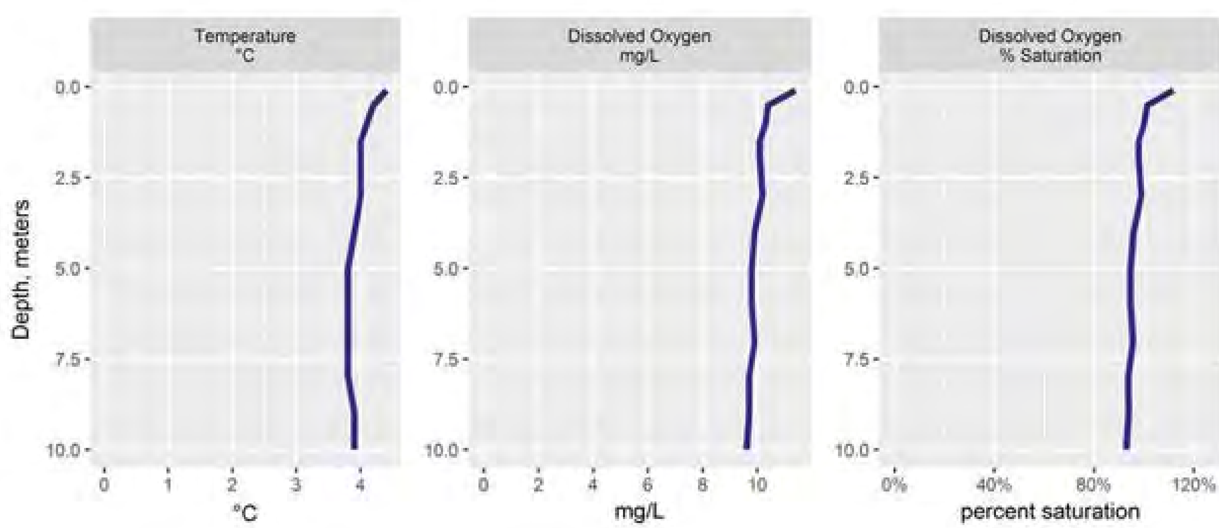
The lake appeared to be well mixed and nearly isothermal through most of the water column (Table 3-4, Graph 3-1). There was a thin layer of ice on the northeast corner of the lake at the time of sampling.

Historical temperature data for the YPP lake (URS 2000) are also available (Table 3-5). Differences between surface and deep water temperatures collected in July, August, and September 1999 suggest stratification may have been relatively weak over the summer, but by September, temperatures at the deepest (central) location are indicative of stable thermal stratification (URS 2000). Historical and recent monitoring station locations for the YPP are shown on Figure 14.

Table 3-4. YPP Lake Measurements (October 3, 2017)

Water Depth (ft)	Temp (°C)	DO (mg/l)	DO Percent Saturation[a]
0.33	4.4	11.34	108.6
0.66	4.2	10.4	99.1
3.3	4.1	10.3	98.3
4.9	4.0	10.1	95.4
6.6	4.0	10.1	95.9
9.8	4.0	10.12	96.3
13.1	3.9	9.9	93.9
16.4	3.8	9.8	92.8
19.7	3.8	9.8	92.7
23.0	3.8	9.9	93.7
26.2	3.8	9.7	91.6
29.5	3.9	9.7	92.0
32.8	3.9	9.6	91.1

[a]Estimated assuming a barometric pressure of 613.0 mm Hg as specified on the field sheet (Appendix A).
mg/l = milligram per liter.



Graph 3-1. YPP Lake Temperature and DO Depth Profiles (October 3, 2017)

Table 3-5. 1999 YPP Lake Profile Data

Station	Temp (°C)			DO (mg/l)		
	7/15/1999	8/31/1999	9/14/1999	7/15/1999	8/31/1999	9/14/1999
GH-1						
Surface	9.7	12	21.3	9.8	7.6	8.1
Mid	8.7	9.6	18.6	11.5	7.4	5.8
Bottom	8.5	9.4	17.9	11.7	6.2	4.9
GH-2						
Surface	8.7	11.9	20.1	9.3	8	7
Mid	7.9	9.4	15.7	9.4	7.2	5.3
Bottom	7.8	8.6	12.6	8.8	0.3	4.7
GH-3						
Surface	8.5	10.5	28.6	9.6	7.9	6.7
Mid	8.1	10	19.4	9	8	4.9
Bottom	8.1	9.5	18.2	9	7.5	4.9

Source: URS 2000.

mg/l = milligram per liter.

Section 4

Methods and Generation of Model Input

This section describes the methods and procedures used to generate model input for the SPLNT model and the underlying models including TTools, Shade, QUAL2K, and GLM.

4.1 Development of Seamless Topographic Coverage

Topographic shading can be created by both near-field and far-field features, and the degree of shading changes with the position of the sun. The Shade.xls model uses the maximum of the near-field (banks, local hills) and far-field (ridgelines) topographic angles in each of the east, south, and west directions to drive topographic shading. The TTools ArcGIS extension described by Boyd and Kasper (2003) uses high resolution topographic data to identify shade angles in the near-field. This high-resolution dataset is derived from LiDAR data everywhere LiDAR data have been collected (the majority of the study area). Far-field topographic shading (from distant ridge lines) was evaluated using TTools and the 30-meter NED from the USGS. Figure 15 shows the seamless topographic coverage generated from the LiDAR and NED data.

4.2 Delineation of Subbasins

The SPLNT model explicitly simulates perennial streams and pit lakes that may be affected by the PRO or alternatives. Areas upstream of this model domain are represented as headwater inputs to the model. To estimate the flows entering as headwaters, the drainage area upstream of each modeled reach is required. BC delineated the drainage areas to each model reach using the seamless topographic coverage described in Section 4.1. Estimates of flows based on these drainage areas vary for the calibration and validation period as described in Section 4.6.2.

BC also delineated drainage areas to locations in the study area where stream cross sections were measured. These drainage areas were used to characterize channel dimensions as described in Section 4.3.

BC delineated the drainage areas to USGS gages with reported drainage areas for comparison to provide a quality assurance check. The drainage areas reported for four USGS gages (13310800 EFSFSR above Meadow Creek, 13311000 EFSFSR at Stibnite, 13311250 EFSFSR above Sugar Creek, and 13311450 Sugar Creek near Stibnite) were within 0.8 percent of those delineated by BC. One USGS gage (13310850 Meadow Creek near Stibnite) had a reported drainage area within 2.1 percent of that delineated by BC. This exercise demonstrates the accuracy of the methods used and provides confidence that using drainage areas delineated by BC and applied in several steps in the development of the SPLNT model does not introduce a noticeable level of uncertainty in the modeling.

4.3 Characterization of Channel Dimensions

Separate components of the SPLNT model require characterization of stream channel dimensions including bankfull width and wetted depth, velocity, and width. The characterization of channel dimensions supports modeling in TTools and QUAL2K. Units in this section are presented as metric units consistent with the input requirements for these tools and to facilitate review by the USFS and cooperating agencies.

Bankfull width is associated with channel forming flows and is often correlated with drainage area (Emmett 1975; Lawlor 2004). Rating curves for bankfull width provided by Emmett and Lawlor were evaluated for the study area and compared to data collected by MWH at 16 sites. Lawlor (2004) provided rating curves for varying amounts of annual average precipitation. The rating curves for regions with 30 to 45 inches of annual precipitation provided a better fit to the data compared to Emmett and were selected to predict bankfull width for streams in the study area:

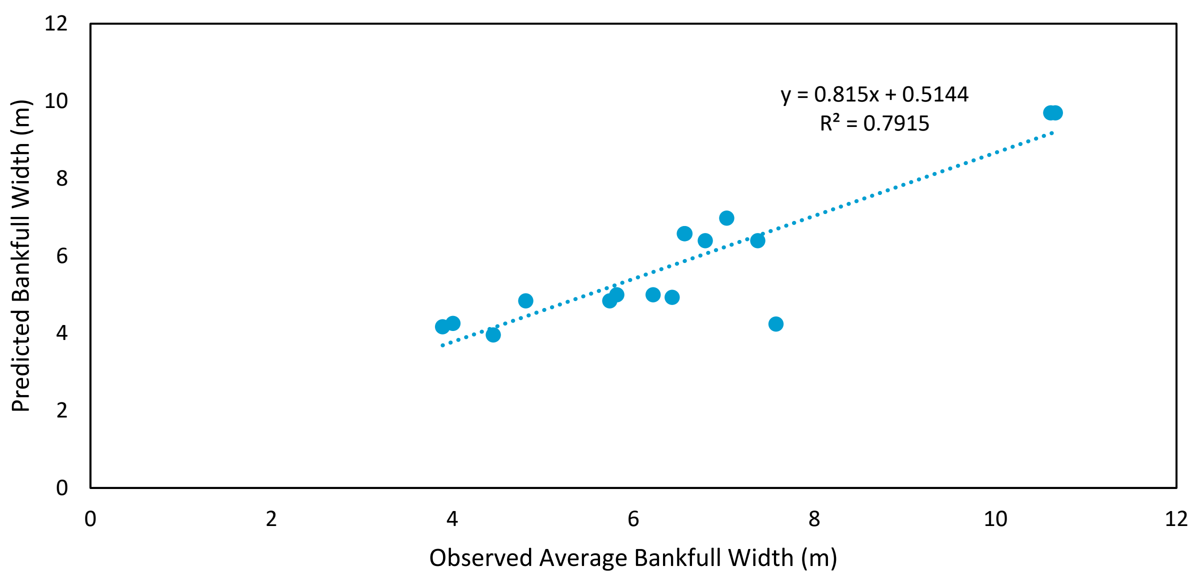
$$W_B = 1.84 * (DA^{0.441})$$

where

W_B = bankfull width in meters

DA = drainage area in square miles

Graph 4-1 compares the predicted and observed bankfull widths using the Lawlor (2004) rating curves. A trendline with a slope of 1 would indicate a near perfect fit. Given the varying conditions observed within a reach (typically comprising riffles, runs, and pools), and the nature of the observations (a limited number of transects were collected within each reach), a trendline slope of 0.81 and an R^2 of 0.79 are sufficiently accurate for this application. TTools requires bankfull width in its determination of topographic and vegetative shading. TTools uses bankfull width to indicate the width across which rooted vegetation would not occur (canopy overhang is accounted for separately). Predicted bankfull widths were assigned to streamlines for this analysis.



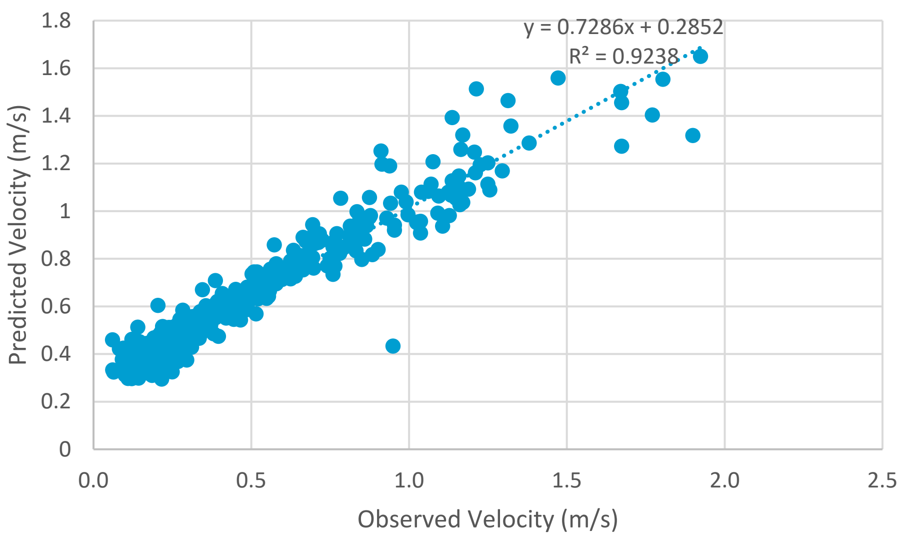
Graph 4-1. Comparison of Predicted to Observed Bankfull Width

Source: BC data analysis in support of existing conditions modeling.

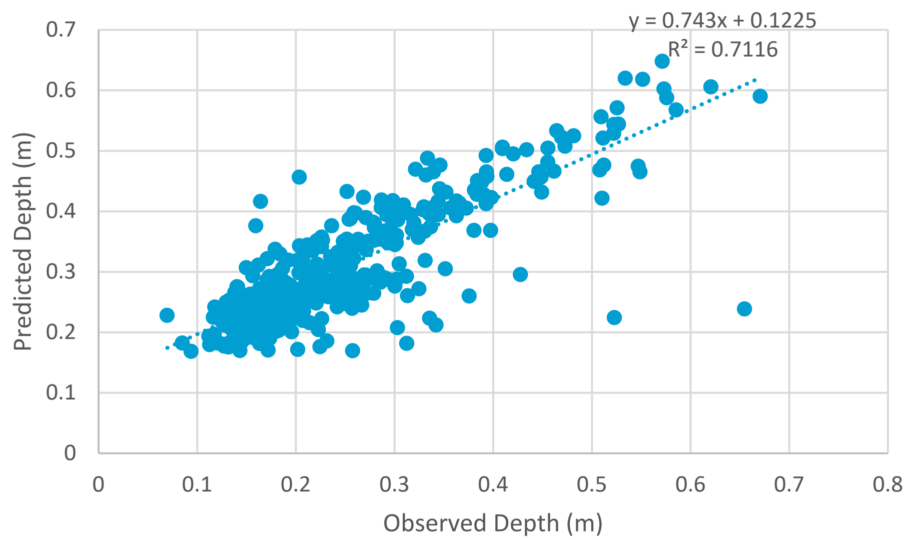
Characteristics describing wetted conditions (velocity, depth, and wetted width) vary with stream flow, and rating curve equations can be developed relating each of the three variables to flow. Laws of continuity summarized by Emmett require that the sum of the rating curve equation exponents equals 1, and the product of the coefficients equals 1. Thus, specification of two of the three curves dictates the third curve. Rating curves were developed using data collected by USGS, MWH, and Rio ASE. For this study area, the following rating curves were developed based on the available data:

$V_W = 0.75 * (Q^{0.32})$
$D_W = 0.35 * (Q^{0.25})$
$W_W = 3.81 * (Q^{0.43})$
where
V_W = Velocity in meters per second
D_W = Wetted depth in meters
W_W = Wetted width in meters
Q = Flow in cubic meters per second

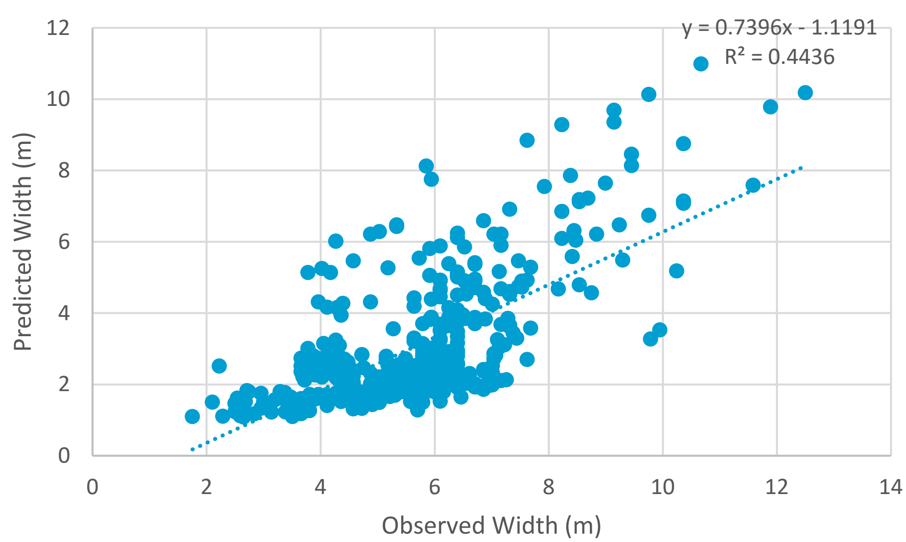
Graph 4-2 through Graph 4-4 show the predicted (i.e., computed from flow using the rating curve equations above; y-axis) versus observed data (i.e., measured in the field by USGS, MWH, and Rio ASE; x-axis) for these three parameters (V_w, D_w, and W_w). Coefficients and exponents were adjusted to achieve the best fit across all three parameters (the closest slopes to 1 for the dotted line and best R^2 values). For these data, slopes of the regression line of 0.73 to 0.74 were achieved across the three parameters. R^2 values ranged from 0.44 (for width) to 0.92 (for velocity). The lower R^2 for width indicates it is less strongly correlated to flow compared to the other parameters. Fitting a rating curve solely to the width data without the constraints of continuity did not result in higher R^2 values.



Graph 4-2. Comparison of Predicted (y-axis) to Observed (x-axis) Velocity (V_W)



Graph 4-3. Comparison of Predicted to Observed Wetted Depth (D_W)



Graph 4-4. Comparison of Predicted to Observed Wetted Width (W_W)

These "global" rating curves were entered into QUAL2K to describe the hydraulic conditions associated with simulated stream flow. During model calibration (described in Section 5.1), rating curves for some segments were revised to better simulate water temperatures. Revisions to rating curves were based on velocity, wetted depth, and wetted width measurements collected by MWH and Rio ASE near the reach being calibrated. Table 4-1 summarizes the rating curve coefficients and exponents for streams in the study area for the calibrated model. The coefficients and exponents for each set of equations maintain the laws of continuity for flow.

Table 4-1. Rating Curves for Streams in the Study Area

Reach Description (Number)	Velocity (m/s)	Depth (m)	Width (m)
Model Reaches Upstream of YPP			
EFSFSR above Meadow Creek (1–6)	$0.75 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$6.06 * (Q^{0.43})$
Lower Meadow Creek above East Fork Meadow Creek (15 and 16)	$0.48 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$9.47 * (Q^{0.43})$
East Fork Meadow Creek (17)	$1.6 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$1.78 * (Q^{0.43})$
EFSFSR below Meadow Creek (21)	$0.48 * (Q^{0.32})$	$0.22 * (Q^{0.25})$	$9.47 * (Q^{0.43})$
Model Reaches Downstream of YPP			
Upper Sugar Creek and unnamed tributaries to upper Sugar Creek (1–7)	$0.48 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$5.95 * (Q^{0.43})$
Model Reaches Upstream and Downstream of YPP			
All other streams in the study area	$0.75 * (Q^{0.32})$	$0.35 * (Q^{0.25})$	$3.81 * (Q^{0.43})$

4.4 Selection of Calibration and Validation Dates

QUAL2K is a steady state model that predicts diurnal temperature variability. To evaluate potential impacts of mining and restoration, simulation dates representative of thermal criteria have been selected as the calibration and validation periods. Late July and late September were selected as the target periods for calibration and validation, respectively. The calibration period was selected as a low-flow, high-temperature condition for comparison to the USFS MWMT and the IDEQ maximum daily maximum temperature (MDMT), MWMT, and maximum daily average temperature (MDAT) described in Section 2.3. The validation period was selected for comparison to spawning season conditions for bull trout and Chinook salmon (the spawning period for steelhead is in the spring when flows due to snowmelt runoff are relatively high and mining operations would be less likely to impact water temperatures).

Evaluating 15-minute flow data available at multiple USGS gages in the study area during these months led to the selection of July 29, 2016, for calibration and September 24, 2014, for validation. Both dates represent steady-state flow conditions as shown in Figure 16 and Figure 17. Fifteen-minute temperature data around this time is shown on Figure 18 and Figure 19.

4.5 TTools and Shade Model Configuration for Existing Conditions

QUAL2K requires hourly estimates of stream shading caused by topography and surrounding vegetation. Estimation of hourly shade values for reaches simulated in QUAL2K have been developed using TTools and Shade.xls. TTools is an ArcMap script that processes spatial coverages of topographic and vegetative data and outputs aspect, topographic angles, canopy height, and canopy density. TTools processes input data in several increments out from the stream channel over a distance of 9 kilometers. Outputs from TTools are entered into the Shade.xls model along with estimates of canopy overhang. Output from the Shade.xls model is entered into QUAL2K as hourly shade estimates by reach. This section of the report describes how TTools and Shade.xls model were used to support development of the SPLNT model.

4.5.1 TTools

The ArcGIS Extension TTools (Boyd and Kasper 2003) was applied to process the spatial data for the study area and generate inputs for the Shade.xls model. The topographic data processed with TTools is described in Section 4.1 and shown in Figure 15.

Shading from riparian vegetation is influenced by canopy height, density, overhang, and distance from the stream. The LiDAR data collected by Midas Gold was used to develop coverages of canopy height and density using methods similar to those described by the USGS (2013) for the data in the vicinity of the streams. Vegetation height was determined as the difference in elevation between returns classified as vegetation and a normalized ground-surface layer based on ground-classified returns. A 10-foot-by-10-foot raster layer of canopy height was created for the region using the top of the vegetative layer in each cell. Vegetation density was estimated as the ratio of LiDAR returns classified as vegetation to the total number of returns classified as vegetation or ground. These height and density coverages were sampled for each stream reach using the TTools extension to provide inputs to the Shade.xls model. Figure 20 through Figure 22 show the vegetation characteristics provided by the USFS or derived from the LiDAR data.

4.5.2 Shade Model

The Washington State Department of Ecology developed the Shade.xls model to facilitate the generation of hourly shade estimates based on previous modeling by the ODEQ (Models for Total Maximum Daily Load Studies; http://www.ecy.wa.gov/programs/eap/models.html). The Shade.xls model accounts for geographic position, topography, and vegetation characteristics to estimate the hourly percent shading by stream reach. Topographic shading can be created by both near-field and far-field features, and the degree of shading changes with the position of the sun.

The Shade.xls model relies on output from TTools (Section 4.5.1) in the determination of hourly shade values for QUAL2K (Section 4.6.5). In addition, the user must also assign canopy overhang estimates. Average overhang was estimated as a percent of height for trees (10 percent) and shrubs (25 percent) based on studies by Stuart (2012) and Shumar and de Varona (2009). The methods from these studies were also used to estimate overhang for the Nemote Creek, Montana, temperature total maximum daily load (TMDL) approved by EPA (Tetra Tech 2014).

The Shade.xls model was used to evaluate shade conditions every 200 feet along the stream network. Substantial changes in hourly shade estimates along the reaches were used to inform reach breaks for QUAL2K. Once the QUAL2K reaches were determined (based on the tributary network and changes in shade estimates), the Shade.xls model was rerun to provide inputs to QUAL2K (hourly shade estimates by reach). Figure 23 shows the hourly Shade.xls model output every 200 feet along the streams. The length shown on the y-axis for each panel is held constant.

4.6 QUAL2K Model Configuration for Existing Conditions

This section describes the configuration and initialization of the QUAL2K model to represent existing conditions for the study area. Future reports will describe the configurations to represent the Proposed Action including post-mining conditions and alternatives if appropriate. While Midas Gold typically reports English units for reports, the QUAL2K model inputs are in metric units. These sections provide inputs in metric units consistent with the QUAL2K model to facilitate review by the USFS and cooperating agencies.

4.6.1 Stream Network and Reach Characterization

QUAL2K defines a model reach as one where average conditions are similar over the length of the reach. Recent work by BC to refine the hydrologic modeling for the SGP was used as the starting point for defining the stream network for consistency across models. The extent of the QUAL2K model was then defined as described in Section 2.1. Reaches were split into separate modeling reaches at tributary confluences, distinct changes in shade (referred to as shadebreaks in Table 4-2), and the upper extent of proposed mine features (Figure 3).

Figure 24 shows the mean hourly shade from 05:00 to 20:00 based on output from the Shade.xls model and conditions representative of early August (solar angles, etc.). The location of reach breaks established for the existing conditions model are shown as vertical lines with blue lines indicating a tributary confluence, green lines showing locations of potential mine features, and orange lines showing where a reach break was assigned due to changes in mean hourly shade. If a tributary or mine feature was already near a change in mean hourly shade, an additional break was not assigned.

Two separate QUAL2K models have been developed to represent the existing conditions for the study area. Because the YPP is in the model domain and is being simulated dynamically using the GLM (Section 4.7), it was necessary to simulate the existing conditions upstream and downstream of the YPP using two separate QUAL2K models. Table 4-2 summarizes the reach configuration including the reach number, description, and length for each model.

Table 4-2. Reach Characteristics for the QUAL2K Models Upstream and Downstream of YPP

Reach Number	Reach Description[a]	Reach Length (km)
Model Reaches Upstream of YPP		
1	EFSFSR, Headwater to reach break	0.50
2	EFSFSR, reach break to EFSFSR Trib 4	0.43
3	EFSFSR Trib 4 Headwater	0.63
4	EFSFSR, EFSFSR Trib 4 to reach break	0.67
5	EFSFSR, reach break to Rabbit Creek	0.86
6	EFSFSR, Rabbit Creek to Meadow Creek	1.91
7	Meadow Creek (MC), Headwater to reach break	1.40
8	Meadow Creek, reach break to MC Trib 2	1.16
9	MC Trib 2, Headwater to reach break	0.76
10	MC Trib 2, reach break to Meadow Creek	0.60
11	Meadow Creek, MC Trib 2 to MC Trib 3	0.34
12	MC Trib 3, Headwater to reach break	0.76
13	MC Trib 3, reach break to Meadow Creek	0.83
14	Meadow Creek, MC Trib 3 to reach break	0.90
15	Meadow Creek, reach break to reach break	1.02
16	Meadow Creek, shadebreak to East Fork MC	0.93
17	East Fork MC, Headwater to shadebreak	2.76
18	East Fork MC, shadebreak to Meadow Creek	1.65
19	Meadow Creek, East Fork MC to shadebreak	1.15

Reach Number	Reach Description[a]	Reach Length (km)
20	Meadow Creek, shadebreak to EFSFSR	0.36
21	EFSFSR, Meadow Creek to Garnet Creek	0.66
22	Garnet Creek, Headwater to shadebreak	1.10
23	Garnet Creek, shadebreak to EFSFSR	0.74
24	EFSFSR, Garnet Creek to Fiddle Creek	1.77
25	Fiddle Creek (FC), Headwater to FC Trib 3	0.52
26	Fiddle Creek, FC Trib 3 to shadebreak	0.33
27	Fiddle Creek, shadebreak to EFSFSR	1.94
28	EFSFSR, Fiddle Creek to shadebreak	0.23
29	EFSFSR, shadebreak to Midnight Creek	0.36
30	Midnight Creek Headwater	2.99
31	EFSFSR, Midnight Creek to YPP Lake	0.12
	Model Reaches Downstream of YPP	
1	Sugar Creek (SC), Headwater to shadebreak	0.55
2	Sugar Creek, shadebreak to SC Trib 4	0.58
3	Sugar Creek Trib 4 Headwater	0.26
4	Sugar Creek, SC Trib 4 to SC Trib 5	0.17
5	Sugar Creek Trib 5 Headwater	0.24
6	Sugar Creek, SC Trib 5 to shadebreak	0.71
7	Sugar Creek, shadebreak to West End Creek	0.92
8	West End Creek, Headwater to shadebreak	0.76
9	West End Creek, shadebreak to shadebreak	1.13
10	West End Creek, shadebreak to Sugar Creek	1.60
11	Sugar Creek, West End Creek to EFSFSR	1.19
12	EFSFSR, YPP Lake to Sugar Creek	1.12
13	EFSFSR, Sugar Creek to Hennessy Ditch	0.15[b]
14	Hennessy Creek, Headwater to shadebreak	1.49
15	Hennessy Ditch, shadebreak to shadebreak	0.92
16	Hennessy Ditch, shadebreak to EFSFSR	0.53
17	EFSFSR, Hennessy Ditch to Model End	0.86

[a]Shadebreaks are locations where a distinct change in shade was determined from the shade modeling and a new reach was assigned.

[b]Actual distance is 0.04 kilometer. However, the QUAL2K model would not compile and complete the Fortran calculations with the actual distance. Increased distance was necessary for the model to complete calculations for concentrated area of confluence between EFSFSR, Sugar Creek, and Hennessy Ditch (upper reaches are referred to as Hennessy Creek due to more natural condition). This resulted in moving the Hennessy Ditch input downstream approximately 360 feet in the model.

4.6.2 Headwater Flows and Temperatures

The model domain for the QUAL2K model is illustrated in Figure 3. Drainage areas upstream of the model domain are represented in the model as headwater inputs. Table 4-3 and Table 4-4 summarize the flow and temperatures specified for these headwaters for the calibration and validation model runs. Flows were based on the drainage areas delineated to each point using the methods described in Section 4.2. Water temperatures were based on observations recorded at nearby, similar temperature monitoring sites. Changes in water temperature relative to stream length (to inform assumptions on headwater temperatures) were estimated based on the difference in measurements at MWH-034 and MWH-003 (Figure 6). These stations were selected because they are the most upstream stations in the headwaters of the study area that are close enough together to not be influenced substantially by diffuse flow inputs or tributaries. Simulated diurnal variability at the headwaters was exaggerated slightly relative to temperatures observed downstream (while the daily averages were maintained). Headwaters have lower stream flows and are subject to greater fluctuations in water temperature. This pattern was observed by comparing upstream and downstream temperature monitoring data.

Table 4-3. Daily Average Stream Flows Specified for Headwaters for the Calibration and Validation Periods

Tributary (see Figure 3)	Drainage Area at Headwater Input (square miles)	Average Daily Flow (cms) for Calibration Date (July 29, 2016)	Average Daily Flow (cms) for Validation Date (September 24, 2014)
Sugar	14.81	0.307	0.200
SugarTrib_4	0.25	0.005	0.003
SugarTrib_5	0.47	0.010	0.006
West End	0.024	0.0005	0.0003
Hennessy	0.25	0.005	0.003
Midnight	0.034	0.001	0.0005
Fiddle	0.96	0.019	0.014
Fiddle_Trib3*	0.078	0.002	0.001
Garnet	0.048	0.0009	0.0007
EastForkMeadow	0.74	0.016	0.010
Meadow_Trib3	1.02	0.022	0.013
Meadow_Trib2	0.31	0.007	0.004
Meadow	0.64	0.014	0.008
Rabbit[a]	0.63	0.015	0.012
EFSFSR_Trib4	1.91	0.044	0.036
EFSFSR_US	4.04	0.093	0.076

[a]*Fiddle_Trib3 and Rabbit are simulated as point source inputs rather than tributaries.*

Table 4-4. Range of Hourly Water Temperatures Specified for Headwaters for the Calibration and Validation Periods

Tributary (see Figure 3)	Minimum, Average, and Maximum Hourly Temperatures (°C) for Calibration Date (July 29, 2016)	Minimum, Average, and Maximum Hourly Temperatures (°C) for Validation Date (September 24, 2014)
Sugar	6.7, 9.8, 13.7	7.5, 8.7, 9.9
West End	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Hennessy	5.6, 8.3, 11.5	6.7, 7.9, 9.1
EFSFSR Below YPP[a]	13.4	10.5
Midnight	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Fiddle	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Fiddle_Trib3[b]	8.3	7.9
Garnet	5.6, 8.3, 11.5	6.7, 7.9, 9.1
EastForkMeadow	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow_Trib3	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow_Trib2	5.6, 8.3, 11.5	6.7, 7.9, 9.1
Meadow	7.8, 10.9, 14.6	7.5, 8.7, 9.9
Rabbit[b]	8.3	7.9
EFSFSR_Trib6	5.6, 8.3, 11.5	6.7, 7.9, 9.1
EFSFSR_US	6.7, 9.8, 13.7	7.5, 8.7, 9.9

[a]*Headwater inputs for EFSFSR below the YPP are derived from the GLM described in Section 4.7.*

[b]*Tributaries simulated as point sources are only assigned a mean daily temperature as model input.*

4.6.3 Diffuse Flow Inputs and Temperatures

Groundwater inputs are simulated by QUAL2K as diffuse flows that are constant inputs over the length of a reach. Assignment of diffuse flows maintains the flow balance throughout the system. Diffuse flows were assigned based on the observed differences at upstream and downstream USGS flow gages. Daily average water temperatures must also be defined for diffuse flows.

Table 4-5 summarizes the diffuse flow inputs and water temperatures assigned to each QUAL2K model reach. Diffuse source temperature was estimated as the average of (1) mean ambient air temperature for the preceding month of the calibration/validation period and (2) the average of seep/adit water temperature data collected by HDR between 2012 and 2016. Seep/adit temperatures were sorted spatially to apply to specific reaches and temporally to apply to the specific calibration and validation periods. This approach allowed for the use of site-specific data and consistency with approaches used for EPA-approved TMDLs (Montana DEQ and EPA Region 8 2014; Tetra Tech 2013, 2014).

Table 4-5. Diffuse Flows and Associated Water Temperature for the QUAL2K Models Upstream and Downstream of YPP

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
Model Reaches Upstream of YPP					
1	EFSFSR, Headwater to reach break	0.0060	11.90	0.0050	10.60
2	EFSFSR, reach break to EFSFSR Trib 4	0.0050	11.90	0.0040	10.60
3	EFSFSR Trib 4 Headwater	0.0070	11.90	0.0060	10.60
4	EFSFSR, EFSFSR Trib 4 to reach break	0.0070	11.90	0.0060	10.60
5	EFSFSR, reach break to Rabbit Creek	0.0100	11.90	0.0080	10.60
6	EFSFSR, Rabbit Creek to Meadow Creek	0.0210	13.90	0.0170	11.60
7	Meadow Creek, Headwater to reach break	0.0180	11.90	0.0110	10.60
8	Meadow Creek, reach break to MC Trib 2	0.0150	11.90	0.0090	10.60
9	MC Trib 2, Headwater to reach break	0.0100	11.90	0.0060	10.60
10	MC Trib 2, reach break to Meadow Creek	0.0080	11.90	0.0050	10.60
11	Meadow Creek, MC Trib 2 to MC Trib 3	0.0040	11.90	0.0030	10.60
12	MC Trib 3, Headwater to reach break	0.0100	11.90	0.0060	10.60
13	MC Trib 3, reach break to Meadow Creek	0.0100	11.90	0.0060	10.60
14	Meadow Creek, MC Trib 3 to reach break	0.0090	13.90	0.0060	11.60
15	Meadow Creek, reach break to reach break	0.0070	13.90	0.0060	11.60
16	Meadow Creek, shadebreak to East Fork MC	0.0060	13.90	0.0060	11.60
17	East Fork MC, Headwater to shadebreak	0.0180	11.90	0.0160	10.60
18	East Fork MC, shadebreak to Meadow Creek	0.0110	11.90	0.0100	10.60
19	Meadow Creek, East Fork MC to shadebreak	0.0080	13.90	0.0070	11.60
20	Meadow Creek, shadebreak to EFSFSR	0.0020	13.90	0.0020	11.60

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
21	EFSFSR, Meadow Creek to Garnet Creek	0.0040	13.90	0.0020	11.60
22	Garnet Creek, Headwater to shadebreak	0.0070	11.90	0.0040	10.60
23	Garnet Creek, shadebreak to EFSFSR	0.0050	11.90	0.0030	10.60
24	EFSFSR, Garnet Creek to Fiddle Creek	0.0110	11.90	0.0060	10.60
25	Fiddle Creek, Headwater to FC Trib 3	0.0030	11.90	0.0020	10.60
26	Fiddle Creek, FC Trib 3 to shadebreak	0.0020	11.90	0.0010	10.60
27	Fiddle Creek, shadebreak to EFSFSR	0.0120	11.90	0.0070	10.60
28	EFSFSR, Fiddle Creek to shadebreak	0.0010	11.90	0.0010	10.60
29	EFSFSR, shadebreak to Midnight Creek	0.0020	11.90	0.0010	10.60
30	Midnight Creek Headwater	0.0190	11.90	0.0100	10.60
31	EFSFSR, Midnight Creek to YPP Lake	0.0010	11.90	0.0004	10.60
Model Reaches Downstream of YPP					
1	Sugar Creek, Headwater to shadebreak	0.0040	11.90	0.0030	10.60
2	Sugar Creek, shadebreak to SC Trib 4	0.0040	11.90	0.0030	10.60
3	Sugar Creek Trib 4 Headwater	0.0020	11.90	0.0010	10.60
4	Sugar Creek, SC Trib 4 to SC Trib 5	0.0010	11.90	0.0010	10.60
5	Sugar Creek Trib 5 Headwater	0.0020	11.90	0.0010	10.60
6	Sugar Creek, SC Trib 5 to shadebreak	0.0050	11.90	0.0030	10.60
7	Sugar Creek, shadebreak to West End Creek	0.0070	11.90	0.0040	10.60
8	West End Creek, Headwater to shadebreak	0.0050	11.90	0.0040	10.60
9	West End Creek, shadebreak to shadebreak	0.0080	11.90	0.0050	10.60

Reach Number	Reach Description	Calibration Run Diffuse Inflow (cms)	Calibration Run Daily Average Water Temperature (°C)	Validation Run Diffuse Inflow (cms)	Validation Run Daily Average Water Temperature (°C)
10	West End Creek, shadebreak to Sugar Creek	0.0050	11.90	0.0030	10.60
11	Sugar Creek, West End Creek to EFSFSR	0.0080	14.80	0.0060	12.00
12	EFSFSR, YPP Lake to Sugar Creek	0.0070	11.90	0.0040	10.60
13	EFSFSR, Sugar Creek to Hennessy Creek	0.0003	14.80	0.0001	12.00
14	Hennessy Creek, Headwater to shadebreak	0.0090	11.90	0.0050	10.60
15	Hennessy Ditch, shadebreak to shadebreak	0.0060	11.90	0.0030	10.60
16	Hennessy Ditch, shadebreak to EFSFSR	0.0030	11.90	0.0020	10.60
17	EFSFSR, Hennessy Ditch to Model End	0.0050	14.80	0.0030	12.00

4.6.4 Meteorological Inputs

For the QUAL2K modeling of existing conditions, observed conditions for the calibration and validation dates were input to the model. QUAL2K calculates the heat balance based on the geographical position, hours of daylight, short- and long-wave radiation, atmospheric attenuation, reflection, conductance, convection, thermal exchange with the sediments, cloud cover, and shade. Cloud cover and shade are input by the user on an hourly basis. QUAL2K provides user-selected calculations for the other required terms of the heat balance. Meteorological data from the MesoWest station in the study area were used to develop the hourly meteorological inputs for the QUAL2K model for the calibration date (July 29, 2016) and the validation date (September 24, 2014) as shown in Figure 25. Hourly air temperature, dew point temperature, and wind speed are directly input to QUAL2K. Solar radiation is used to estimate cloud cover. For the calibration and validation dates selected, the solar radiation observations generate a smooth curve with values expected for this time of year when no cloud cover is present. Thus, for these dates, percent cloud cover was set to zero each hour. This assumption also results in conservative assumptions for evaluating model scenarios because the maximum amount of solar radiation would reach the streams under this condition.

In subsequent reports, these scenarios will represent the Proposed Action and alternatives by altering the channel configurations, stream flows, and shading values as appropriate (i.e., increased shading due to riparian vegetation restoration or decreased shading due to removal of vegetation). Meteorological conditions will not be varied when evaluating potential changes to water temperature caused by mining operations. Some meteorological inputs were varied during model sensitivity analyses as described in Section 5.3.

4.6.5 Shade Inputs

Section 4.5.2 describes how the Shade.xls model was used to evaluate the fraction of shade each hour of the day every 200 feet along the tributaries evaluated. Section 4.6.1 provides graphical displays of how the mean hourly shade values were used to inform reach breaks for QUAL2K. Once the reaches were defined, the incremental output (every 200 feet) from Shade.xls was averaged to provide inputs to the QUAL2K model. Figure 26 shows the hourly shade values for each of the 31 reaches located upstream of YPP. Figure 27 shows the values for each of the 17 reaches located downstream of the YPP. Reach numbers in these figures correspond to those listed in Table 4-2.

4.6.6 QUAL2K Inputs for the Light and Heat Budget

QUAL2K simulates the heat balance with a series of equations describing short- and long-wave radiation, thermal exchange with the air and sediments, and evaporation. The various methods and assumptions are described in the *QUAL2K User Manual* (Chapra et al. 2008). Table 4-6 lists the inputs specified for the calibration and validation runs for the SGP. Default model parameters were applied. The model was not sensitive to altering the default values as shown in Section 5.3.

Table 4-6. Specifications for the QUAL2K Heat Balance Described by Chapra et al. (2008)

Parameter	Value	Units
Solar shortwave radiation model		
Atmospheric attenuation model for solar	Ryan-Stolzenbach	–
Atmospheric turbidity coefficient (2 = clear, 5 = smoggy, default = 2)	2	–
Atmospheric transmission coefficient (0.70–0.91, default 0.8)	0.8	–
Atmospheric longwave emissivity model	Brunt	–
Evaporation and air convection/conduction		
Wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer	–
Sediment heat parameters		
Sediment thermal thickness	10	cm
Sediment thermal diffusivity	0.0064	cm^2/s
Sediment density	1.6	g/cm^3
Water density	1	g/cm^3
Sediment heat capacity	0.4	cal/(g °C)
Water heat capacity	1	cal/(g °C)

– = unitless.

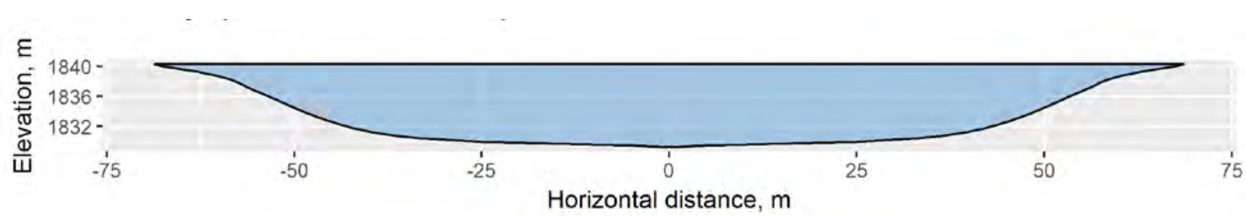
4.7 GLM Configuration for Existing Conditions

The GLM dynamically simulates the heat and water balance of the YPP lake over depth and through time and therefore requires time series inputs of model drivers and boundary conditions. This section describes the model configuration, assumptions, and data sources for simulating the existing temperature conditions as water enters and passes through the YPP.

4.7.1 Bathymetry

Existing bathymetric data (Figure 8, Quadrant Consulting, Inc. 2016) were used to quantify the relationship between water depth, surface area, and water volume. Because the model uses a 1-dimensional approximation of the lake, the structure in the horizontal direction is simplified to a simple relationship relating the vertical depth increments to water volume (Graph 4-5). Water volume within any specified depth layer can be integrated from this relationship.

These data were used directly in the GLM model to dynamically calculate the volume of water within each thermal layer as they expand and shrink through time.

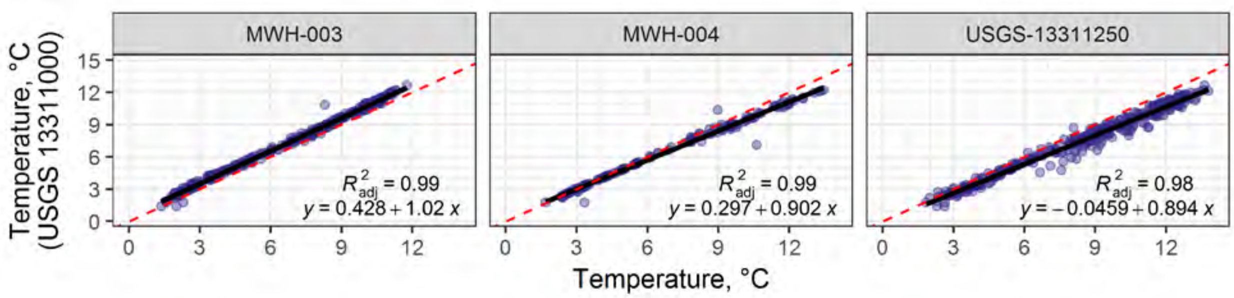


Graph 4-5. Cross Section (to Scale) of the Relationship Between Water Depth and Horizontal Distance

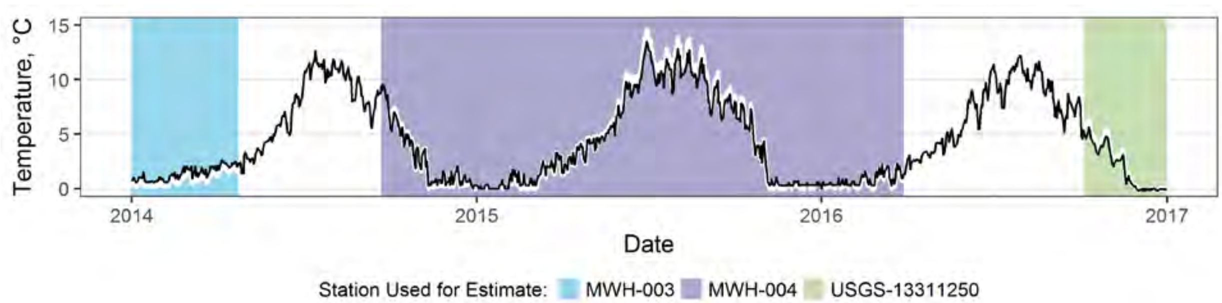
4.7.2 Upstream Inflow and Water Temperature

Daily inflow volume was obtained from a continuous record of flow from USGS Gage 13311000 EFSFSR at Stibnite, which is the nearest gage upstream of the YPP (Figure 6). The volume of water entering the YPP is high relative to the size of the lake. When flows are their greatest during the spring, residence time of the lake is under one day and inflow often provides enough water to refill the lake two to eight times in a single day. Even during the periods of low flow, residence time of the lake is on the order of only 5 to 7 days. This rate of flow-through relative to the volume of the lake is the most important driver of conditions in the YPP. Figure 28 shows the observed flows upstream and downstream of the YPP and the estimated residence time.

The record of water temperature at USGS Gage 13311000 EFSFSR at Stibnite is not as complete as the flow record and only includes the periods between April 25, 2014, to Sept 20, 2014, and between March 29, 2016, and October 4, 2016. To develop a full record of temperature for input for the model, water temperatures from nearby sites with a more complete record were compared with water temperature at Gage 13311000 EFSFSR at Stibnite for all overlapping periods. Because of a strong coherence in temperature among sites on the stream network (slopes near 1 and R^2 values between 0.98 and 0.99), statistical relationships were used to develop a complete time series of temperatures for the water entering the YPP (Graph 4-6). The closest upstream station with available data was used for each missing period (MWH-004, then MWH-003). For the last missing period, beginning in October 2016, no upstream data were available and the next downstream station was used (USGS 13311250) (Graph 4-7).



Graph 4-6. Stream Temperature Relationships Used to Estimate Input Temperatures for the YPP Model



Graph 4-7. Water Temperature Time Series used as Input for the YPP GLM

Shaded regions indicate periods without temperature data at the closest upstream gage (USGS-13311000), and the color identifies which temperature gage was used for generating the input data set during each period.

4.7.3 Meterological Drivers

The GLM requires at least daily values of air temperature, relative humidity, incoming solar radiation, wind speed, and precipitation. These datasets were primarily compiled from Midas Gold's on-site weather station record. For periods of missing data, values were obtained through the best available statistical relationships with other data sources, including the National Climatic Data Center dataset from McCall, Idaho (National Centers for Environmental Information, https://www.ncei.noaa.gov), and grid-based data sets including PRISM (PRISM Climate Group, http://prism.oregonstate.edu) and Daymet (Thornton et al. 2017).

Daymet provided the relationship with the on-site mean daily air temperatures (R^2 = 0.97) and was used to fill in all gaps in temperature when it was available. Daymet provided the only other source for incoming solar radiation during times the on-site station was down and was used to fill in missing values.

On-site relative humidity was best predicted from the data recorded at the National Climatic Data Center weather station in McCall (R^2 = 0.79), and the PRISM dataset was used to fill in the few times when data were unavailable from the McCall station. Wind speed and precipitation are typically more local phenomena with only longer-term averages showing spatial correspondance among distant stations. Data from the McCall weather station were used as surrogates when necessary, with the understanding that any single predicted value may not be accurate but that accuracy improves when averaged over several days.

The full set of daily meteorologic input values are provided in Figure 29.

Section 5

Results

This section summarizes the calibration and validation results developed for the existing conditions SPLNT model. Additional scenarios will be developed to represent conditions during and post-mining and reported in the SGP SPLNT Model Proposed Action Report. A combination of statistical and graphical comparisons were used to evaluate model calibration.

5.1 Model Evaluation Criteria

The SPLNT model predictions (predictions, P) were evaluated using the mean error (ME) and absolute mean error (AME) as measures of goodness of fit compared to observations (O) for daily minimum, mean, and maximum temperatures across all *N* sites with observations (sites, *i*). These performance measures were calculated as follows and are reported in measurement units (°C).

$$ME = \frac{1}{N}\sum_{i=1}^{N} P_i - O_i$$

$$AME = \frac{1}{N}\sum_{i=1}^{N} |P_i - O_i|$$

The time series of predicted outlet temperatures (P) from YPP were additionally evaluated against downstream observations (O) using the Nash-Sutcliffe efficiency coefficient (*E*) calculated as follows:

$$E = 1 - \frac{\sum_{t=1}^{T}(P_t - O_t)^2}{\sum_{t=1}^{T}(O_t - \bar{O})^2}$$

The Nash-Sutcliffe efficiency coefficient can range from negative infinity to 1. A value of zero indicates the model does no better than simply using the mean of the observed values as the prediction. A value of 1 indicates the model predicts the observations perfectly. A value of less than 0 indicates the model residual variance is greater than the variance in the data—that is, the model is a worse predictor of the observations than mean of all the observations.

5.2 Model Calibration and Validation

The SPLNT model was calibrated for July 29, 2016, and validated for September 24, 2014. The QUAL2K simulated daily maximums, daily minimums, and daily averages compared to observations for streams upstream and downstream of the YPP are shown in Table 5-1, Figure 30, and Figure 33. For the calibration date, observations are available at eight locations above YPP and three locations below YPP for comparison to simulated water temperatures. Across the model domain, the mean error of model simulated daily average and maximum temperatures indicates little bias with values less than 0.1 °C. The mean error of minimum daily temperatures was 0.4 °C, showing, on average, a slightly conservative overestimate of minimum temperature. Mean absolute errors for all three metrics were 0.3, 0.4, and 0.6 °C respectively. For the validation date, observations are available at seven locations upstream of YPP and four locations below YPP. Mean error of the minimum, average, and maximum simulated water temperatures are 0.3, 0.4, and 0.6 °C respectively, indicating the validated model was slightly conservative in its predictions (estimating temperatures slightly higher than those observed). Mean absolute errors were comparable to the calibration values, with values of 0.4, 0.7, and 0.6°C for the daily average, maximum, and minimum, respectively.

Figure 31 shows the temperature results for the YPP GLM. The top half of the figure shows the time series of simulated outflow temperature values compared to those observed downstream of YPP. For periods when observations are available, the model output matches the observed data well, with a mean absolute error of 0.7 °C. Modeled YPP outlet temperatures are on average 0.4 °C lower than the observed temperatures at the USGS gage (13311250) approximately 1 kilometer downstream from YPP. This error is small compared to the daily range in observed temperatures of 2.4 °C and is in the right direction given that the water temperature should warm slightly as it moves out of the YPP and flows downstream in the EFSFSR. The lower half of the figure shows the daily average observed temperatures versus predicted (R^2 = 0.96, Nash-Sutcliffe efficiency = 0.94). This comparison to observed data indicates that the GLM is suitable for simulating pit lake temperatures as a component of the SPLNT model.

Model results for DO and temperature over the depth of the YPP lake are shown in Figure 32. The model shows the lake beginning to stratify during periods of low flow and warm weather, but stratification often appears to be weak and easily disturbed by moderate flow events during its onset. For the summer of 2015, stratification appears to have been able to set in with less disturbance, allowing a stronger temperature gradient and thus stratification to persist for a longer period.

Table 5-1. Simulated, Observed, and Temperature Differences Compared to Observations for the QUAL2K Model

Model Above or Below YPP	Reach No.	Reach Description	Distance Upstream from Mouth of Tributary (km)	Temperature (°C) Simulated Average	Simulated Minimum	Simulated Maximum	Observed Average	Observed Minimum	Observed Maximum	Sim-Obs Average	Sim-Obs Minimum	Sim-Obs Maximum
For the Calibration Date												
Above	5	EFSFSR3	5.8	9.76	7.24	12.92	9.87	7.24	13.02	-0.11	0.00	-0.10
Above	6	EFSFSR4 (at Rabbit Creek)	3.4	9.83	7.62	12.23	10.00	7.20	13.20	-0.17	0.42	-0.97
Above	21	EFSFSR5 (at Meadow Creek)	2.6	11.79	8.02	16.56	12.20	8.20	17.00	-0.41	-0.18	-0.44
Above	11	MC2 (at MC Trib 2)	4.5	11.27	9.58	13.73	10.99	8.53	13.95	0.28	1.05	-0.22
Above	14	MC4 (at MC Trib 3)	3.7	10.92	9.22	13.16	10.60	8.20	13.50	0.32	1.02	-0.34
Above	15	MC6	3.0	11.88	8.98	16.02	11.29	8.27	15.26	0.59	0.71	0.76
Above	20	MC10	0.27	13.34	8.59	20.33	13.47	8.54	19.59	-0.13	0.05	0.74
Above	18	MC9	0.10	11.83	8.75	16.83	11.60	7.63	17.00	0.23	1.12	-0.18
Below	11	SC5	1.2	10.79	7.54	15.40	11.60	8.40	15.70	-0.81	-0.86	-0.30
Below	12	YPP Lake Headwater	0.25	13.46	12.82	14.99	13.60	12.00	14.70	-0.14	0.82	0.29
Below	12	YPP Lake Headwater	0.15	13.46	12.82	14.99	13.70	12.20	14.80	-0.24	0.62	0.19
			Average	11.67	9.20	15.20	11.72	8.76	15.25	-0.05	0.43	-0.05
			Mean Error	-0.05	0.43	-0.05	–	–	–	–	–	–
			Mean Absolute Error	0.31	0.62	0.41	–	–	–	–	–	–
For the Validation Date												
Above	6	EFSFSR4 (at Rabbit Creek)	3.4	8.39	6.99	10.27	8.40	6.70	10.40	-0.01	0.29	-0.13
Above	21	EFSFSR5 (at Meadow Creek)	2.6	9.41	6.95	13.20	9.60	7.00	13.20	-0.19	-0.05	0.00
Above	11	MC2 (at MC Trib 2)	4.5	9.50	8.27	11.60	8.86	7.38	10.71	0.64	0.89	0.89
Above	14	MC4 (at MC Trib 3)	3.7	9.29	8.04	11.32	8.40	7.00	10.80	0.89	1.04	0.52
Above	15	MC6	3.0	9.85	7.65	13.75	9.11	6.93	12.17	0.74	0.72	1.58
Above	20	MC10	0.27	10.54	7.32	16.23	10.49	7.03	15.72	0.05	0.29	0.51
Above	18	MC9	0.10	10.00	8.04	13.84	8.99	6.61	13.02	1.01	1.43	0.82
Below	11	SC5	1.6	8.87	7.13	11.78	8.77	7.02	11.08	0.10	0.11	0.70
Below	11	SC5	1.2	8.87	7.08	11.81	8.80	7.00	11.10	0.07	0.08	0.71
Below	12	YPP Lake Headwater	0.25	10.47	10.01	11.74	10.60	9.20	12.50	-0.13	0.81	-0.76
Below	12	YPP Lake Headwater	0.15	10.47	10.01	11.74	10.76	9.26	12.73	-0.29	0.75	-0.99
			Average	9.61	7.95	12.48	9.34	7.38	12.13	0.26	0.58	0.35
			Mean Error	0.26	0.58	0.35	–	–	–	–	–	–
			Mean Absolute Error	0.37	0.59	0.69	–	–	–	–	–	–

5.3 Sensitivity Analyses

Several sensitivity analyses were conducted to evaluate how changes in model input may affect simulated water temperatures. Two separate QUAL2K models have been developed to represent the existing conditions for the study area (upstream and downstream of the YPP). All QUAL2K sensitivity analyses were performed using the model upstream of the YPP. Sensitivity analyses for the YPP GLM are not included in this report but were conducted for light extinction, wind speed, and sediment oxygen demand parameters with little impact on simulated results because the YPP has a minimal impact on water temperatures. Sensitivity analyses for the proposed pit lake simulations will be included in the SGP SPLNT Model Proposed Action Report.

Model inputs used for the calibration date were applied for these analyses. The following parameters were analyzed:

- Air temperatures
- Cloud cover
- Diffuse flow input temperatures
- Sediment thermal thickness
- Hourly shade values
- Stream flow

The results of the sensitivity analyses compare model results for the minimum value simulated and the maximum value simulated. For reference, the observed data for the calibration day are also included in the figures for the sensitivity analyses. The resulting variation in model output described below is not in reference to the calibrated model or to the observations but rather the range over which the sensitivity analyses were conducted. Appendix B provides the input and output for the sensitivity analyses in tabular format.

Figure 34 shows the sensitivity of the model to altered air temperatures, which were either increased or decreased by 5 °C relative to the model inputs. Across this 10 °C variation, simulated water temperatures varied by up to approximately 1 °C.

Figure 35 shows the effects of increasing cloud cover. During both the calibration and validation runs, cloud cover was set to zero based on analysis of solar radiation data. Increasing the cloud cover to 50 percent across the site has the effect of lowering maximum simulated water temperatures by up to approximately 1 °C. Increasing the cloud cover to 100 percent had a more substantial effect and lowered simulated maximum water temperatures by up to 5 °C. Increasing cloud cover raised minimum water temperatures slightly in some areas, likely due to the insulating effect.

Figure 36 shows the sensitivity of the model to altered diffuse flow input temperatures, which were either increased or decreased by 2 °C relative to the model inputs. This 4 °C range in inputs resulted in changes in maximum water temperature up to 2 °C and minimum water temperature slightly more than 2 °C.

Figure 37 shows the sensitivity of the model to changes in diffuse flow rates. These sensitivity analyses were run assuming either a 50 percent decrease or 50 percent increase in diffuse flow rates. This variation in diffuse flow rates impacted simulated temperatures by up to approximately 1 °C.

Figure 38 shows the effect of altering the sediment thermal thickness to 5 cm less than or greater than the default value (10 cm) that was used for the model calibration. Over this 10-cm variation, simulated water temperatures were affected by up to approximately 0.5 °C.

Figure 39 shows the effect of altering the hourly shade values. The sensitivity analyses for this parameter were created assuming either the minimum shade (reach 19) or the maximum shade (reach 13) was applied across every reach. This variation in shade resulted in simulated maximum water temperatures that were affected by more than 10 °C at the downstream ends of the model reaches, indicating the model is relatively sensitive to shade values. Simulated minimum water temperatures were not greatly affected.

Figure 40 shows the sensitivity of the model to changes in total stream flow. Headwater flows, tributaries simulated as point sources, and diffuse flow inputs were decreased or increased by 50 percent for these model runs. Simulated minimum and average temperatures across this range of flows varied by up to 1 °C. Simulated maximum temperatures across this range of flows varied by up to 3 °C.

These sensitivity analyses indicated that the QUAL2K model is most sensitive to shade values, followed by maximum cloud cover. The model was least sensitive to the sediment thermal depth and air temperatures. Alterations to diffuse flow temperatures and stream flows caused moderate changes to stream temperatures. Sensitivity analyses were also conducted for inorganic suspended sediment (ISS) based on agency comments on the draft of this report. The results of this analysis are included in Appendix B. Increasing the ISS concentration from 0 mg/l as assumed under the existing condition to 5 or 10 mg/l did not impact simulated stream temperatures. While QUAL2K accounts for the effect of ISS on light penetration, it is not a variable that is considered in the heat balance.

Section 6

Summary

The SPLNT model was developed for the SGP to evaluate the potential changes to stream water temperatures and pit lake water temperatures and DO that may occur as a result of proposed mining features and subsequent site restoration. A series of tools and models were used to develop SPLNT: TTools, Shade.xls model, QUAL2K, and GLM.

The SPLNT existing conditions model was developed and calibrated primarily using data collected at the SGP. The models have been calibrated and validated and provide a relatively accurate tool that is considered sufficient for simulating water temperatures.

For the calibration date, simulated stream water temperatures are within 1.1 °C of observed values. For the validation date, simulated stream water temperatures are within 1.6 °C of observed values. Daily average outflow temperatures for the pit lake are generally predicted within 1 °C. For both the streams and pit lake, the model sometimes over predicts and sometimes under predicts water temperature, indicating the differences are random rather than biased.

The sensitivity analyses of the stream temperature model indicated that the model is most sensitive to shade values, followed by maximum cloud cover. The model was least sensitive to the sediment thermal depth and air temperatures. Alterations to diffuse flow temperatures and stream flows caused moderate changes to stream temperatures. Sensitivity analyses for the YPP GLM are not included in this report but were conducted for light extinction, wind speed, and sediment oxygen demand parameters with little impact on simulated results.

Subsequent reports will apply the SPLNT model to the Proposed Action and any alternatives that may affect water temperatures. Model output for the existing conditions, Proposed Action, and alternatives will be compared to criteria established by the USFS and Idaho. The comparisons (including for existing conditions) will be presented in the SGP SPLNT Model Proposed Action Report and SGP SPLNT Model Alternatives Report.

Section 7

Limitations

This document was prepared solely for Midas Gold in accordance with professional standards at the time the services were performed and in accordance with the contract between Midas Gold and BC dated January 16, 2017. This document is governed by the specific scope of work authorized by Midas Gold; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Midas Gold and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 8

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Section 9

Figures

Figure 1. SGP Modeling Process Overview

Figure 2. Existing Stream Network for the Study Area

Figure 3. QUAL2K Pour Points and Segmentation Points

Figure 4. SPLNT Area Topography (Contours Generated from LiDAR Data Collected by Midas Gold)

Figure 5. Meteorological Data Collected in the Study Area

Figure 6. Locations of MWH Stream Cross-Section Measurements in and near the Study Area

Figure 7. Locations of Rio ASE Stream Cross-Section Measurements in and near the Study Area

Figure 8. Bathymetric Data for Yellow Pine Pit

Figure 9. Flow and Temperature Monitoring Stations in and near the Study Area

Figure 10. Box Plots of Stream Flow Measured at USGS Gages in the Study Area from September 2011 to August 2017

Figure 11. Average Daily Flow Measured at USGS Gages in the Study Area

Figure 12. Average Daily Temperature (Dark Line) and the Daily Range of 15-Minute Measurements (Light Shading) Measured at USGS Gages in the Study Area

Figure 13. Average Daily Temperature (Dark Line) and the Daily Range of 15-Minute Measurements (Light Shading) Measured by MWH in the Study Area

Figure 14. Historical and Recent Monitoring Stations for the YPP

Figure 15. 10-ft and 30-m Topographic Raster Data for the Study Area

Figure 16. 15-Minute Flow Data (Centered on August 1) Measured by USGS in the Study Area

Figure 17. 15-Minute Flow Data (Centered on September 21) Measured by USGS in the Study Area

Figure 18. 15-Minute Temperature Data (Centered on August 1) Measured by USGS and MWH in the Study Area

Figure 19. 15-Minute Temperature Data (Centered on September 21) Measured by USGS and MWH in the Study Area

Figure 20. Local Vegetation Type for the Study Area from USFS

Figure 21. Canopy Height Derived from Midas Gold LiDAR Data

Figure 22. Canopy Density Derived from Midas Gold LiDAR Data

Figure 23. Hourly Output from the Shade Model at 200-ft Increments for Streams in the SPLNT Model

Figure 24. QUAL2K Reach Breaks and Mean Daytime Shade

Figure 25. Hourly Meteorological Inputs for the Calibration (July 29, 2016) and Validation (September 24, 2014) Dates

Figure 26. Mean Hourly Shade for Reaches Upstream of YPP

Figure 27. Mean Hourly Shade for Reaches Downstream of YPP

Figure 28. Observed Flows Upstream and Downstream of YPP (top) and Estimated Residence Time of YPP (bottom)

Figure 29. Meteorological Inputs for the GLM

Figure 30. Temperature (C) Calibration and Validation Results for the QUAL2K Model Above YPP

Figure 1. Stibnite Gold Project Modeling Process Overview

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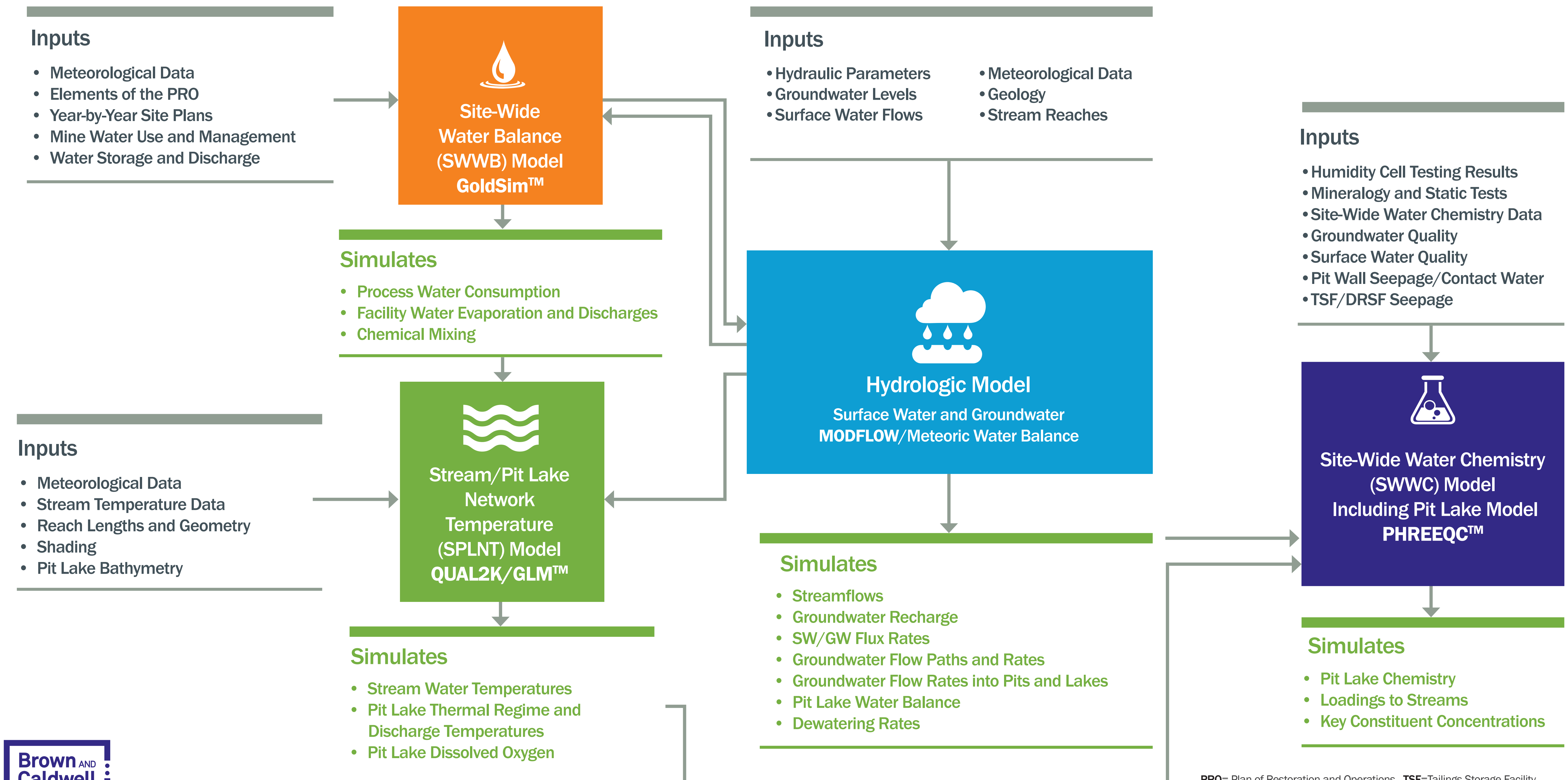

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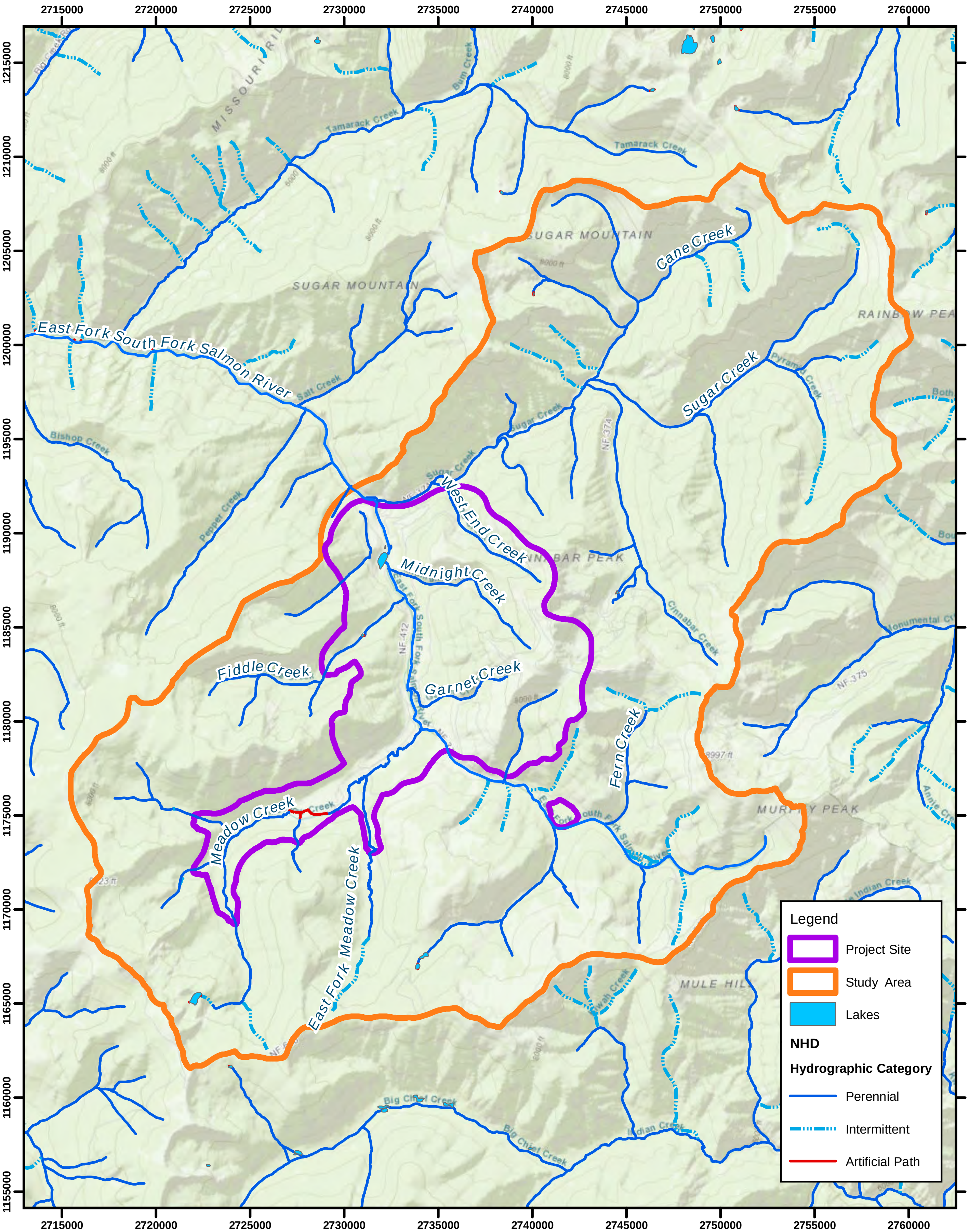
GLM= General Lake Model **DRSF**=Development Rock Storage Facility

Brown AND Caldwell



Date: 1/10/2018

Project No: 150696

Client: Midas Gold

Basemap: ESRI World Topographic

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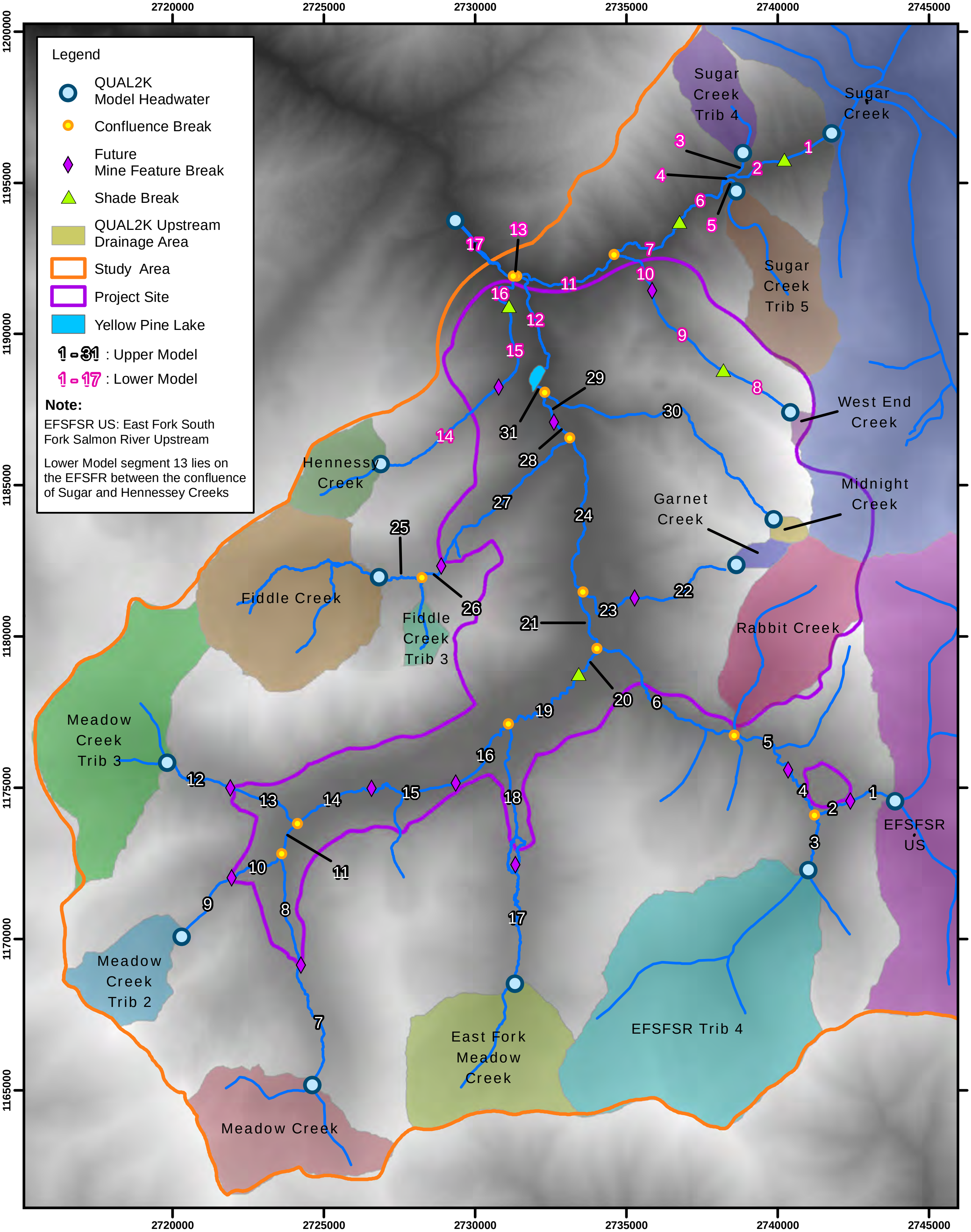
Figure 2
Existing Stream Network for the Study Area
SPLNT Modeling
Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\ExistingStreamNetwork_NHD_HydrographicCategory.mxd



Brown AND Caldwell

Date: 2/26/2018

Project No: 150696

Client: Midas Gold

Basemap:DEM, 10 Foot

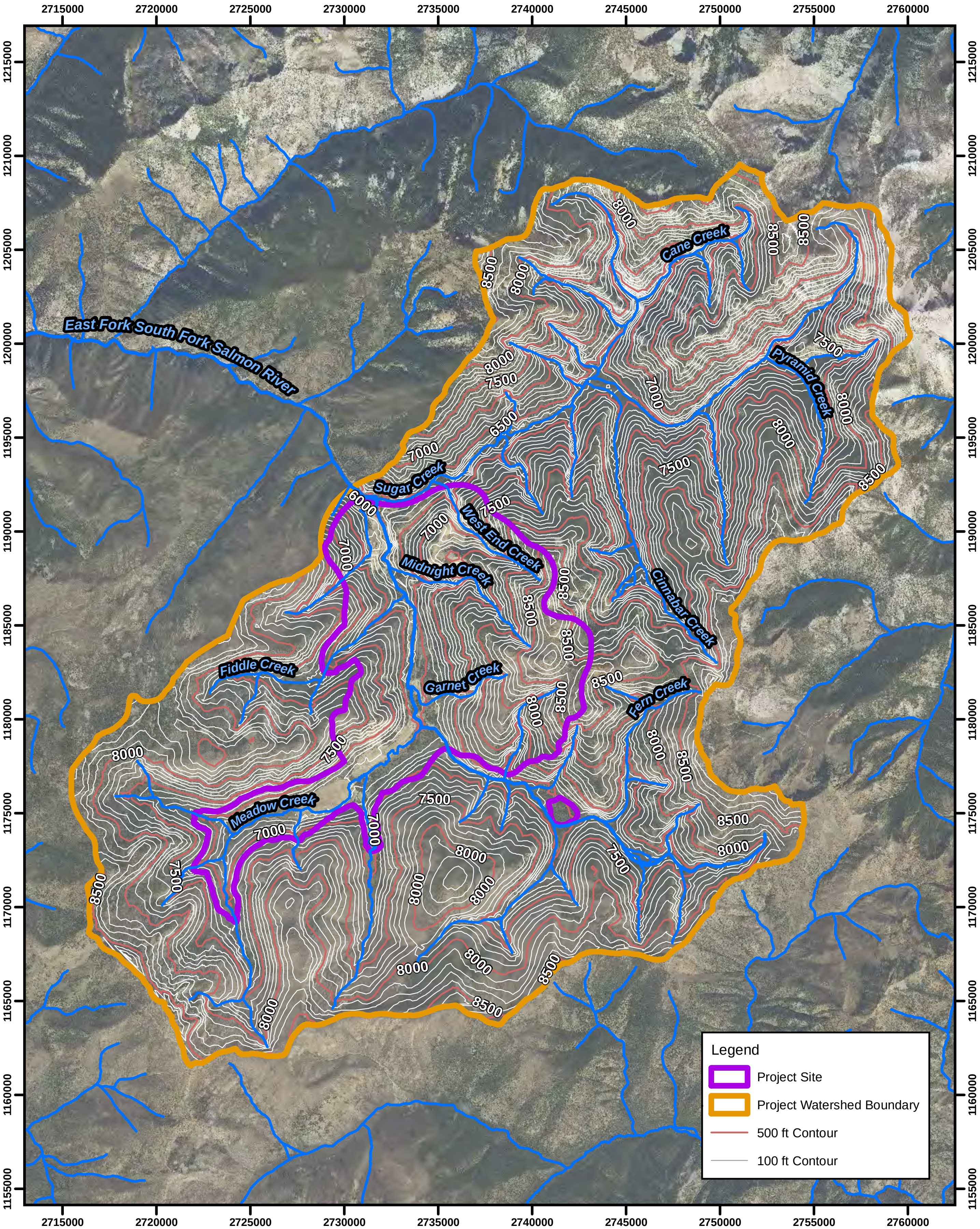
0 0.25 0.5 1 Miles

Figure 3 QUAL2K Pour Points and Segmentation Points

SPLNT Modeling

Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\Qual2K_StreamSegmentation.mxd



Brown AND Caldwell	Date: 1/10/2018 Project No: 150696 Client: Midas Gold	Basemap: Midas Gold Aerial Imagery 0 0.5 1 2 Miles	**Figure 4** **SPLNT Area Topography** SPLNT Modeling Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\StudyArea_Topography.mxd

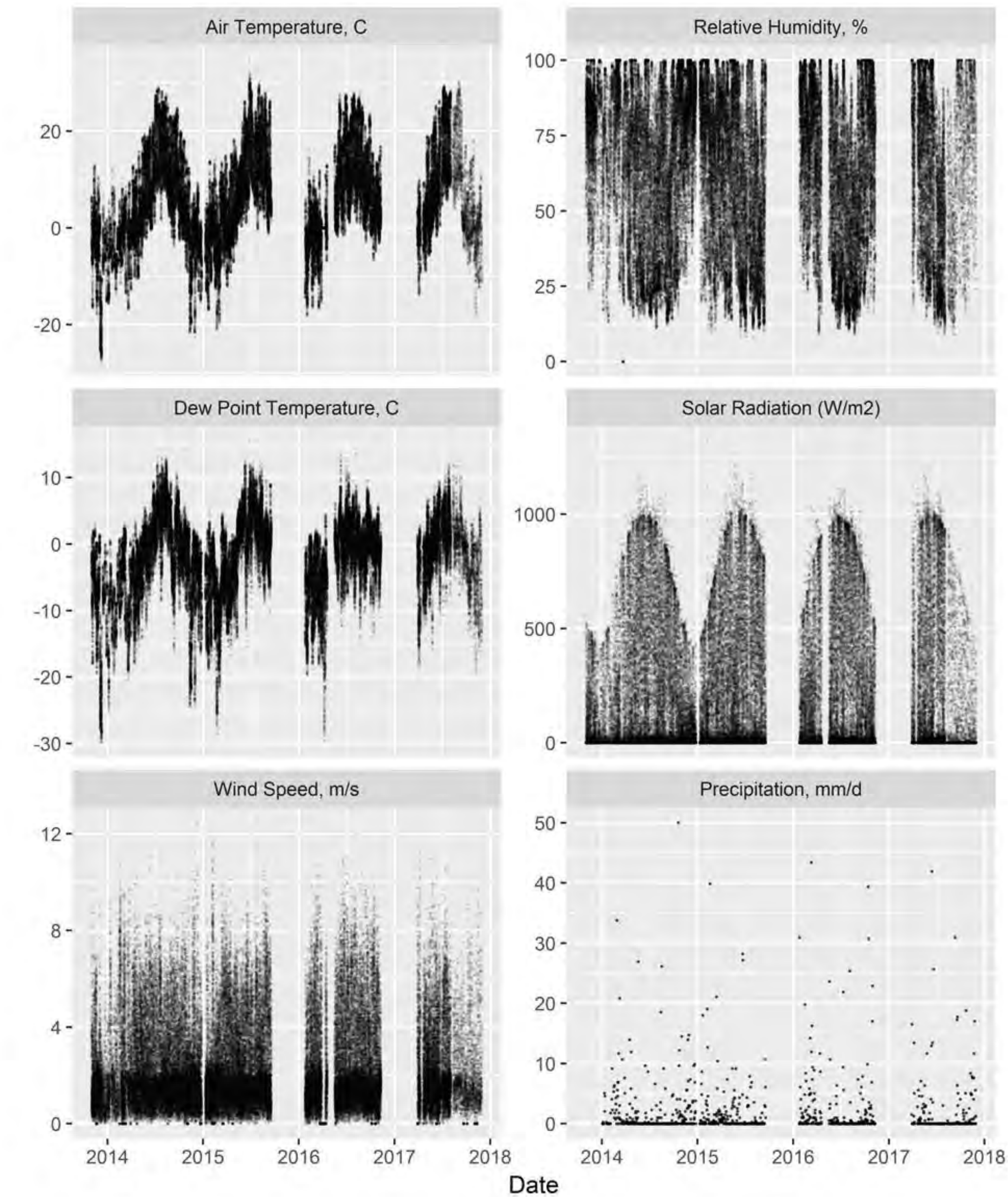
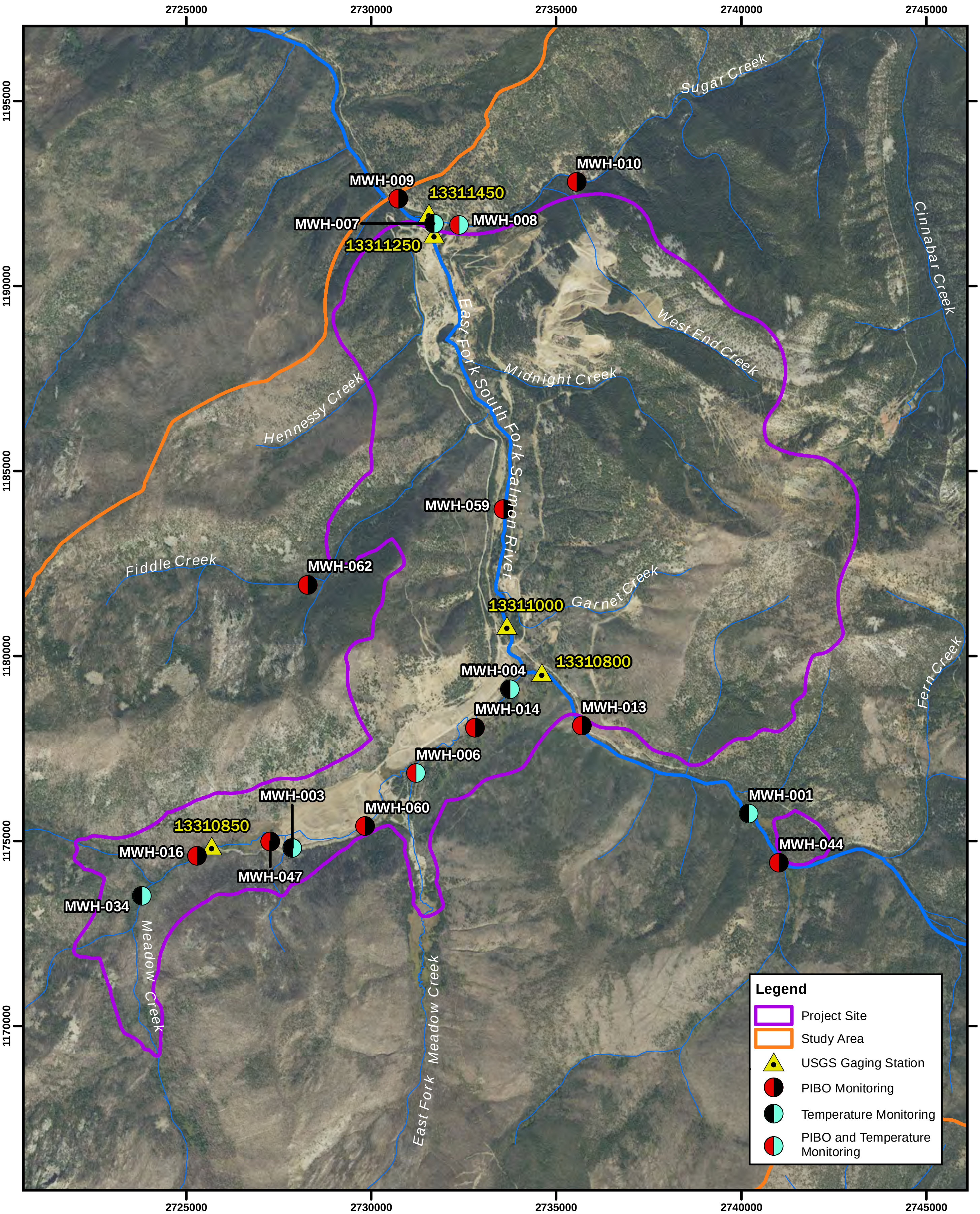


Figure 5. Meteorological Data Collected in the Study Area



Brown AND Caldwell

Date: 2/1/2018

Project No: 150696

Client: Midas Gold

Source: MWH 2017

0 0.25 0.5 1

Miles

N

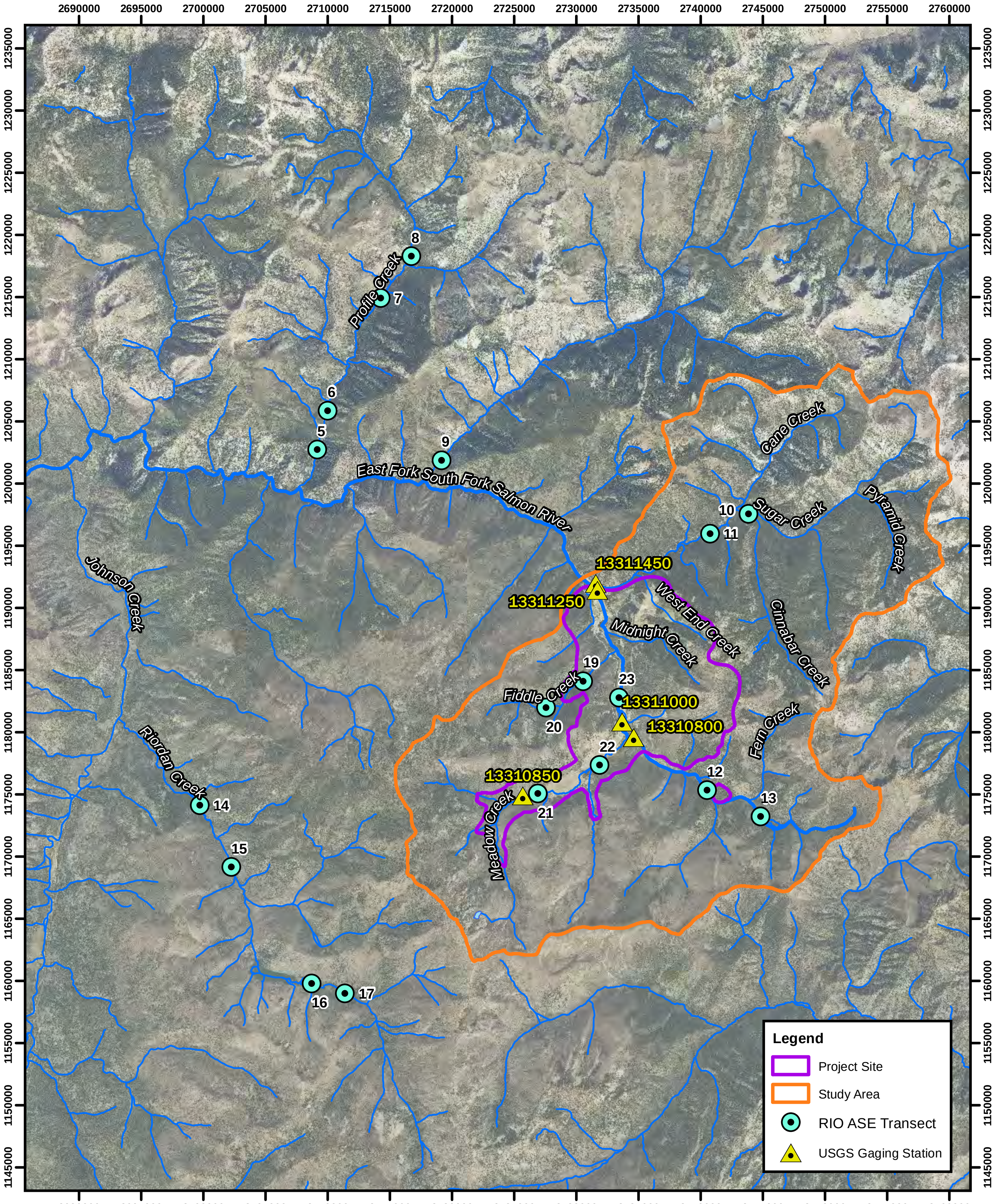
Figure 6 Locations of MWH Stream Cross-Section Measurements in and near the Study Area

SPLNT Modeling

Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\MWH_PIBO_MonitoringLocations_USGS_GagingStations.mxd

Last saved by: Nherzog



Brown AND Caldwell

Date: 1/10/2018

Project No: 150696

Client: Midas Gold

Source: RIO ASE, in progress

0 0.5 1 2 Miles

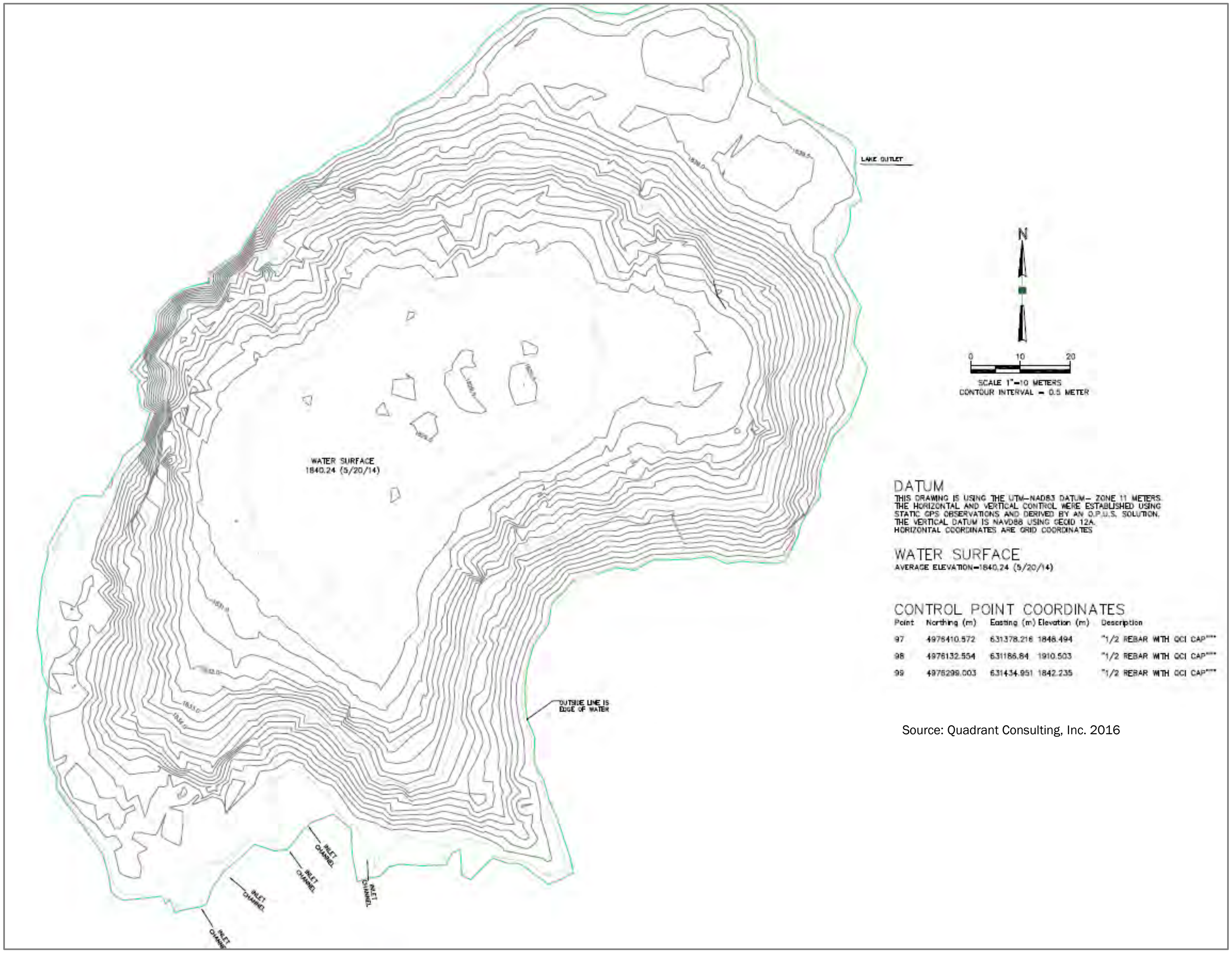
Figure 7 Locations of Rio ASE Stream Cross-Section Measurements in and near the Study Area

SPLNT Modeling

Stibnite Gold Project

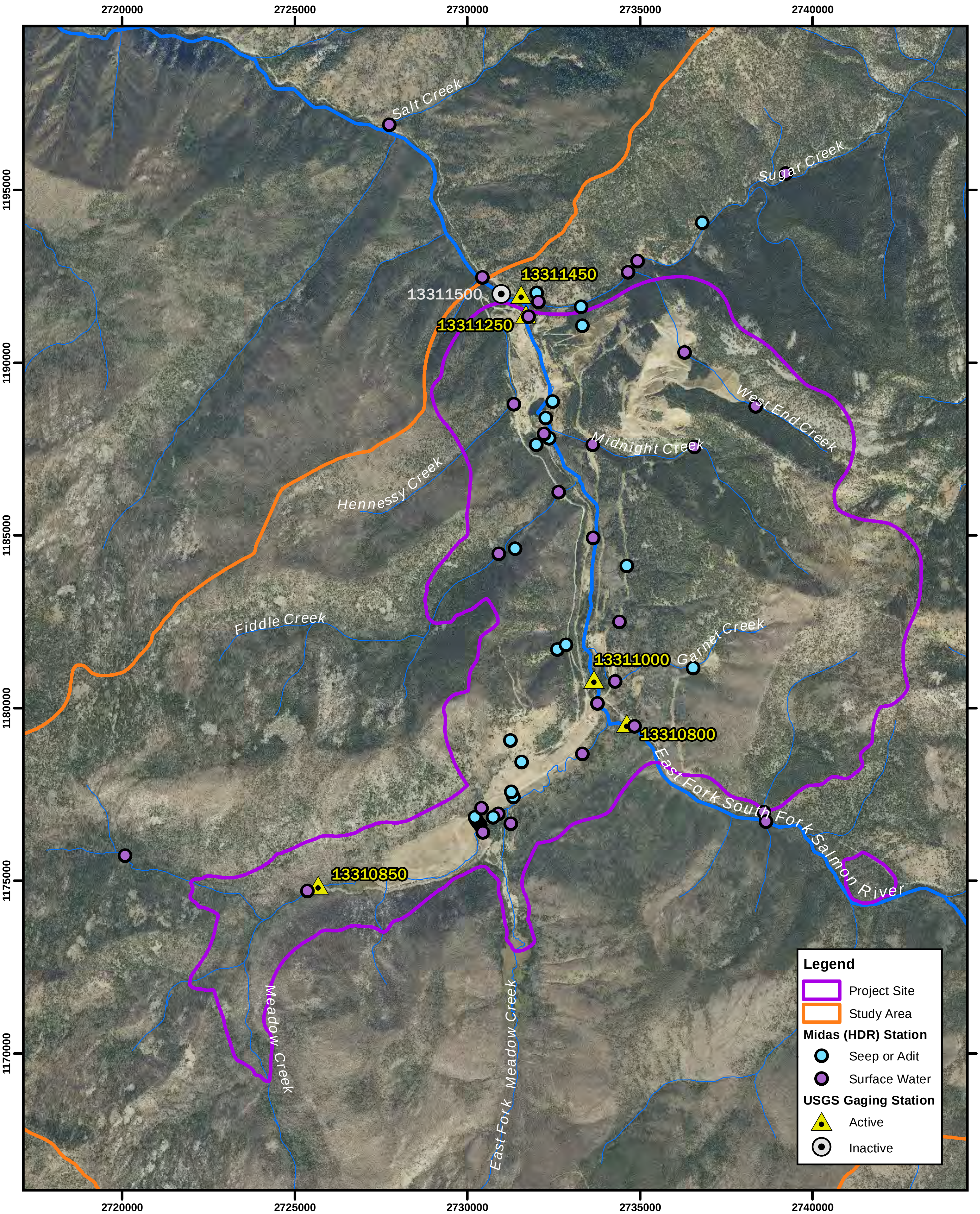
Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\RIO_MonitoringLocations_USGS_GagingStations.mxd

Last saved by: Nherzog



Source: Quadrant Consulting, Inc. 2016

Figure 8. Bathymetric Data for Yellow Pine Pit



Brown AND Caldwell	Date: 1/10/2018 Project No: 150696 Client: Midas Gold	Source: HDR 2017b 0 0.25 0.5 1 Miles N	**Figure 9 Flow and Temperature Monitoring Stations in and near the Study Area** SPLNT Modeling Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\MidasSamplingPoints_USGS_Gaging Stations.mxd

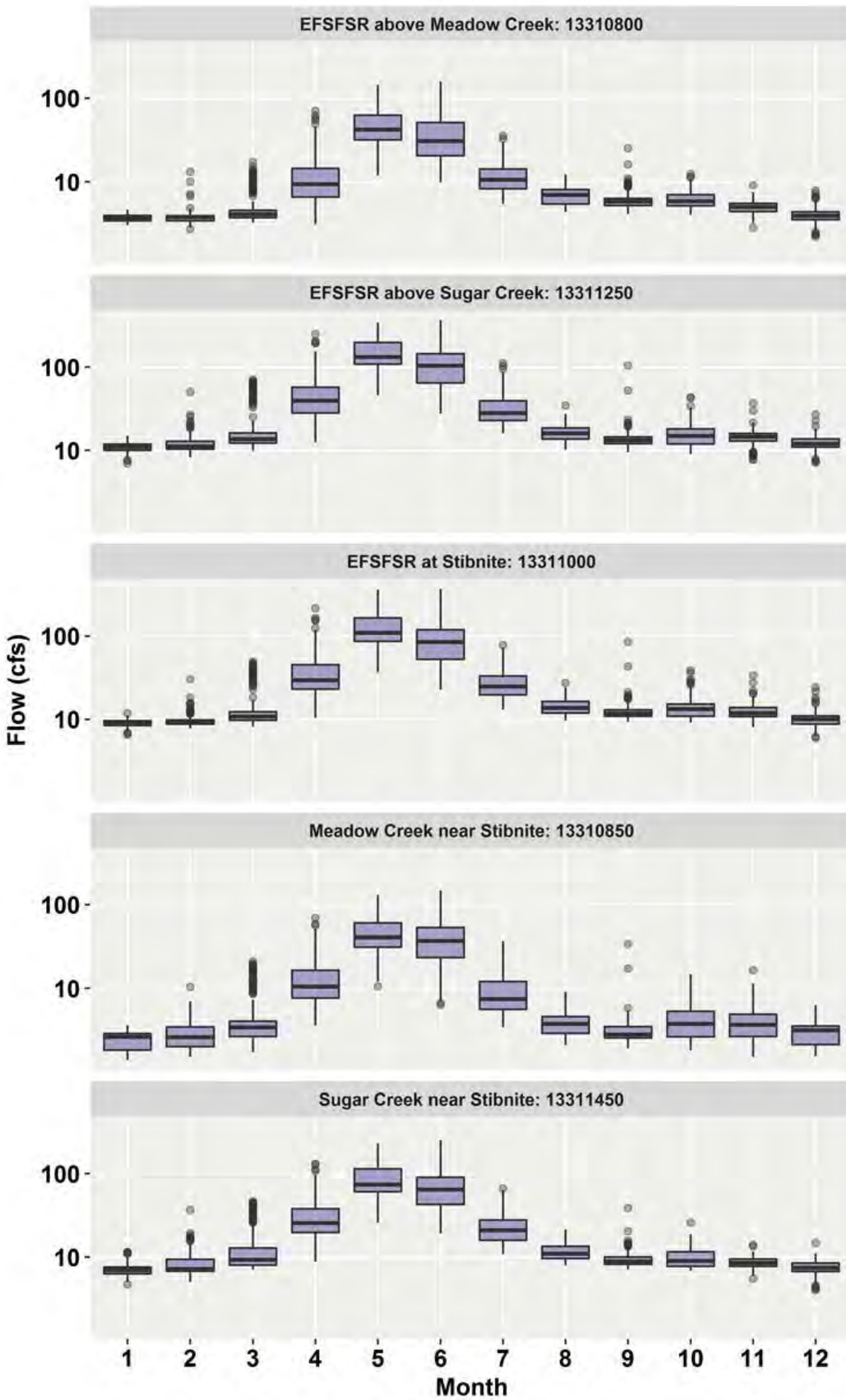


Figure 10. Box Plots of Stream Flow Measured at USGS Gages in the Study Area from September 2011 to August 2017 (Colors Vary by Month)

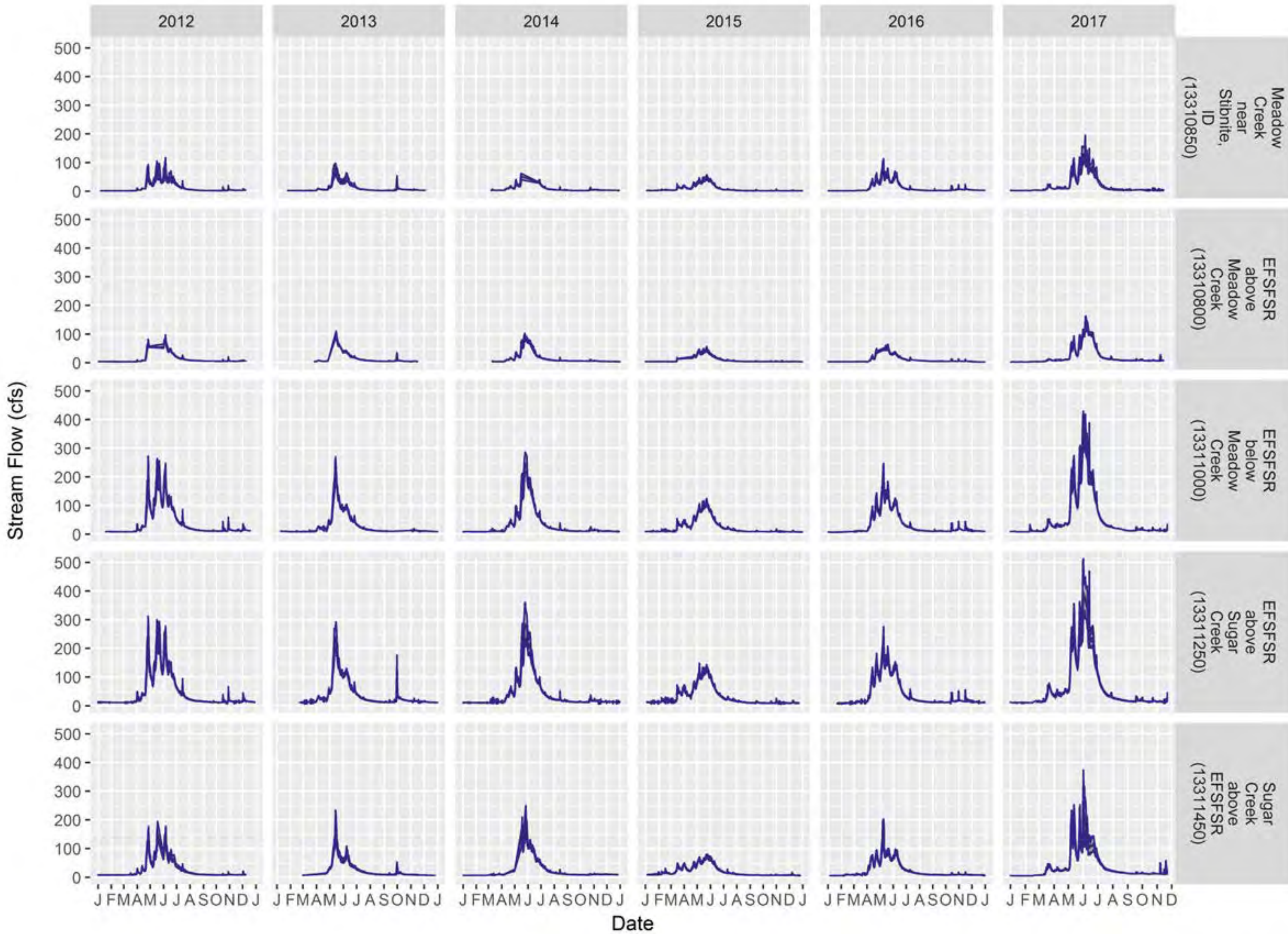


Figure 11. Average Daily Flow Measured at USGS Gages in the Study Area

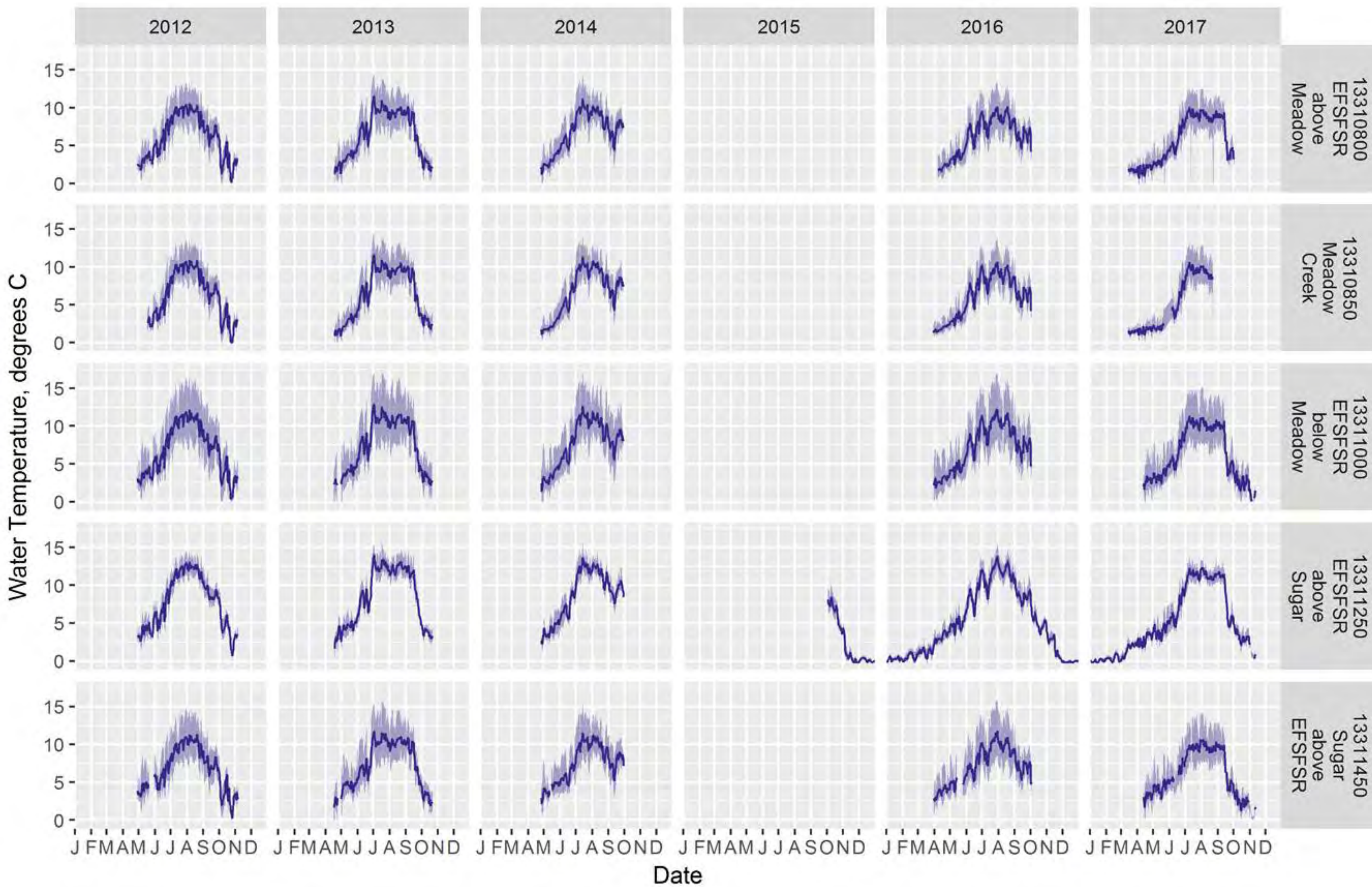


Figure 12. Average Daily Temperature (Dark Line) and the Daily Range of 15-Minute Measurements (Light Shading) Measured at USGS Gages in the Study Area

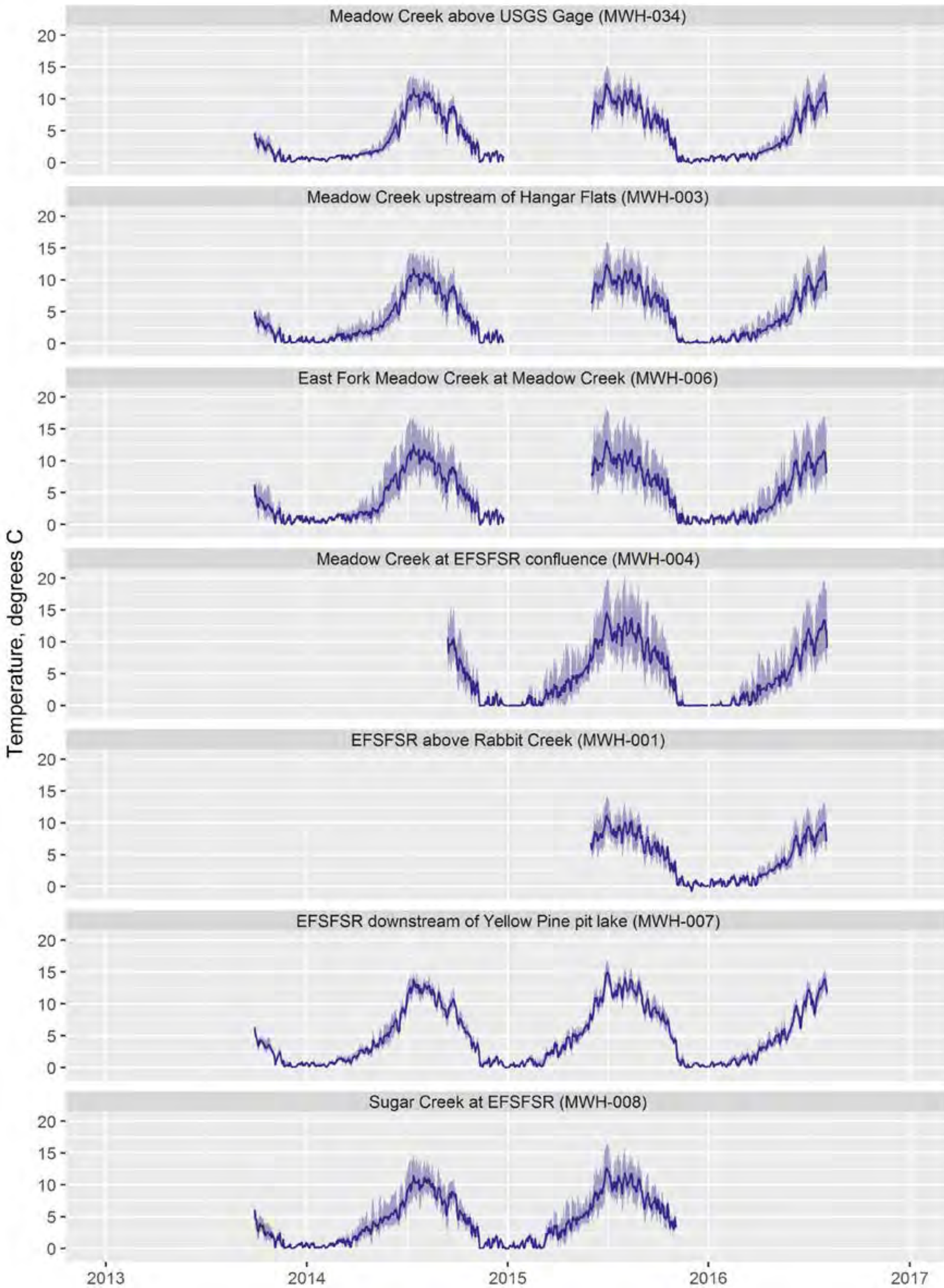


Figure 13. Average Daily Temperature (Dark Line) and the Daily Range of 15-Minute Measurements (Light Shading) Measured by MWH in the Study Area

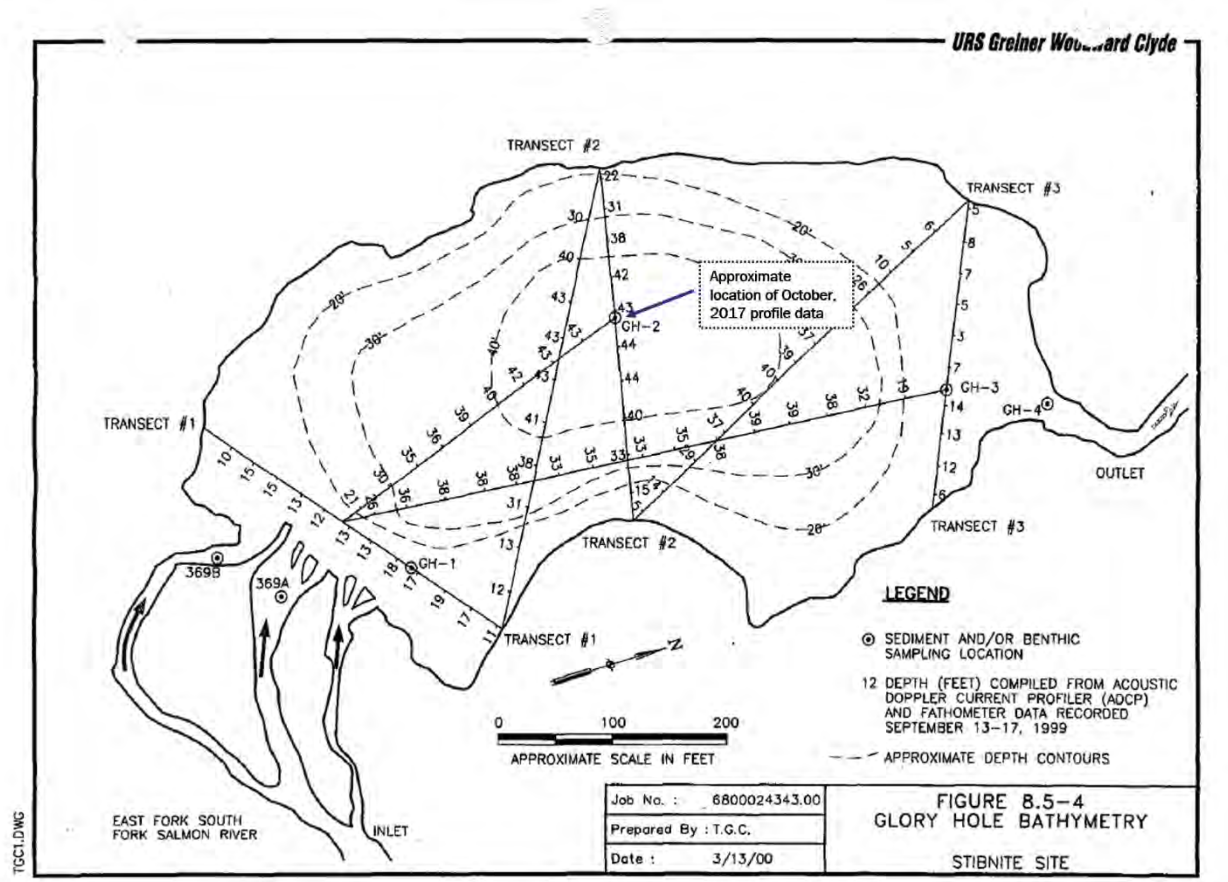
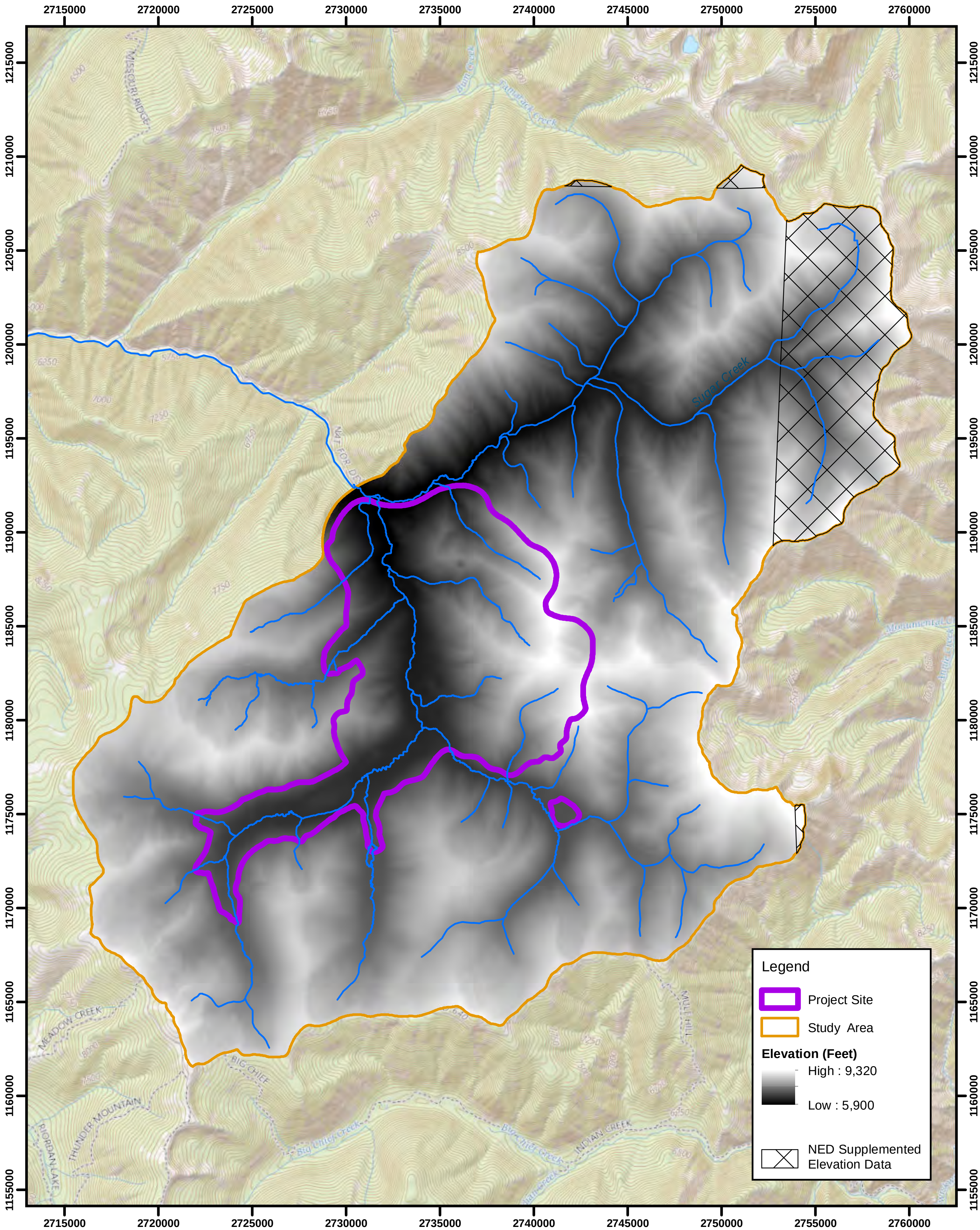


Figure 14. Historical and Recent Monitoring Stations for the YPP



Brown AND Caldwell

Date: 1/10/2018

Project No: 150696

Client: Midas Gold

Basemap: ESRI World Topographic

0 0.5 1 2

Miles

N

Figure 15: 10-ft and 30-m Topographic Raster Data for the Study Area

SPLNT Modeling

Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\DEM_StudyArea.mxd

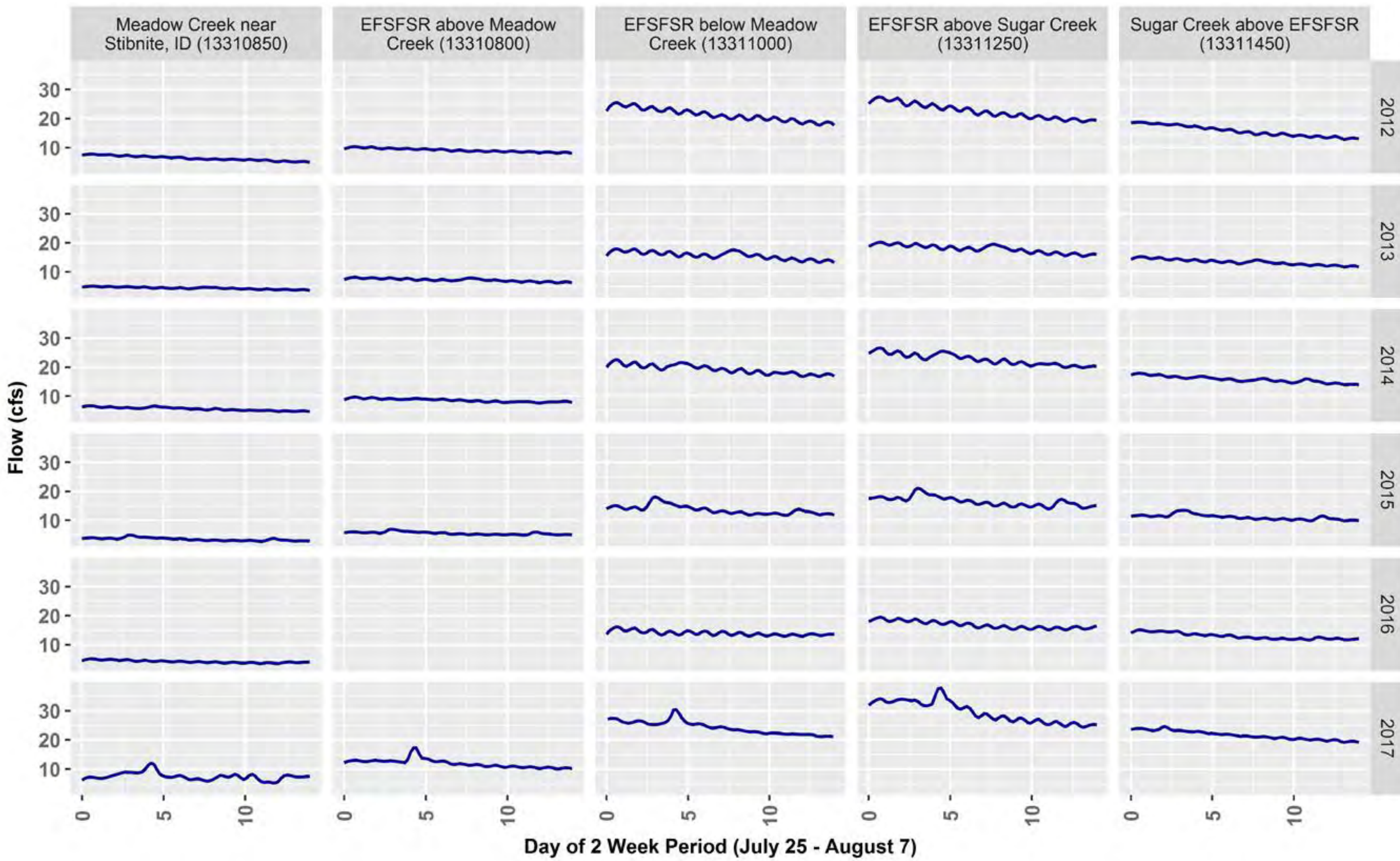


Figure 16. 15-Minute Flow Data (Centered on August 1) Measured by USGS in the Study Area

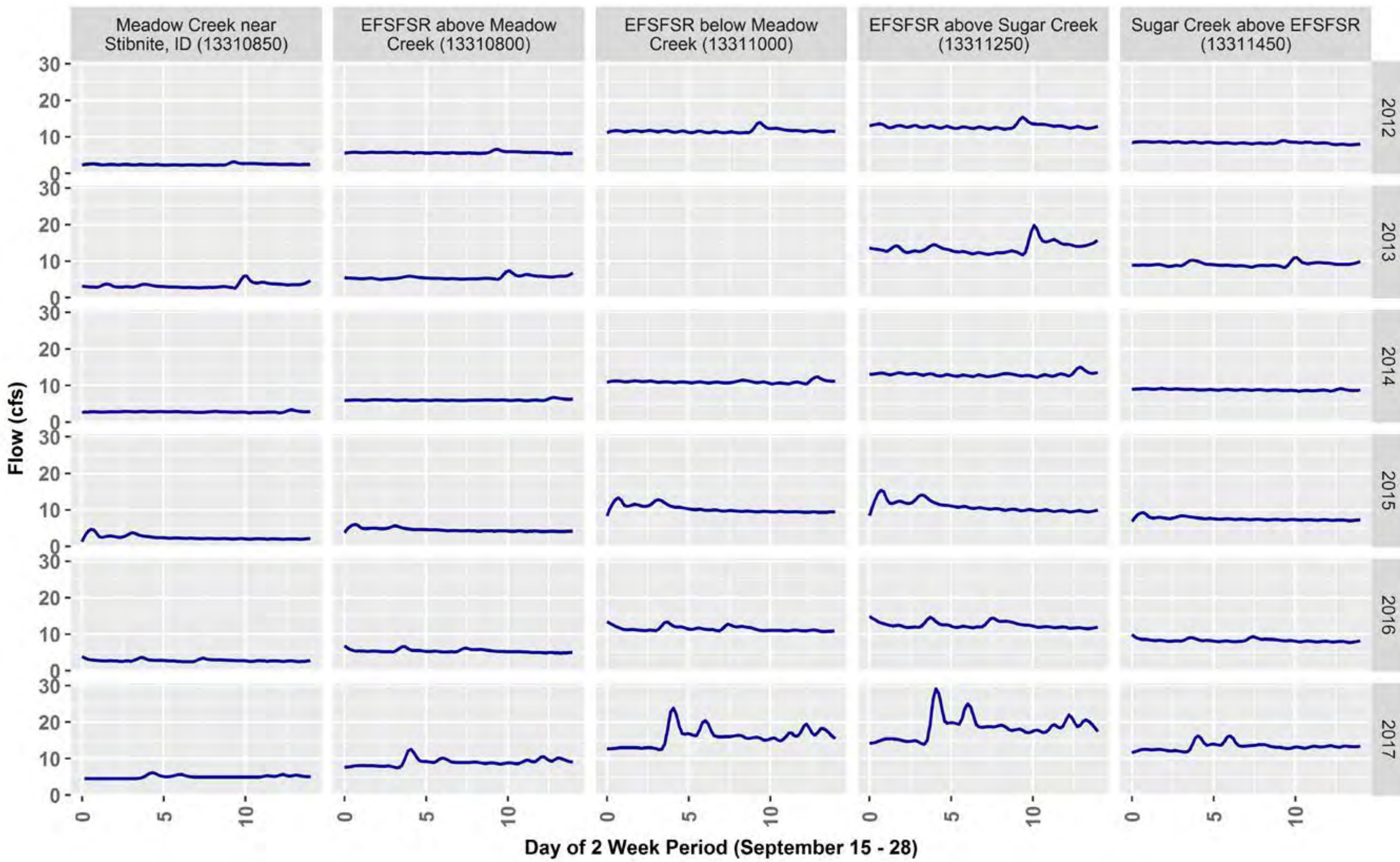


Figure 17. 15-Minute Flow Data (Centered on September 21) Measured by USGS in the Study Area

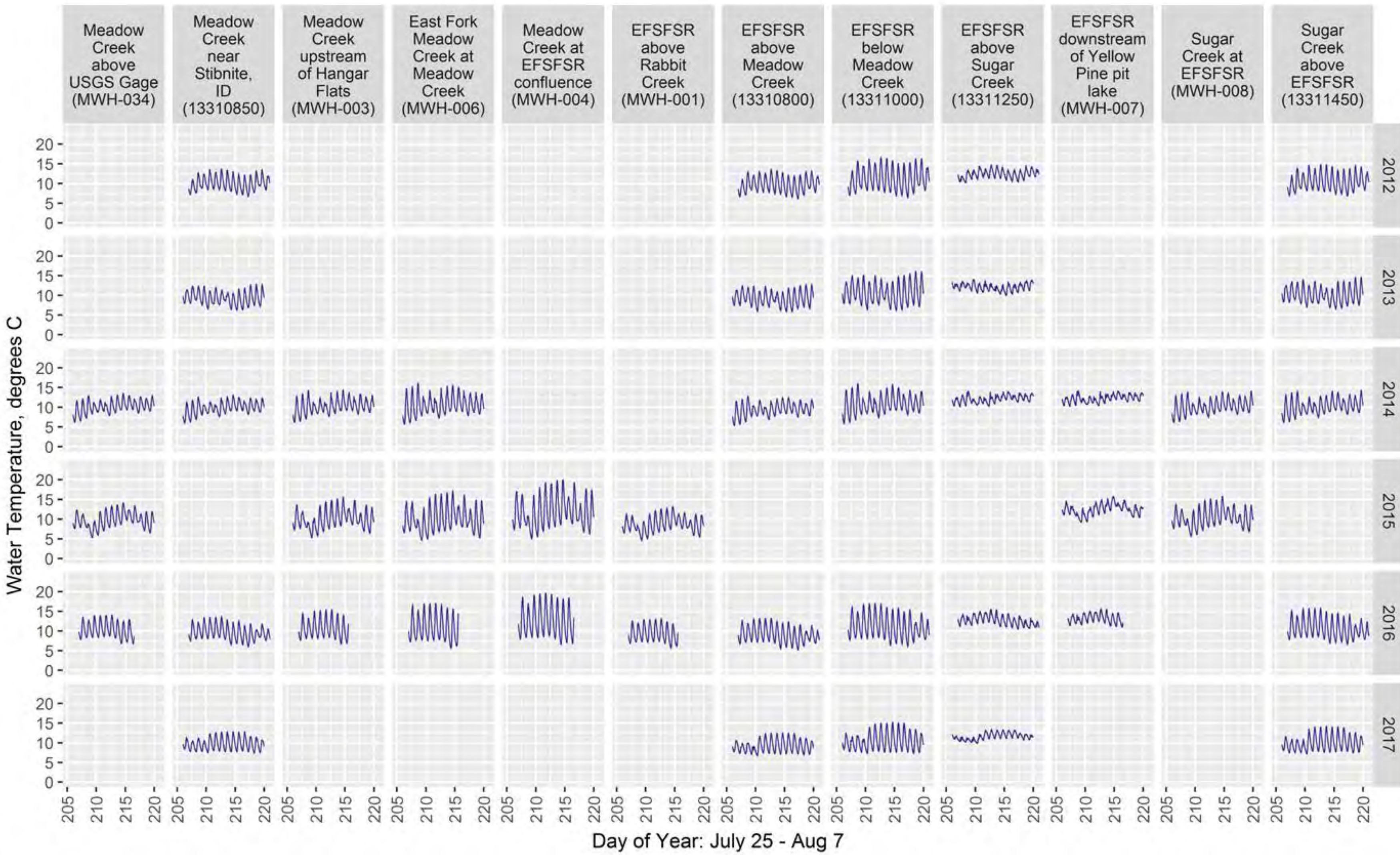


Figure 18. 15-Minute Temperature Data (Centered on August 1) Measured by USGS and MWH in the Study Area

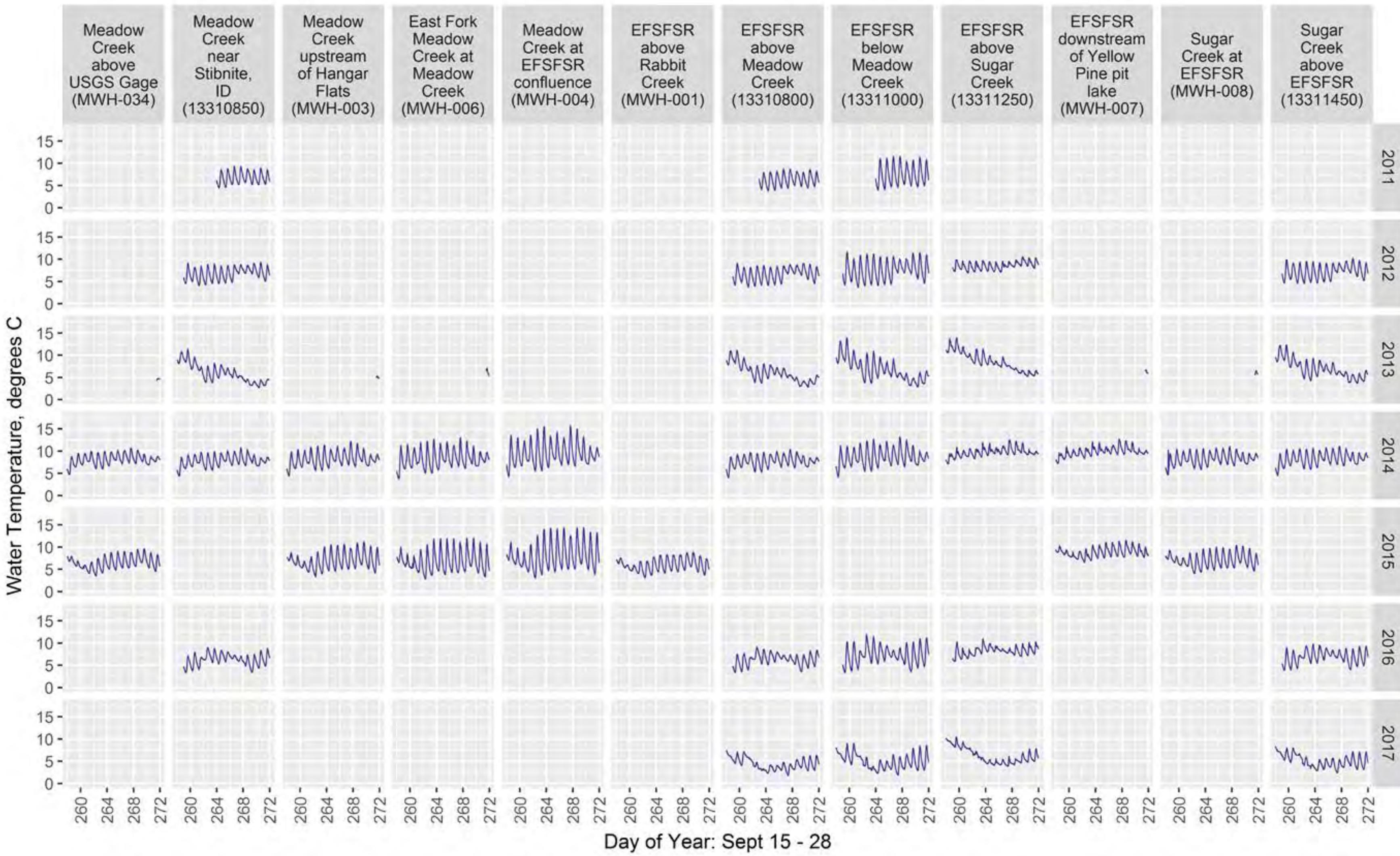
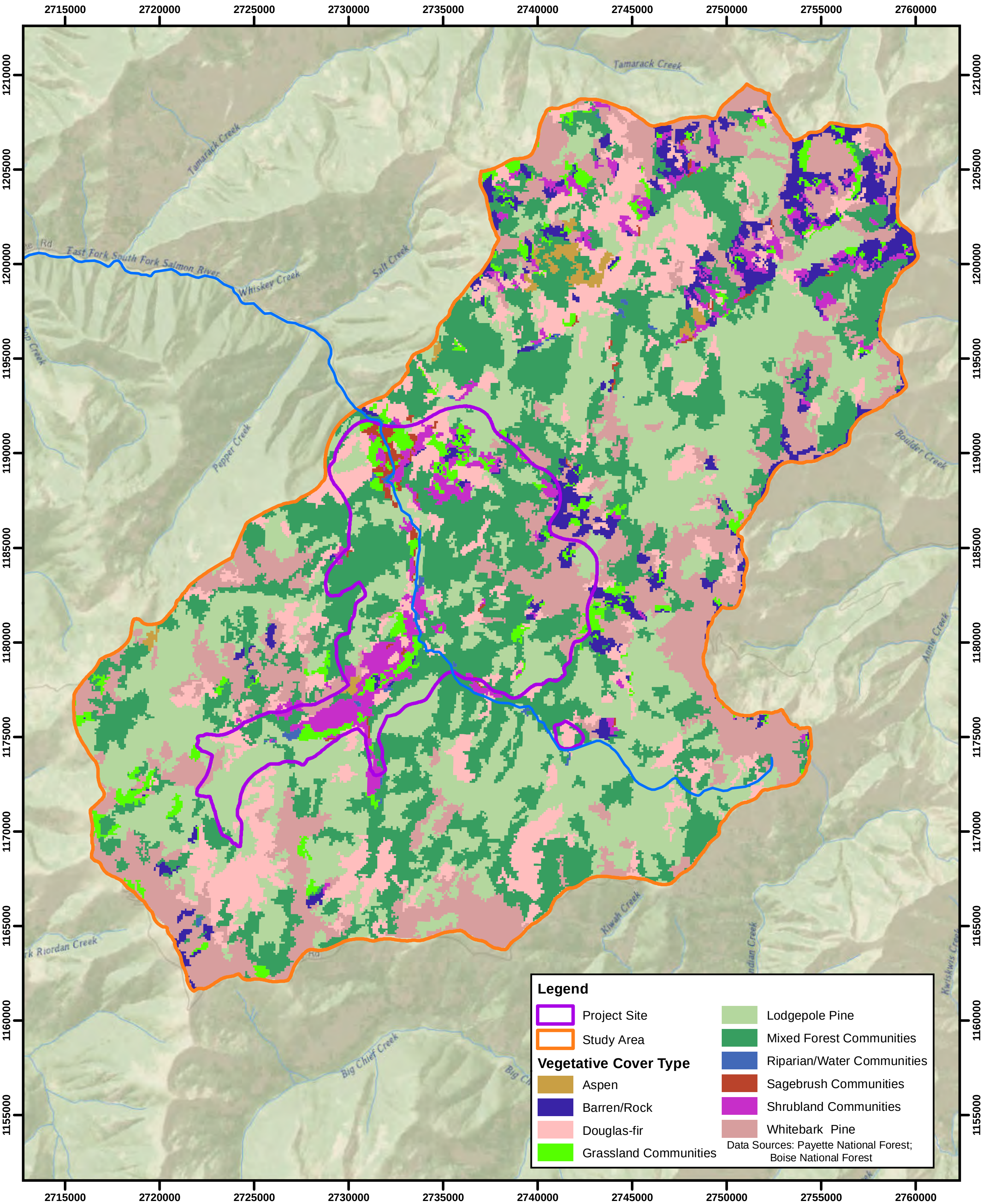


Figure 19. 15-Minute Temperature Data (Centered on September 21) Measured by USGS and MWH in the Study Area



Brown AND Caldwell

Date: 1/10/2018

Project No: 150696

Client: Midas Gold

Basemap: National Geographic World Map

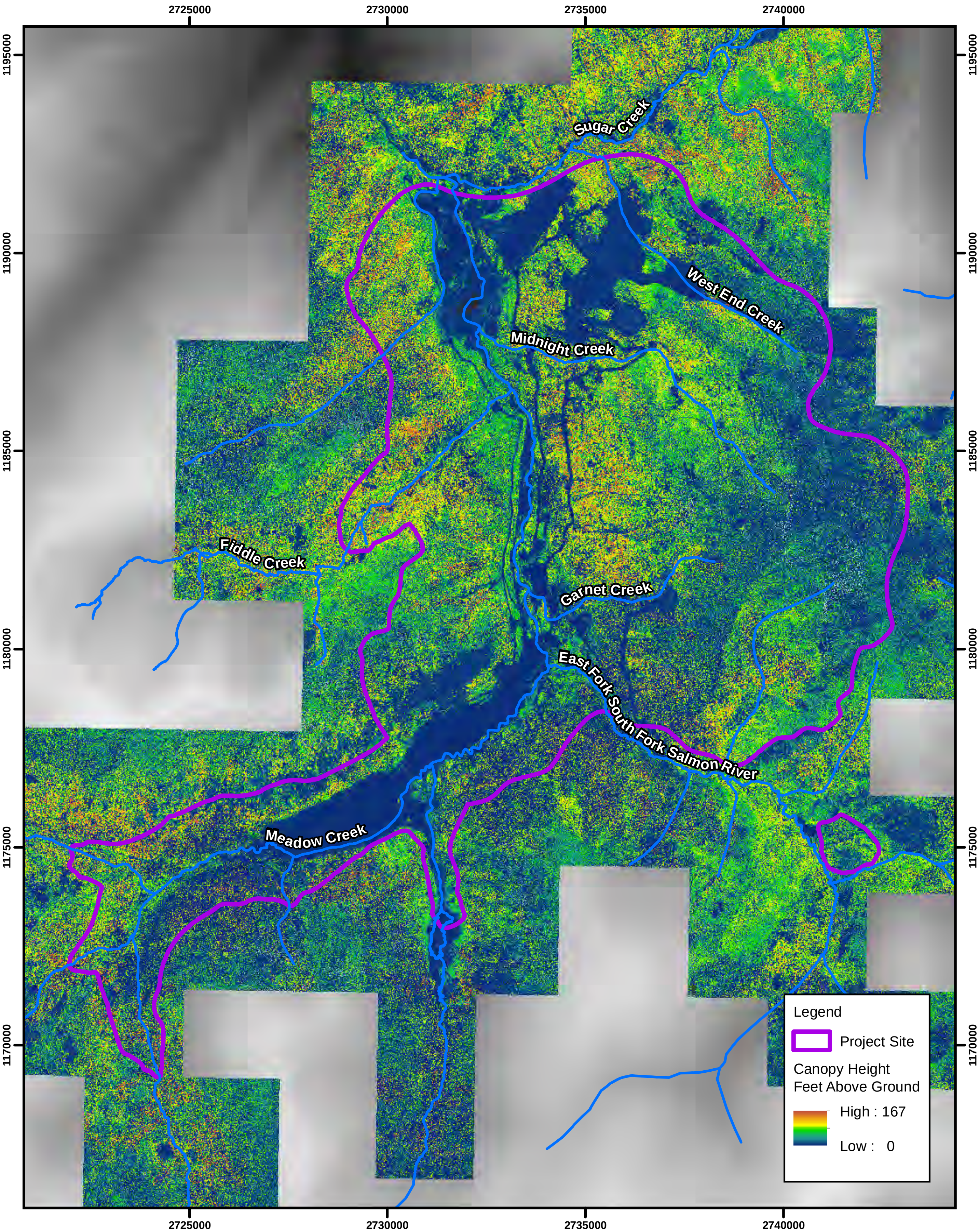
0 0.5 1 2

Miles

N

Figure 20
Local Vegetation Type from USFS for the Study Area
SPLNT Modeling
Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\VegetativeCoverType.mxd
Last saved by: Nherzog



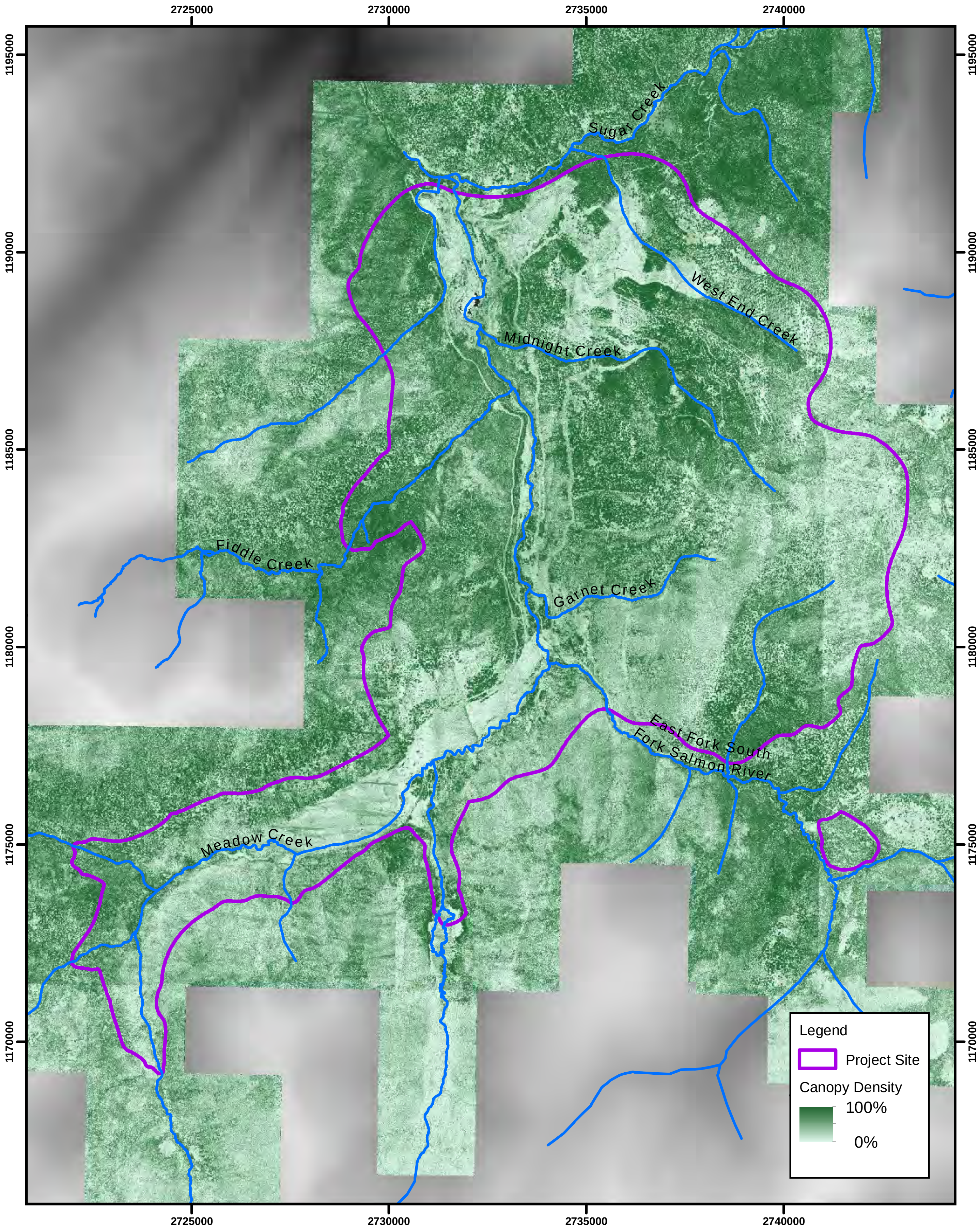
Date: 1/10/2018
Project No: 150696
Client: Midas Gold

Basemap: ESRI World Topographic

0 0.25 0.5 1
Miles

Figure 21
Canopy Height Derived from Midas Gold LiDAR Data
SPLNT Modeling
Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\ProjectSite_CanopyHeight.mxd



Date: 1/10/2018
Project No: 150696
Client: Midas Gold

Basemap: ESRI World Topographic

0 0.25 0.5 1
Miles

N

Figure 22
Canopy Density Derived from Midas Gold LiDAR Data
SPLNT Modeling
Stibnite Gold Project

Path: Bcboi02\P:_Midas Gold\150696 - Midas 2017 GW Modeling Support\GIS\Maps\ProjectSite_CanopyDensity.mxd

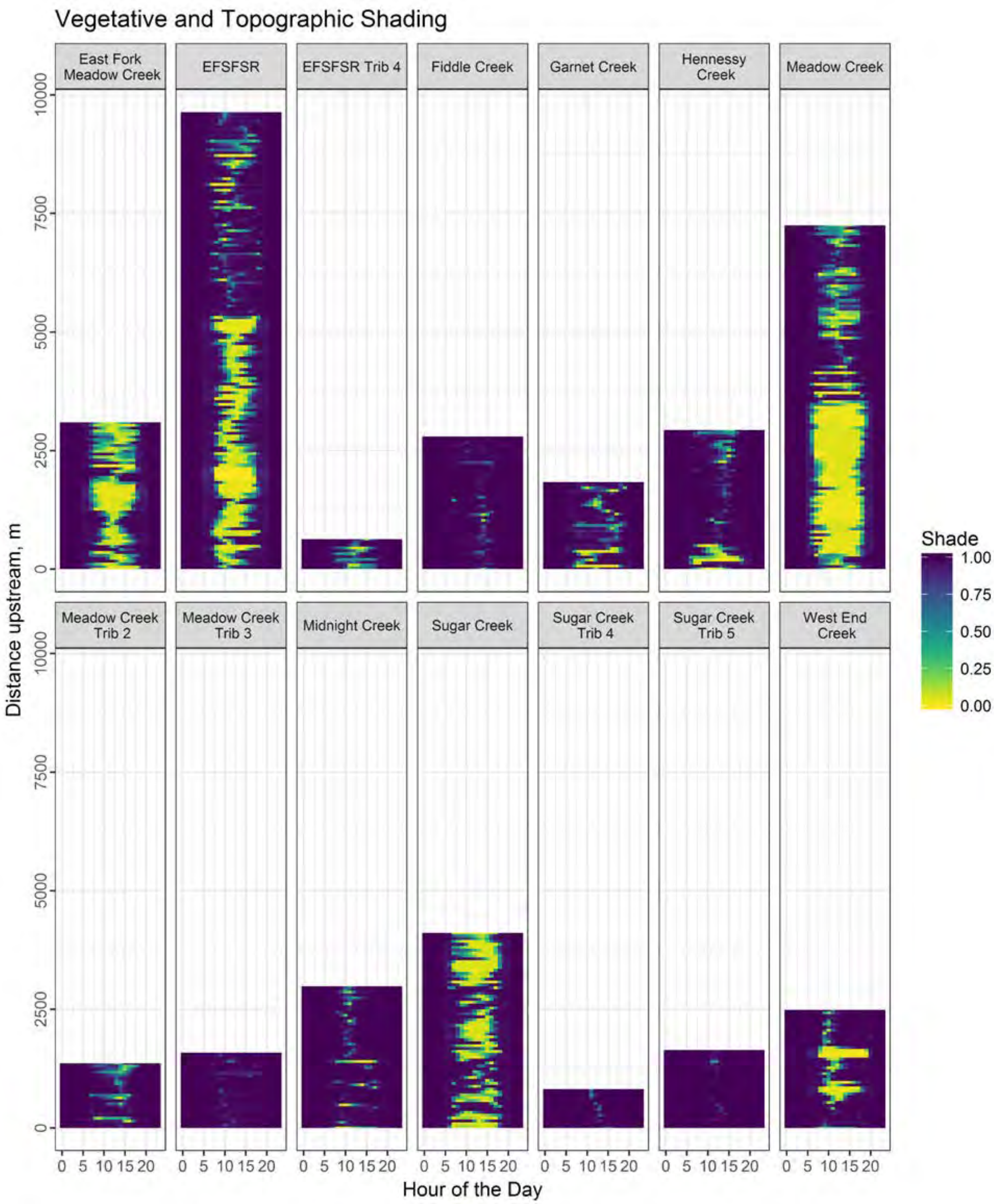


Figure 23. Hourly Output from the Shade Model at 200-ft Increments for Streams in the SPLNT Model

The length shown on the y-axis for each panel is held constant.

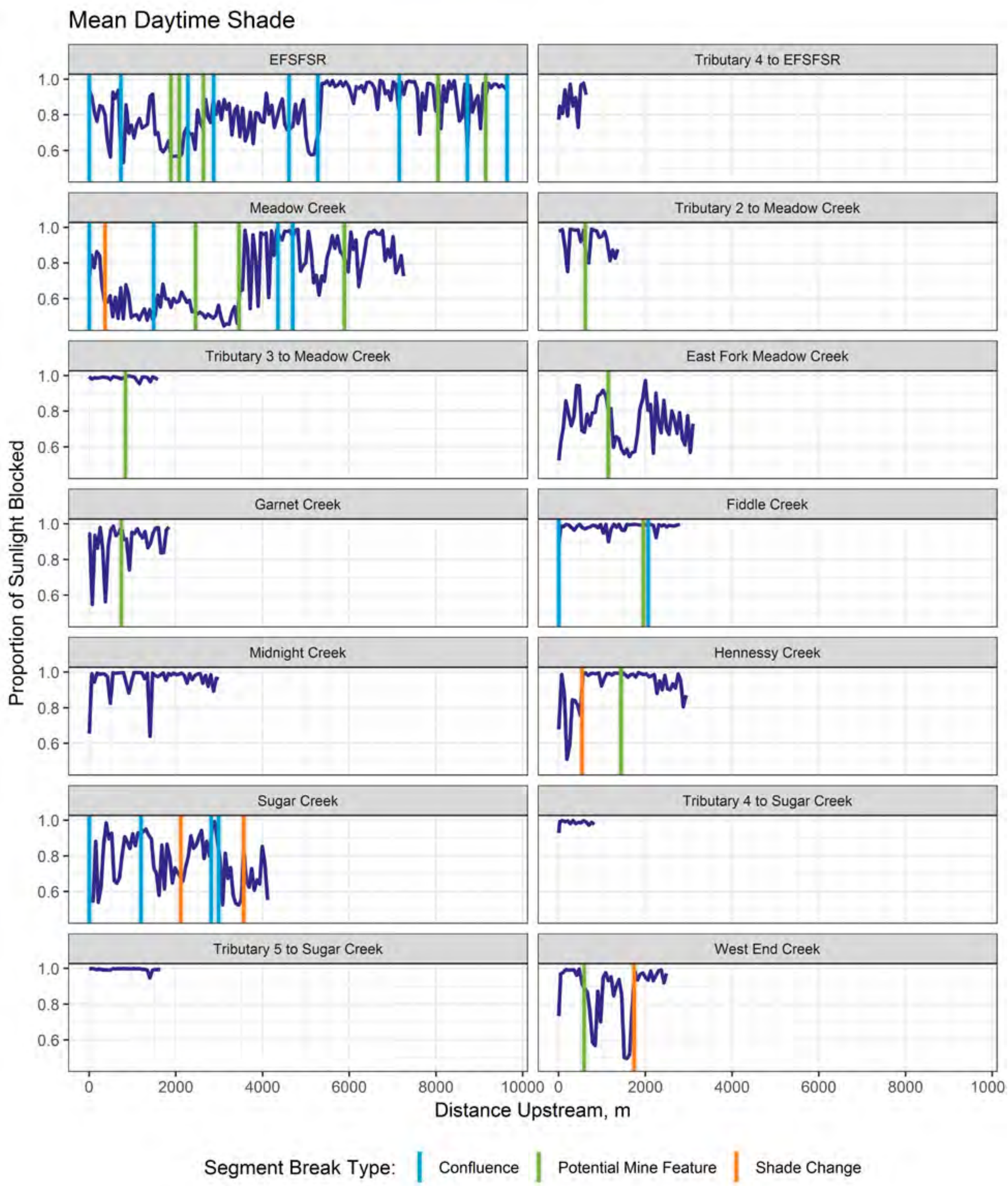


Figure 24. QUAL2K Reach Breaks and Mean Daytime Shade

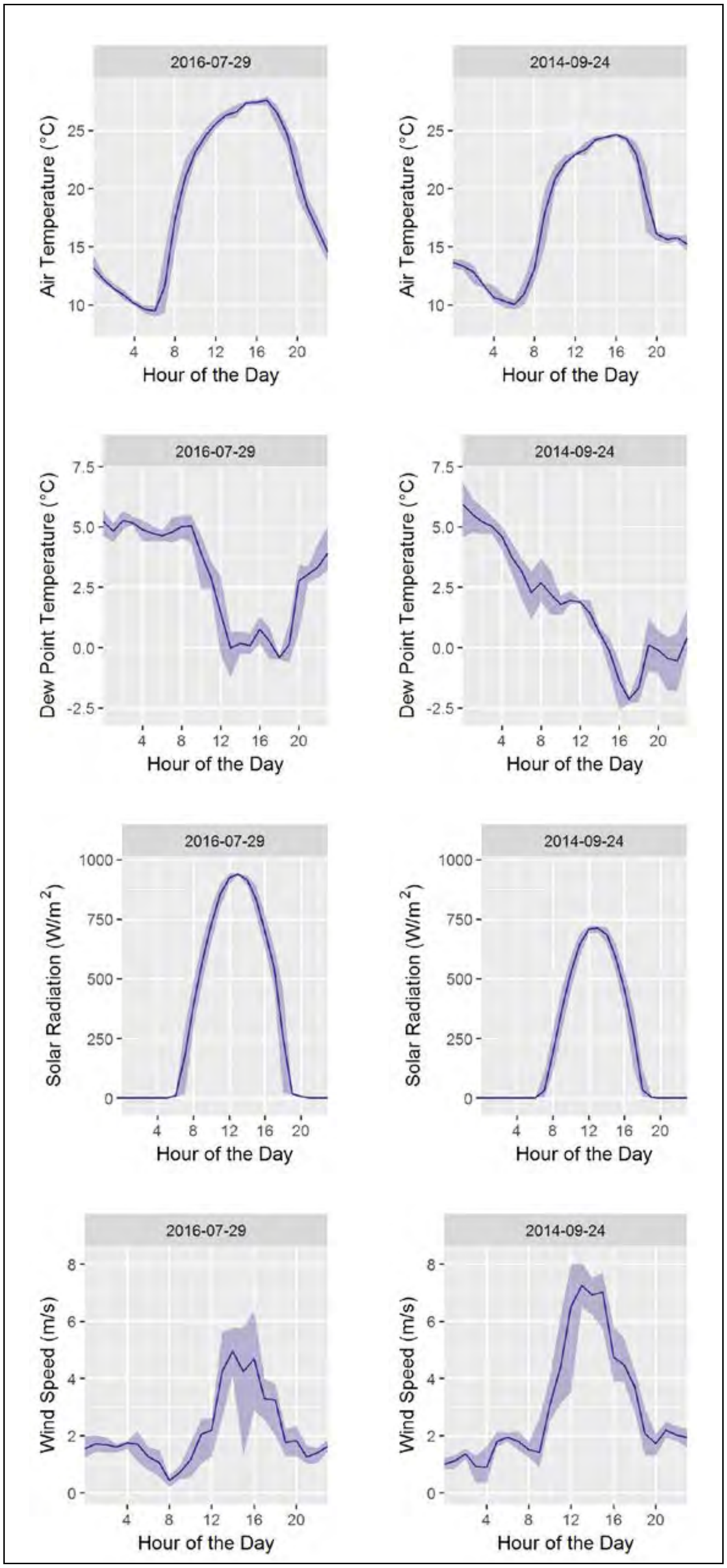


Figure 25. Hourly Meteorological Inputs for the Calibration (July 29, 2016) and Validation (September 24, 2014) Dates

Dark blue line is average hourly value; blue shade is range of min and max during the hour.

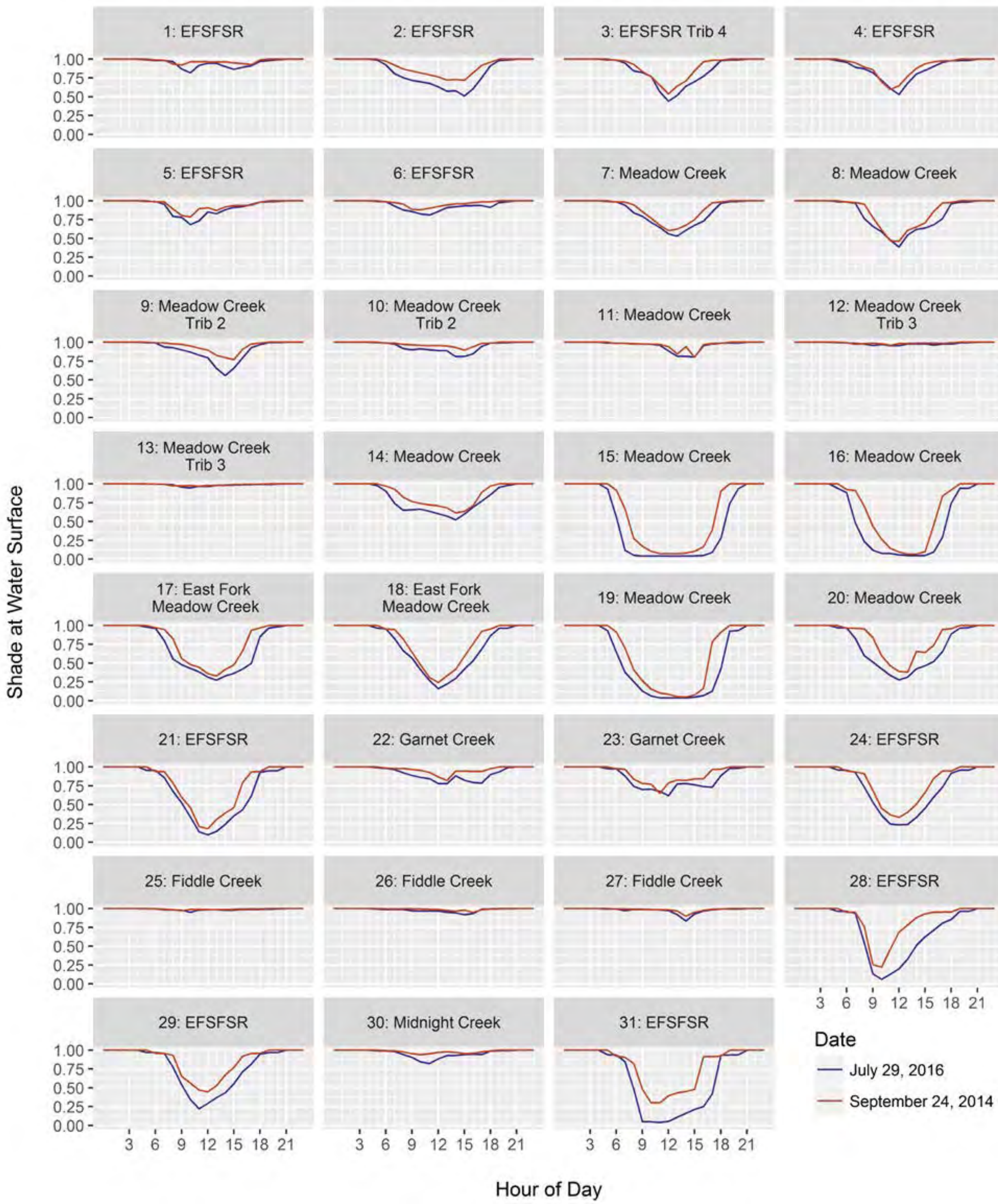


Figure 26. Mean Hourly Shade for Reaches Upstream of YPP

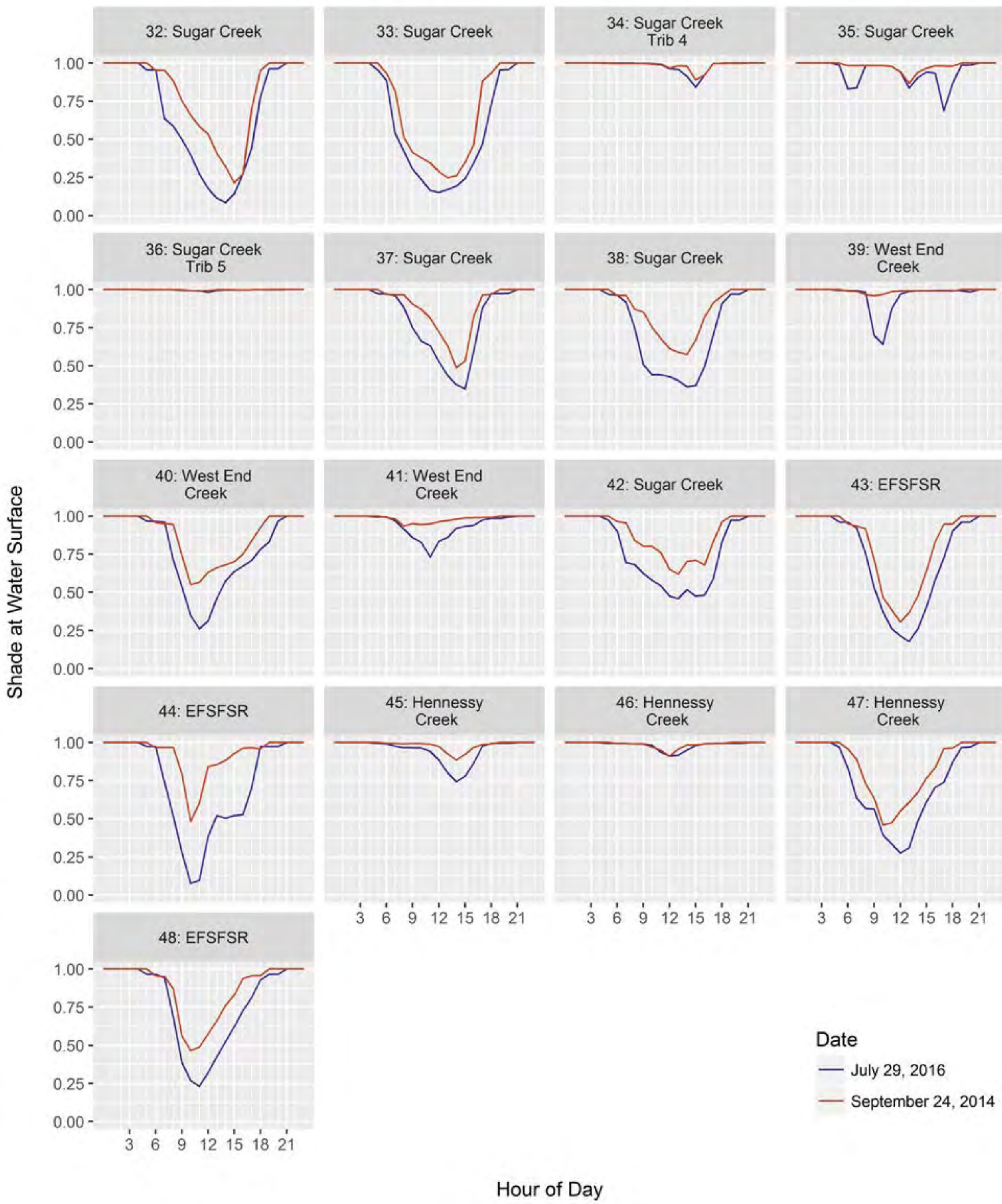


Figure 27. Mean Hourly Shade for Reaches Downstream of YPP

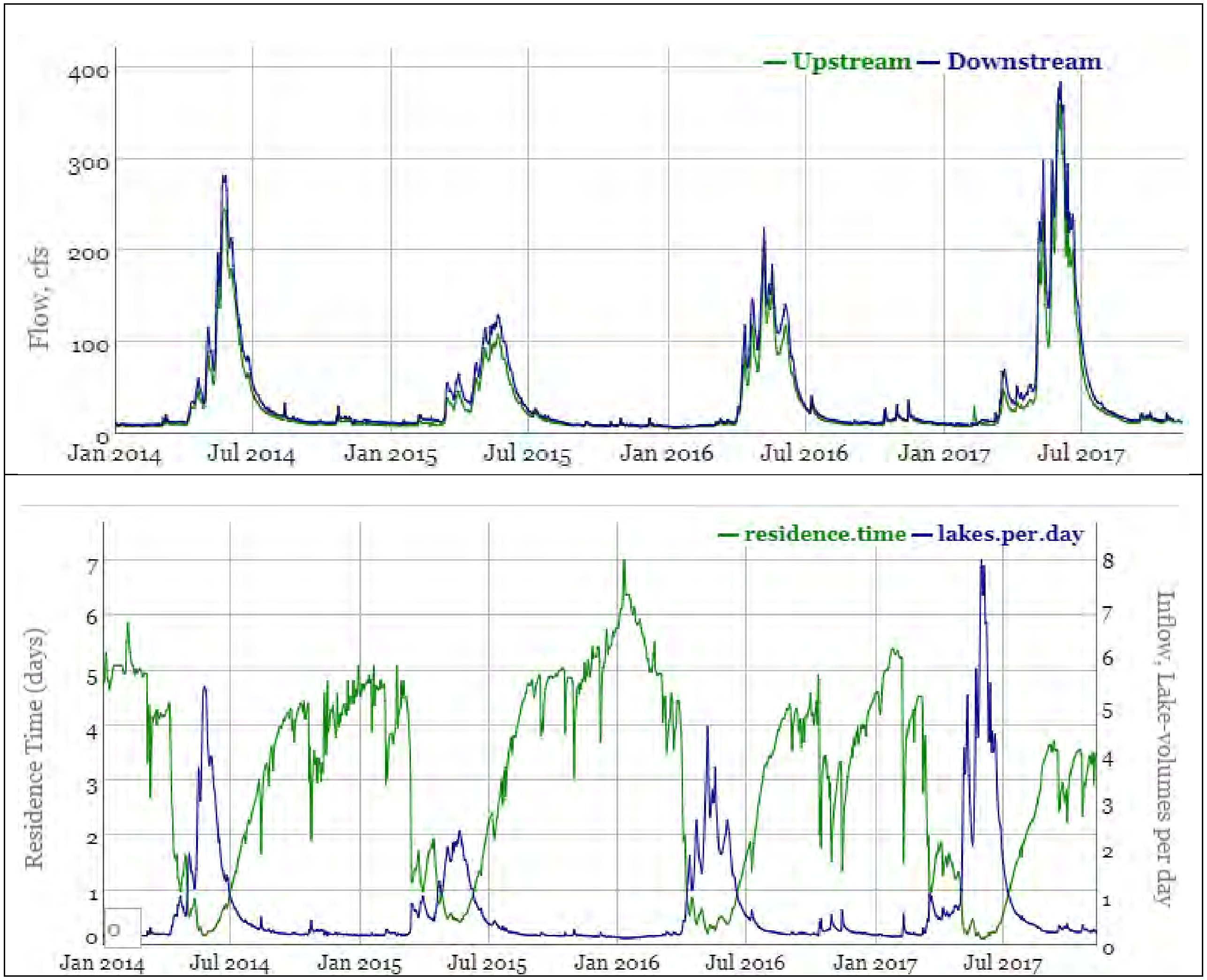


Figure 28. Observed Flows Upstream and Downstream of YPP (top) and Estimated Residence Time of YPP (bottom)

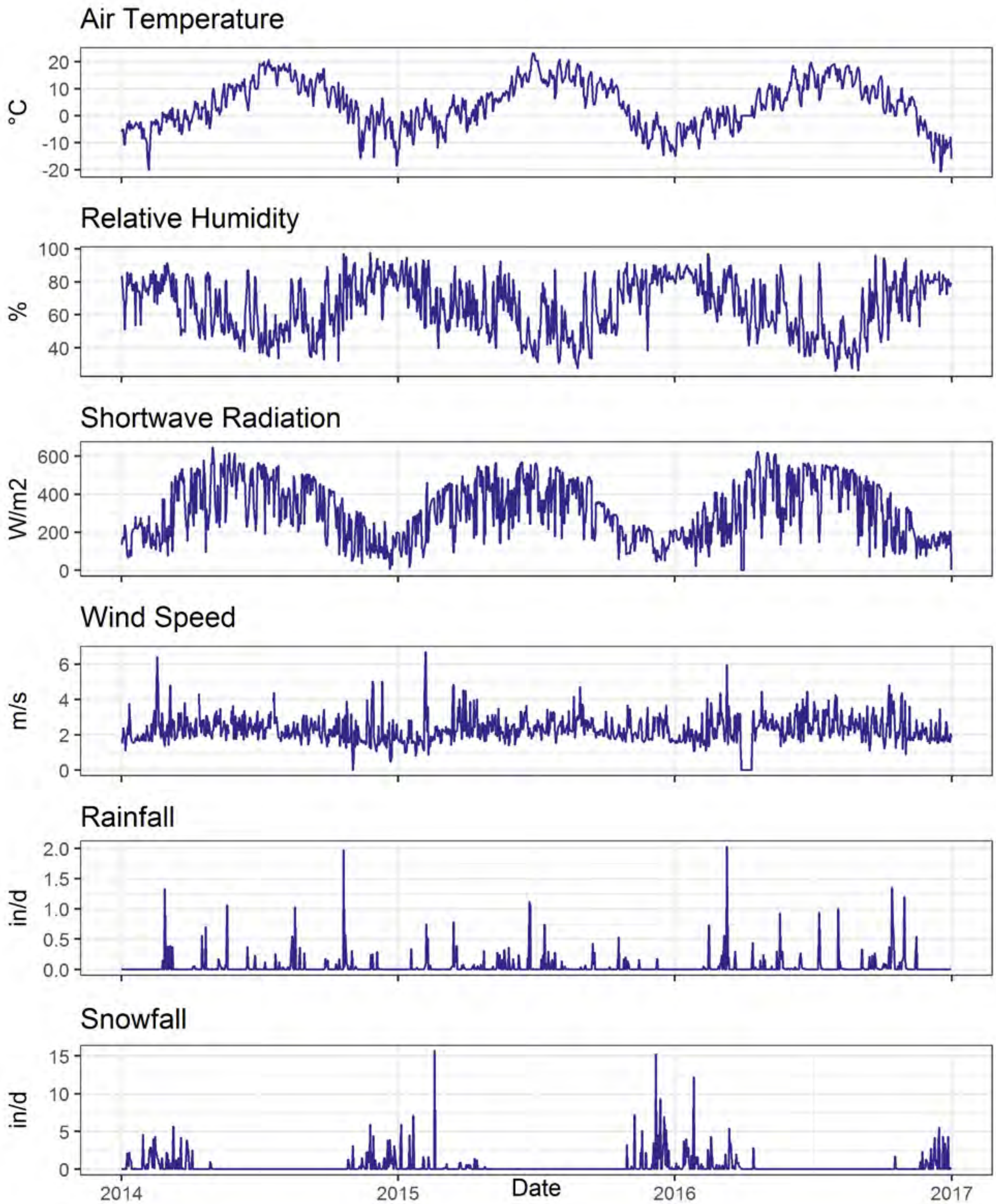


Figure 29. Meteorological Inputs for the GLM

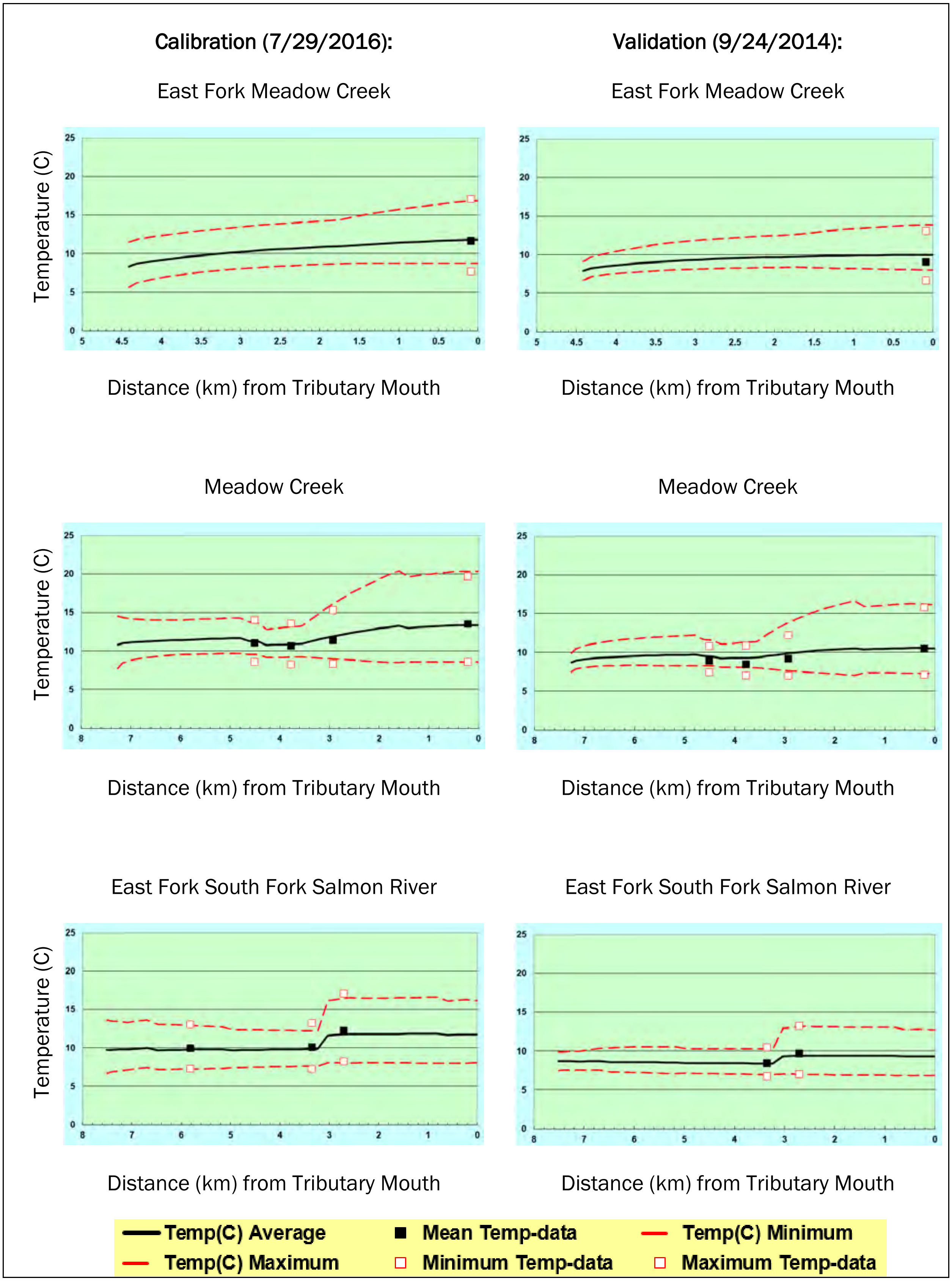


Figure 30. Temperature (C) Calibration and Validation Results for the QUAL2K Model Above YPP

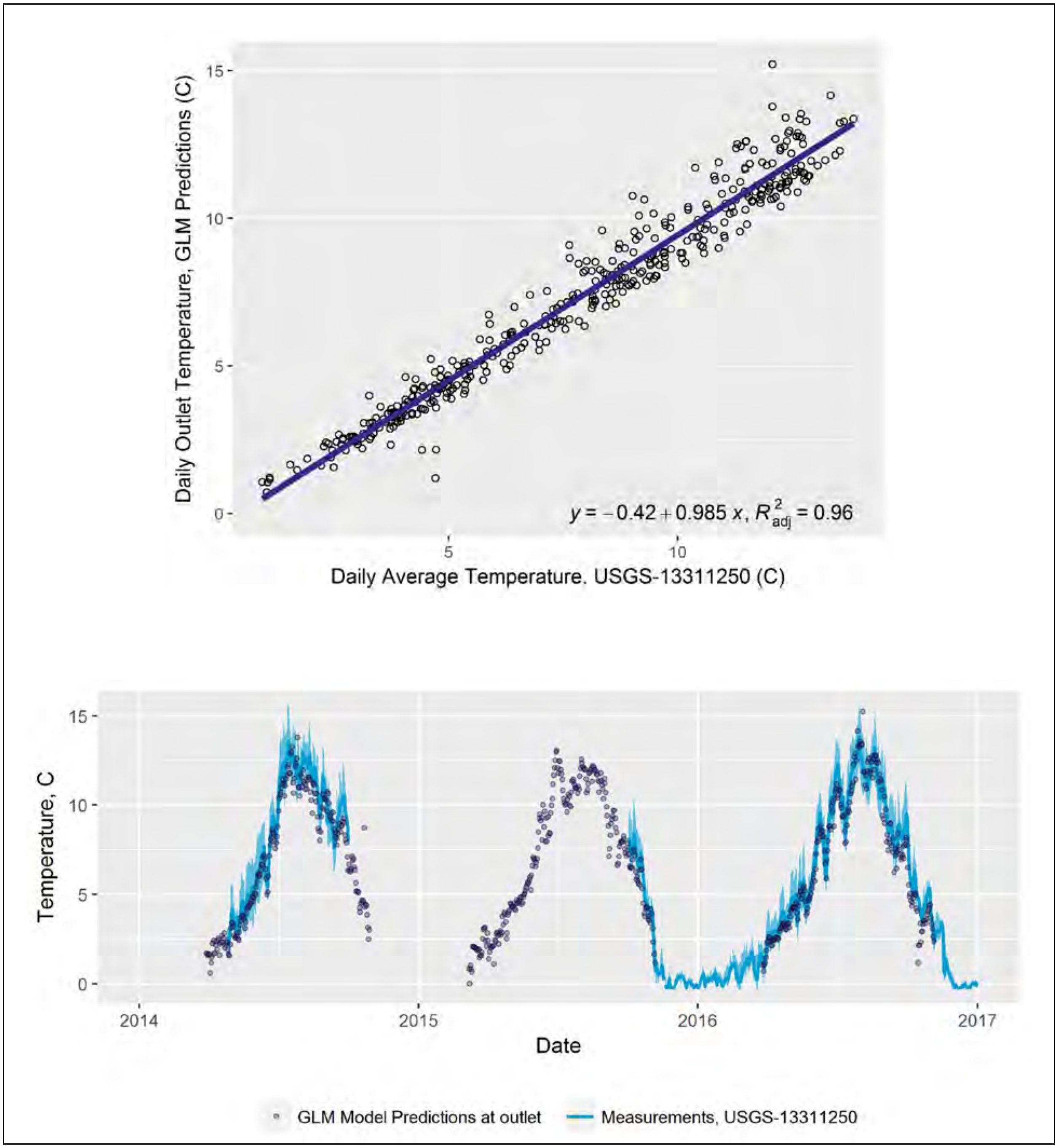


Figure 31. Temperature Calibration and Validation of the GLM for YPP

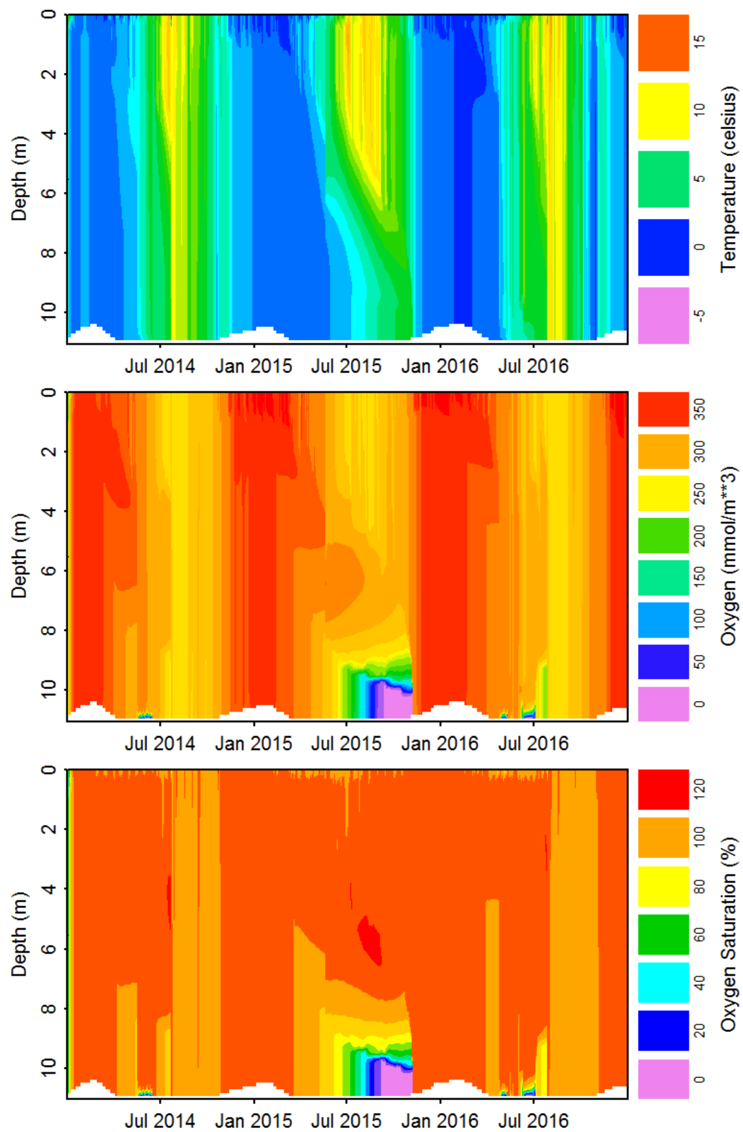


Figure 32. DO and Temperature Output for the GLM for YPP

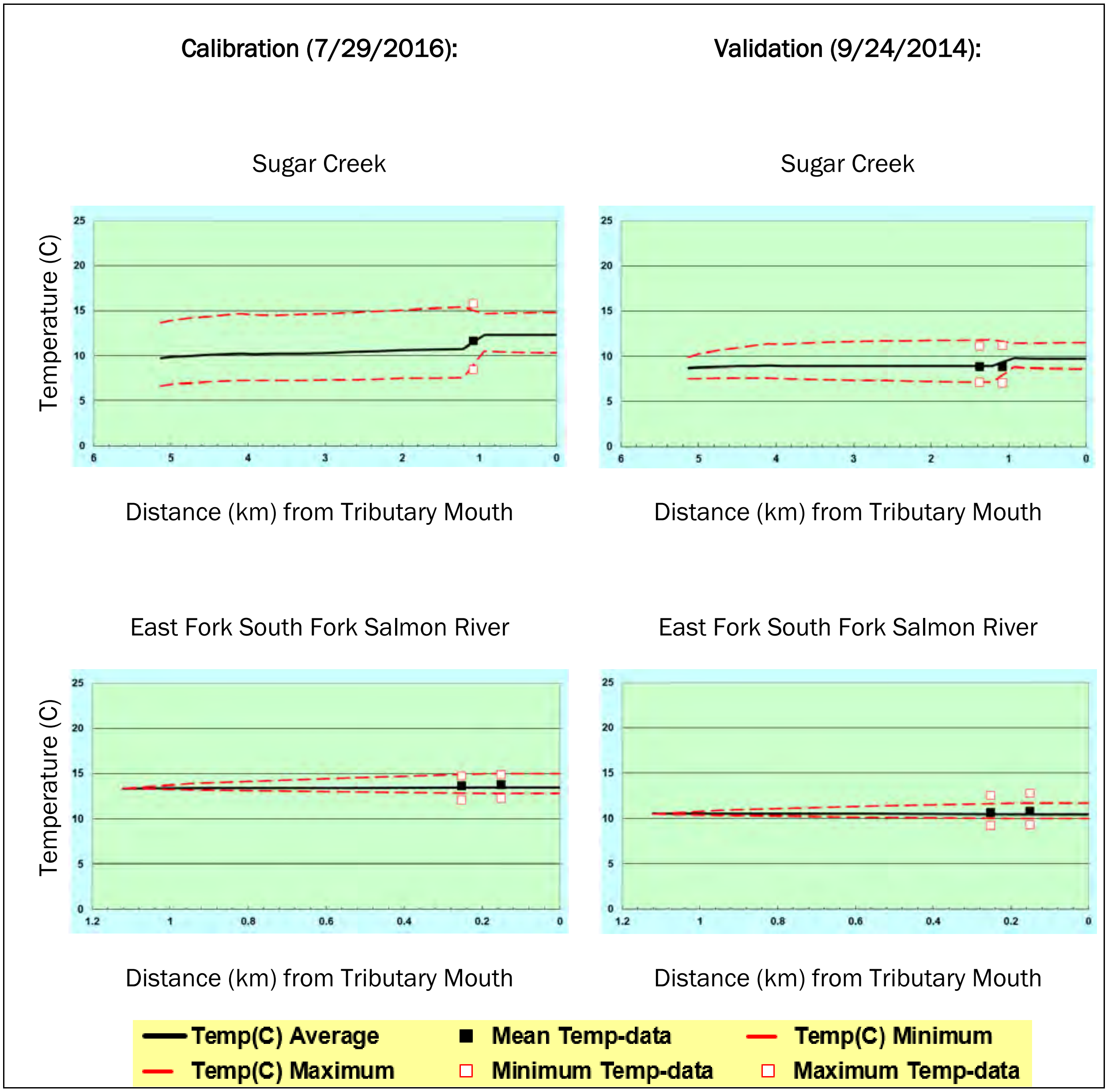


Figure 33. Temperature (C) Calibration and Validation Results for the QUAL2K Model Below YPP

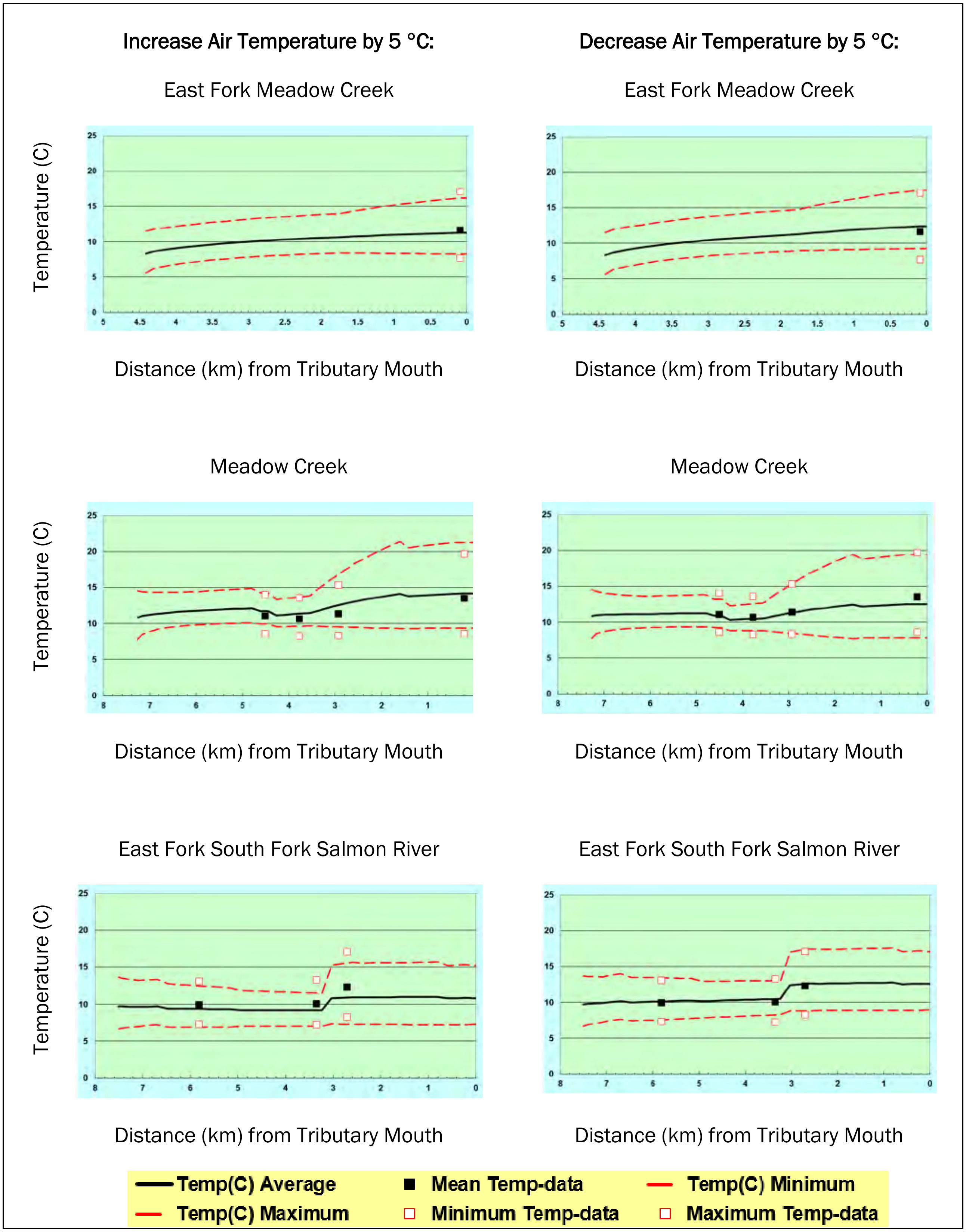


Figure 34. Sensitivity of Simulated Temperature (C) to Changes in Air Temperature Relative to the Calibration Model Run

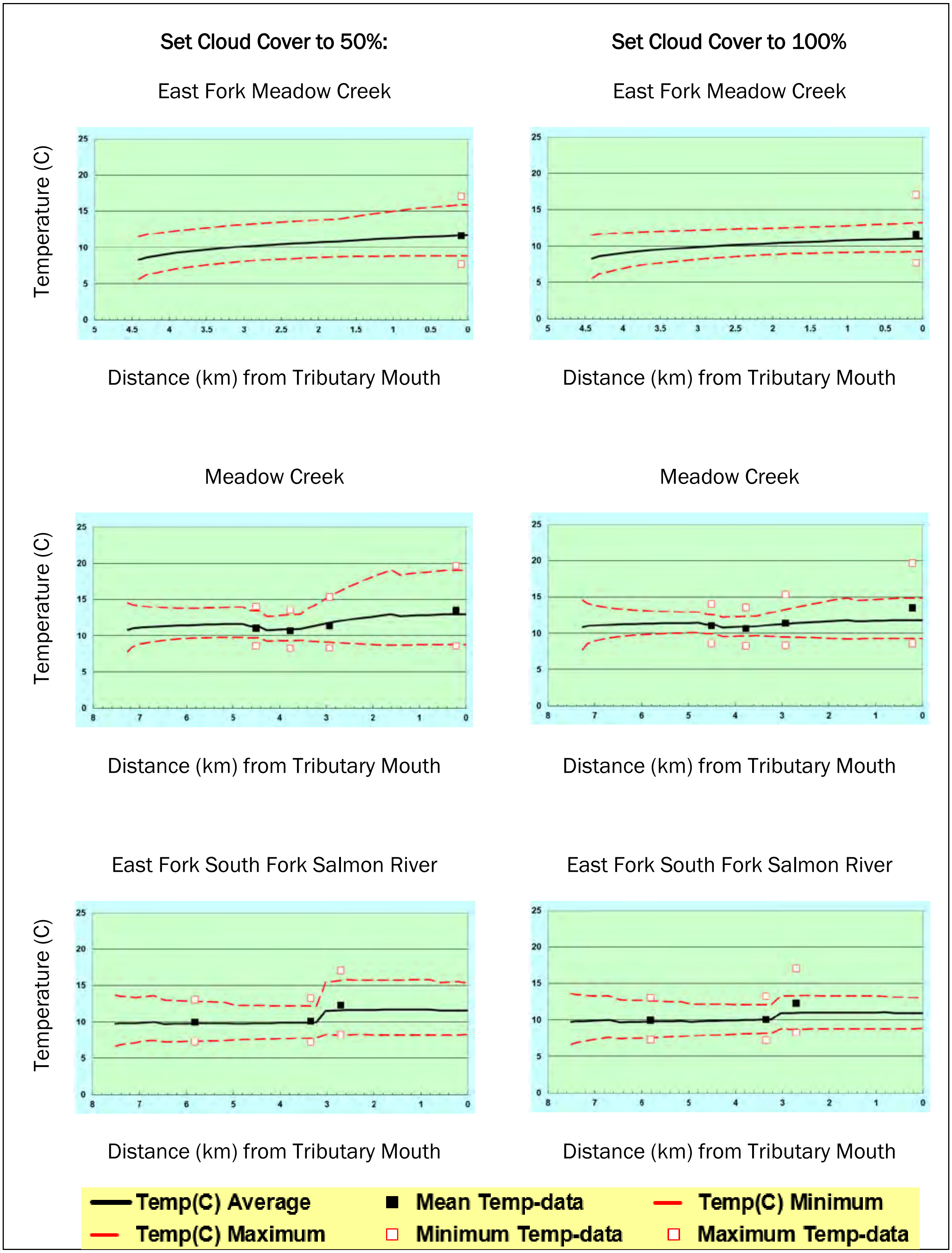


Figure 35. Sensitivity of Simulated Temperatures (C) to Changes in Cloud Cover Relative to the Calibration Model Run where Cloud Cover = 0 Percent for All Reaches and Times of Day

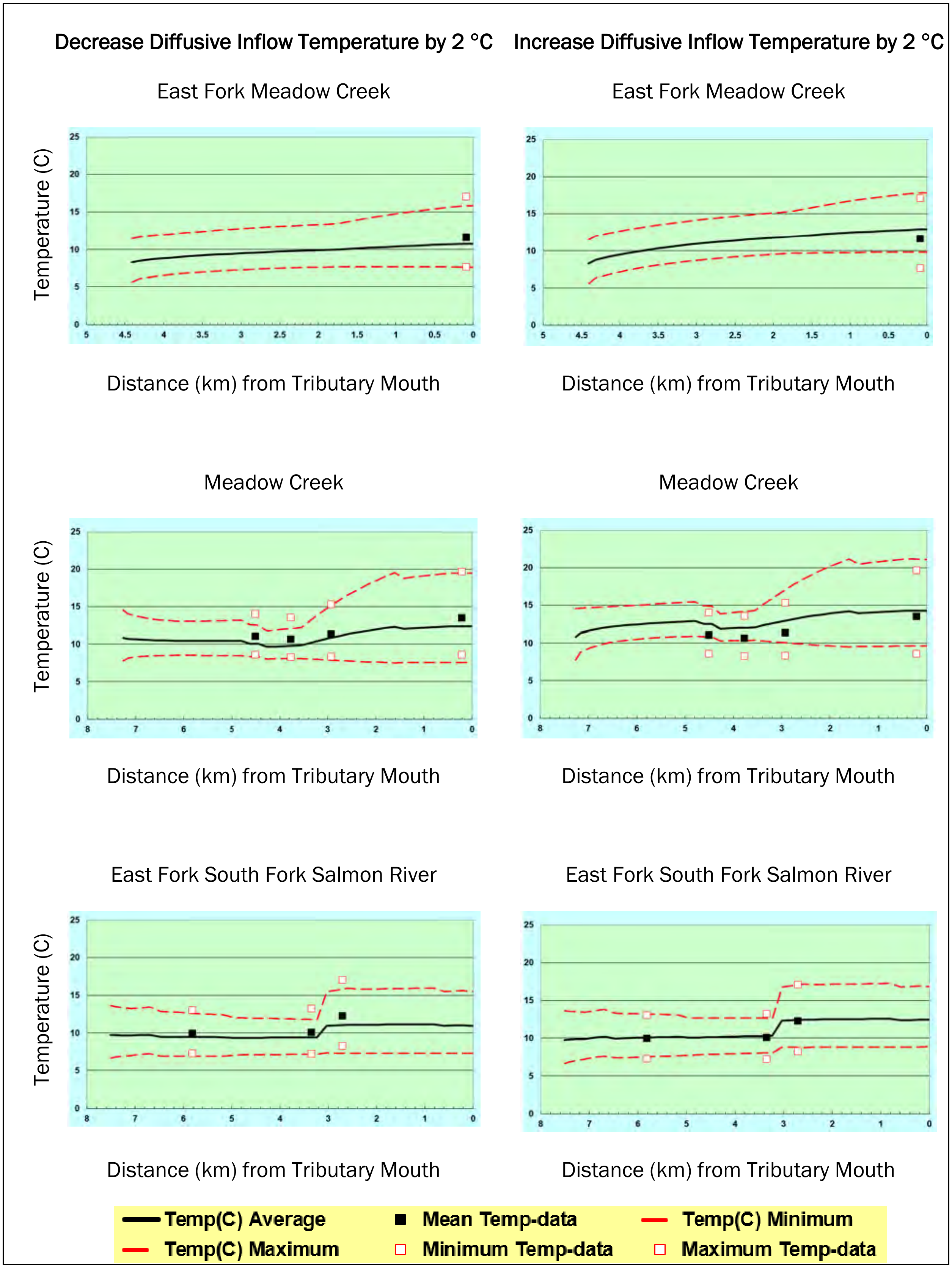


Figure 36. Sensitivity of Simulated Temperatures (C) to Changes in Diffusive Inflow Temperatures

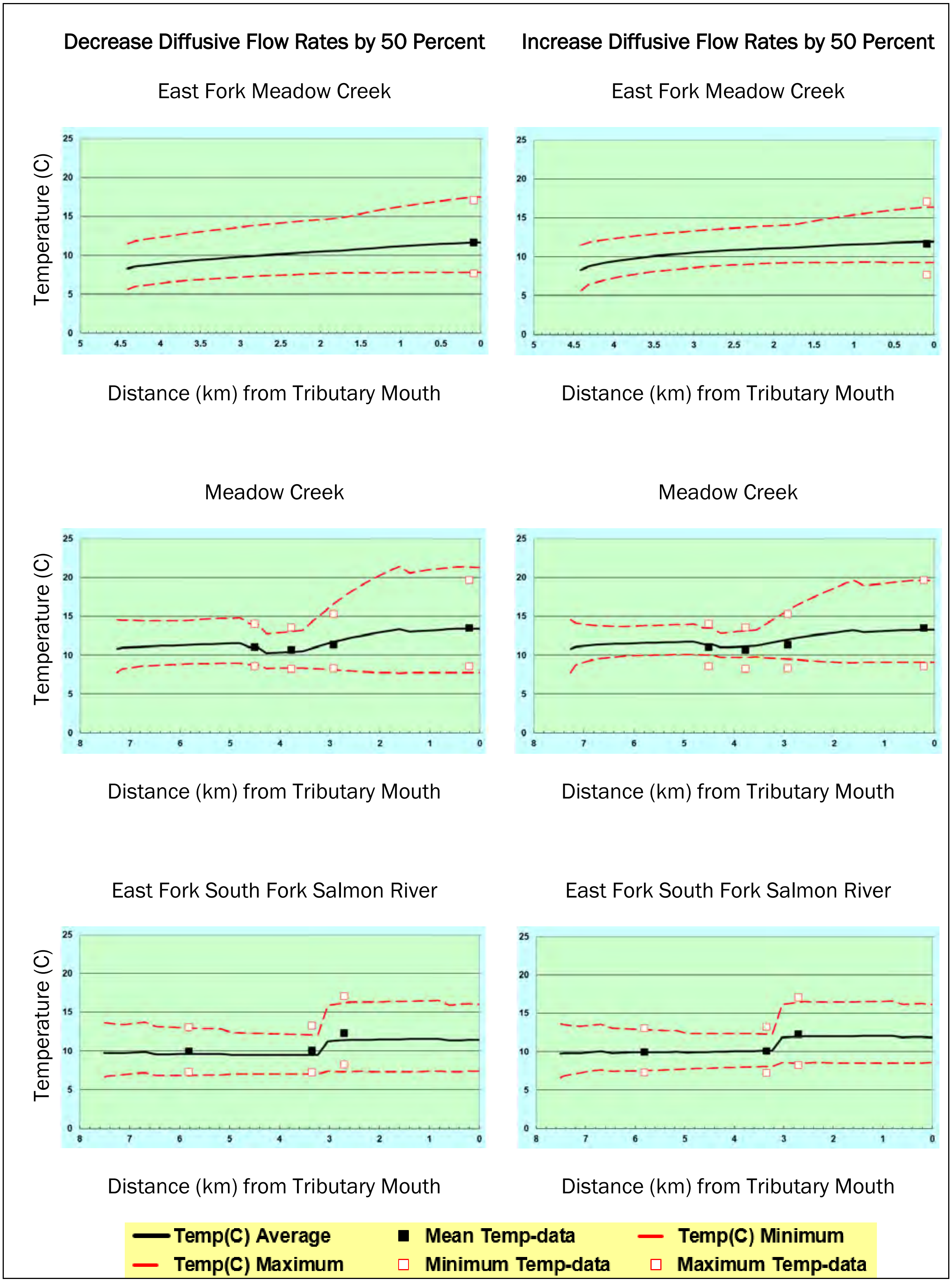


Figure 37. Sensitivity of Simulated Temperatures (C) to Changes in Diffusive Flow Rates

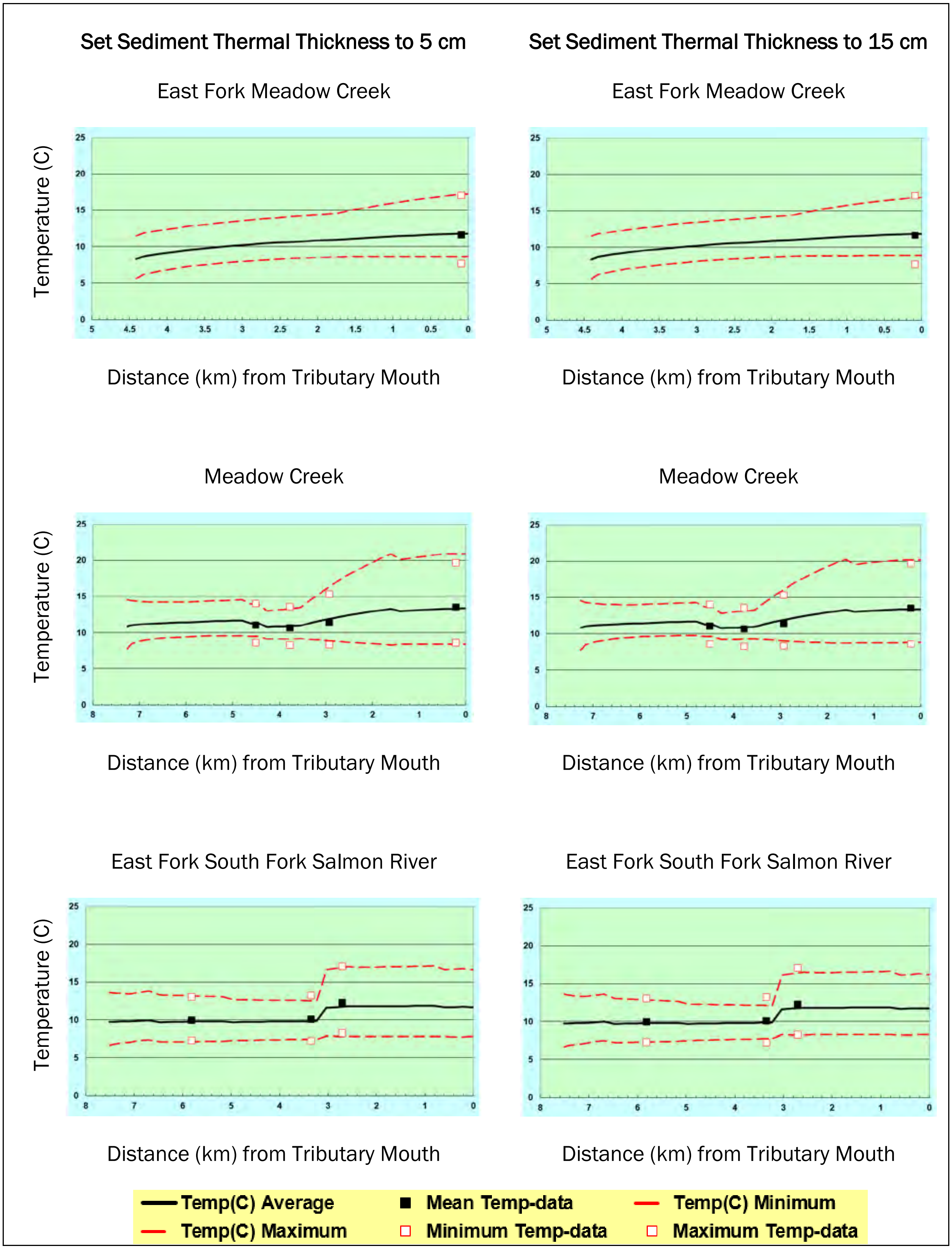


Figure 38. Sensitivity of Simulated Temperatures (C) to Changes in Sediment Thermal Thickness Relative to Calibration Model Run Which Assumed 10 Cm

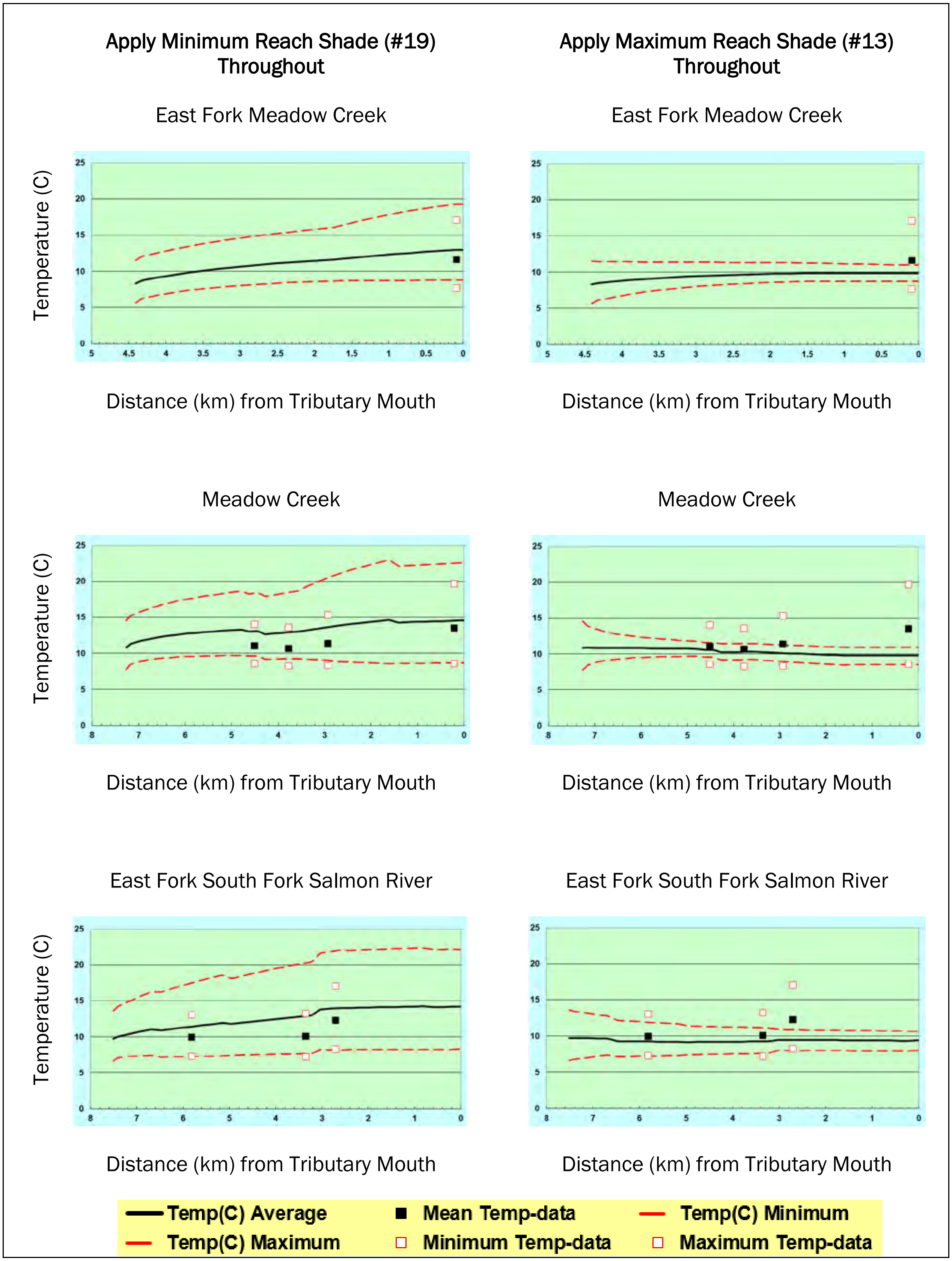


Figure 39. Sensitivity of Simulated Temperatures (C) to Changes in Shading Relative to Calibration Model Run

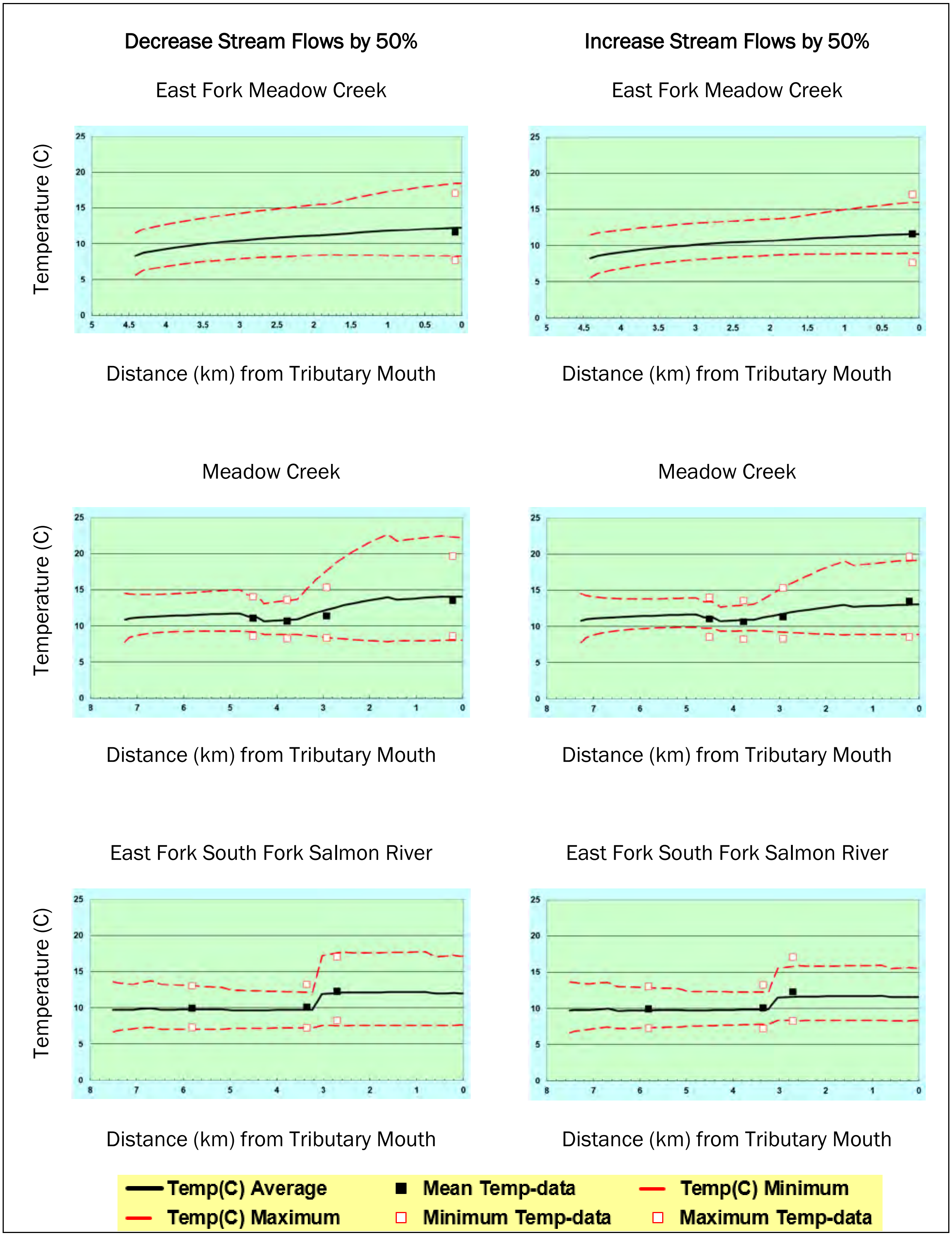


Figure 40. Sensitivity of Simulated Temperatures (C) to Changes in Stream Flow Relative to Calibration Model Run

Appendix A: 2017 YPP Field Sheets

Page: ____ of ____

Brown AND Caldwell

Daily Field Report

Project Name: Seeps/Springs SW, SPLNT Project/Phase Number: 151161.003 150696 008 Client Name: Midas City, State: Stibnite, ID	Field Personnel: J. Ekhoff (BC) Subcontractor: B. Serrin (Midas) Site Visitors: / Weather: Partly cloudy, mid-20s	Date: 10/3/17 Arrival Time: 0615 Departure Time: 1915
Event Description: Seep/Spring SW, SPLNT profile Day of Event: 2 of 2	Field Equipment: YSI, HACH, Secchi Disk, raft, peri pump	

Field Activities:

0615 - Calibrate
0700 - Leave YP house
0740 - Arrive at Stibnite office
0915 - Arrive GM-RC216
0920 - Sample GM-RC216
0940 - Arrive GM-RC220
0945 - Sample GM-RC220 + DUP10-2017
1130 - Arrive YP pit
1210 - Begin pit SPLNT profile
1245 - End pit SPLNT profile
1310 - offsite
1350 - Drop Blaine off in YP
1815 - Back in Boise, return raft, unload truck.
1915 - Done for Day.

★★ END OF DAILY LOG ★★

[signature] 10/3/17

Field Report-01 REV. 7/2016

Initials: _____

Water Quality Equipment Calibration Form

Brown AND Caldwell

Project: Midas Spring/Seep Survey Date: 10/3/17

Water Quality Parameter Meter

Unit Name/ID: YSI 556 Serial Number: 07C 1046
Calibrated By: J. Ekhoff Assigned User:

Water Quality Parameter Meter Calibration Form								
10.51°C	Cal Std. Expiration Date	Initial Calibration		Re-Calibration		Drift Check		
		Time: 0630		Time:		Time: 1000 10/4/17		20.51°C
		Cal	Read	Cal	Read	Read	Acceptable Performance	
pH (3-point)							±Δ 0.20	
Buffer 2.0								
4.00 Buffer 4.0	3/19	x	3.78			4.18	✓	
7.06 Buffer 7.0	3/19	x	7.09			7.09	✓	
10.12 Buffer 10.0	3/19	x	10.26			10.26	✓	
Conductivity							±10%	
447 uS/cm	7/18		492			441	✓	
1413 uS/cm	2/18	x	~~1586~~ 1473			1384	✓	
8974 uS/cm								
15,000 uS/cm								
ORP							±10%	
225 220 mv	4/18	x	238.9			209.7	✓	
Dissolved Oxygen							±10%	
Open Air (mg/L)		x						
Zero Oxy Std (mg/L)	1/18		~~7.32~~ 07			5.18		
Barometer (mm Hg)		x	637.9			692.7	✓	

Turbidity Meter

Unit Name/ID: Serial Number:
Calibrated By: Assigned User:

Turbidity Meter Calibration Form							
	Cal Std. Expiration Date	Initial Calibration		Re-Calibration		Drift Check	
		Time:		Time:		Time:	
		Cal	Read	Cal	Read	Read	Acceptable Performance
Turbidity							±10%
10 Standard							
20 Standard							
100 Standard							
800 Standard							

SPLNT Data Log

Brown AND Caldwell

Project: Midas SPLINT ~~150696.008~~ Client: Midas Date: 10/3/17 Project #: 150696.008 Sampler: J. Ekhoff

Field Meter: YSI 556, S/N: 07C1046

Barometric Pressure (units): 613.0

Weather Conditions (cloud cover, wind, precipitation observations):

Sunny, 40's, mild breeze. No precip. Thin skin of ice ~~[illegible]~~ in NE corner of Lake

Secchi Depth (m): Out: 20.8 ft In: 21.2 ft. Average: 21.0 ft. Time: 1240

Location Description and Coordinates (if available): 0631346E 4976250N UTM

~middle of pit, in the narrow waist.

Water Depth (m)	Temperature (°C)	SC (µs/cm)	DO (mg/L)	pH (s.u.)	ORP mV	Time
0.1	4.37	100	~~12~~ 11.35	5.50	148.6	1211
0.5	4.21	90	10.40	6.39	155.0	1215
1.0	4.10	200	10.34	6.49	146.8	1217
1.5	3.99	~~12~~,0300	10.07	6.47	143.4	1219
2.0	4.01	100	10.12	6.46	144.5	1221
3.0	3.95	100	10.17	6.44	143.0	1223
4.0	3.86	100	9.94	6.42	141.0	1225
5.0	3.81	99	9.84	6.40	141.4	1227
6.0	3.82	104	9.83	6.32	143.8	1229
7.0	3.81	98	9.93	6.33	141.4	1230
8.0	3.84	100	9.71	6.33	141.0	1232
9.0	3.86	99	9.74	6.23	143.8	1234
10.0	3.92	101	9.63	6.11	146.6	1236

SC erratic (0.1 m to 3.0 m) x

Lat - 44.92755

Long - -115.3355932

x Conductivity readings were erratic for depths 0.1m to 3.0m. Values shown are best eyeballed median of reading range. Conductivity readings were stable from 4.0m down.

Appendix B: Sensitivity Analyses Inputs and Outputs

Air Temperature Input																								
	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Calibration	13.164	12.2	11.392	10.808	10.128	9.652	9.498	11.64	17.38	20.98	23.182	24.614	25.576	26.308	26.58	27.374	27.4	27.586	26.55	24.716	21.252	18.332	16.448	14.562
+ 5 Degrees	18.164	17.2	16.392	15.808	15.128	14.652	14.498	16.64	22.38	25.98	28.182	29.614	30.576	31.308	31.58	32.374	32.4	32.586	31.55	29.716	26.252	23.332	21.448	19.562
- 5 Degrees	8.164	7.2	6.392	5.808	5.128	4.652	4.498	6.64	12.38	15.98	18.182	19.614	20.576	21.308	21.58	22.374	22.4	22.586	21.55	19.716	16.252	13.332	11.448	9.562

Air Temperature Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+5	-5	Calibration	+5	-5	Calibration	+5	-5
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.81	9.71	6.82	6.86	6.78	13.54	13.60	13.47
0	EFSFSR Headwater	7.26	9.76	9.85	9.67	6.96	7.05	6.88	13.44	13.56	13.32
0	EFSFSR Headwater	7.09	9.76	9.90	9.63	7.09	7.21	6.98	13.35	13.53	13.18
0	EFSFSR1	6.90	9.86	10.05	9.68	7.32	7.49	7.16	13.51	13.75	13.27
0	EFSFSR1	6.69	9.96	10.19	9.73	7.41	7.61	7.21	13.65	13.95	13.35
0	EFSFSR2	6.47	9.69	9.96	9.42	7.17	7.41	6.93	13.10	13.46	12.74
0	EFSFSR2	6.25	9.72	10.03	9.42	7.19	7.47	6.92	13.03	13.44	12.63
0	EFSFSR2	6.02	9.75	10.10	9.41	7.22	7.52	6.92	12.98	13.43	12.54
0	EFSFSR3	5.80	9.76	10.15	9.39	7.24	7.58	6.91	12.92	13.40	12.45
0	EFSFSR3	5.59	9.77	10.19	9.37	7.26	7.63	6.90	12.86	13.38	12.35
0	EFSFSR3	5.37	9.78	10.23	9.35	7.28	7.68	6.90	12.80	13.36	12.26
0	EFSFSR3	5.16	9.79	10.27	9.33	7.30	7.72	6.89	12.75	13.33	12.18
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	10.15	9.24	7.42	7.83	7.01	12.38	12.94	11.82
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	10.20	9.24	7.45	7.88	7.02	12.36	12.95	11.78
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	10.24	9.23	7.47	7.93	7.03	12.34	12.96	11.74
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	10.28	9.23	7.50	7.98	7.03	12.33	12.97	11.70
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	10.32	9.22	7.53	8.02	7.04	12.31	12.97	11.66
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	10.36	9.22	7.55	8.07	7.04	12.29	12.98	11.62
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	10.40	9.21	7.57	8.11	7.05	12.27	12.98	11.57
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	10.44	9.21	7.60	8.16	7.05	12.25	12.98	11.53
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	10.47	9.20	7.62	8.20	7.05	12.23	12.98	11.49
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	10.50	9.20	7.64	8.24	7.06	12.21	12.98	11.45
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	12.40	10.86	8.07	8.79	7.37	16.15	17.05	15.27
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	12.51	10.92	8.04	8.79	7.31	16.36	17.27	15.46
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	12.61	10.98	8.02	8.79	7.27	16.56	17.49	15.64
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	12.61	10.98	8.06	8.83	7.31	16.47	17.40	15.55
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	12.63	10.98	8.06	8.83	7.30	16.49	17.42	15.57
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	12.65	10.99	8.05	8.83	7.29	16.50	17.44	15.58
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	12.67	10.99	8.05	8.83	7.28	16.52	17.46	15.59
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	12.68	11.00	8.05	8.84	7.27	16.54	17.48	15.60
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	12.70	11.00	8.04	8.84	7.26	16.56	17.51	15.62
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	12.72	11.01	8.04	8.85	7.25	16.58	17.54	15.64
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	12.74	11.01	8.04	8.85	7.25	16.61	17.57	15.66
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	12.75	11.02	8.04	8.86	7.24	16.64	17.60	15.69
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	12.54	10.84	8.03	8.84	7.25	16.13	17.08	15.20
0	EFSFSR8	0.39	11.71	12.57	10.86	8.03	8.84	7.24	16.21	17.16	15.27
0	EFSFSR8	0.21	11.73	12.60	10.88	8.03	8.85	7.23	16.28	17.24	15.34
0	EFSFSR9 (at Midnight Cree	0.06	11.71	12.58	10.86	8.09	8.90	7.30	16.16	17.11	15.22
0	Terminus	0.00	11.71	12.58	10.86	8.09	8.90	7.30	16.16	17.11	15.22
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.66	8.48	6.07	6.14	5.99	11.75	11.87	11.63
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.98	8.65	6.37	6.52	6.23	11.98	12.20	11.76
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.27	8.80	6.59	6.80	6.39	12.20	12.51	11.90
1	Terminus	0.00	9.03	9.27	8.80	6.59	6.80	6.39	12.20	12.51	11.90
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.11	10.94	8.47	8.54	8.40	14.34	14.46	14.23
2	Meadow Creek Headwater	6.96	11.15	11.30	11.00	8.86	8.99	8.73	14.19	14.39	13.99
2	Meadow Creek Headwater	6.76	11.24	11.44	11.04	9.10	9.28	8.93	14.10	14.36	13.84
2	Meadow Creek Headwater	6.56	11.31	11.55	11.07	9.27	9.48	9.06	14.05	14.36	13.73
2	Meadow Creek Headwater	6.36	11.36	11.65	11.09	9.39	9.63	9.14	14.02	14.38	13.66
2	Meadow Creek Headwater	6.16	11.41	11.72	11.10	9.47	9.75	9.20	14.01	14.41	13.62

Air Temperature Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+5	-5	Calibration	+5	-5	Calibration	+5	-5
2	Meadow Creek Headwater	5.96	11.44	11.78	11.11	9.54	9.84	9.24	14.02	14.46	13.60
2	MC1	5.76	11.50	11.86	11.14	9.58	9.91	9.27	14.08	14.54	13.63
2	MC1	5.57	11.55	11.93	11.17	9.62	9.96	9.28	14.14	14.62	13.66
2	MC1	5.38	11.59	11.99	11.19	9.65	10.01	9.29	14.19	14.69	13.69
2	MC1	5.18	11.62	12.04	11.21	9.66	10.04	9.30	14.24	14.76	13.72
2	MC1	4.99	11.65	12.09	11.22	9.68	10.07	9.29	14.28	14.83	13.75
2	MC1	4.80	11.68	12.13	11.24	9.69	10.09	9.29	14.33	14.89	13.78
2	MC2 (at MC Trib 2)	4.62	11.30	11.74	10.88	9.59	9.99	9.21	13.76	14.30	13.23
2	MC2 (at MC Trib 2)	4.45	11.27	11.72	10.83	9.58	9.99	9.19	13.73	14.29	13.19
2	MC4 (at MC Trib 3)	4.27	10.74	11.17	10.33	9.17	9.55	8.80	12.82	13.35	12.30
2	MC4 (at MC Trib 3)	4.09	10.80	11.25	10.37	9.19	9.58	8.80	12.94	13.49	12.40
2	MC4 (at MC Trib 3)	3.91	10.86	11.32	10.41	9.21	9.62	8.81	13.05	13.62	12.49
2	MC4 (at MC Trib 3)	3.73	10.92	11.39	10.46	9.22	9.65	8.81	13.16	13.74	12.58
2	MC4 (at MC Trib 3)	3.55	10.97	11.45	10.50	9.24	9.68	8.82	13.26	13.86	12.67
2	MC6	3.36	11.29	11.82	10.77	9.16	9.64	8.68	14.19	14.84	13.55
2	MC6	3.15	11.59	12.17	11.02	9.07	9.59	8.55	15.14	15.83	14.45
2	MC6	2.95	11.88	12.50	11.26	8.98	9.55	8.43	16.02	16.76	15.30
2	MC6	2.75	12.15	12.82	11.49	8.90	9.51	8.30	16.85	17.63	16.08
2	MC6	2.54	12.41	13.11	11.71	8.82	9.47	8.19	17.61	18.43	16.80
2	MC7	2.35	12.60	13.34	11.87	8.75	9.43	8.08	18.25	19.10	17.41
2	MC7	2.16	12.78	13.56	12.02	8.68	9.40	7.98	18.84	19.72	17.97
2	MC7	1.98	12.96	13.77	12.16	8.62	9.37	7.88	19.40	20.31	18.50
2	MC7	1.79	13.13	13.97	12.30	8.56	9.34	7.79	19.91	20.85	18.98
2	MC7	1.60	13.29	14.16	12.43	8.50	9.32	7.70	20.39	21.35	19.44
2	MC8 (at East Fork MC)	1.41	13.00	13.80	12.21	8.56	9.31	7.83	19.63	20.52	18.75
2	MC8 (at East Fork MC)	1.22	13.07	13.88	12.27	8.57	9.33	7.83	19.79	20.69	18.90
2	MC8 (at East Fork MC)	1.03	13.14	13.95	12.33	8.58	9.34	7.83	19.94	20.84	19.04
2	MC8 (at East Fork MC)	0.84	13.20	14.03	12.39	8.58	9.36	7.83	20.08	20.99	19.18
2	MC8 (at East Fork MC)	0.65	13.26	14.10	12.44	8.59	9.37	7.82	20.21	21.13	19.31
2	MC8 (at East Fork MC)	0.46	13.33	14.17	12.50	8.60	9.39	7.82	20.34	21.26	19.43
2	MC10	0.27	13.34	14.18	12.50	8.59	9.39	7.81	20.33	21.25	19.41
2	MC10	0.09	13.35	14.20	12.50	8.59	9.40	7.80	20.31	21.24	19.39
2	Terminus	0.00	13.35	14.20	12.50	8.59	9.40	7.80	20.31	21.24	19.39
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.38	9.16	7.32	7.42	7.22	12.00	12.15	11.86
3	MC Trib 2 Headwater	1.08	9.82	10.00	9.64	8.18	8.34	8.03	12.34	12.58	12.11
3	MC Trib 2 Headwater	0.89	10.16	10.40	9.94	8.67	8.87	8.47	12.61	12.91	12.31
3	MC Trib 2 Headwater	0.70	10.40	10.67	10.13	8.98	9.22	8.74	12.87	13.22	12.52
3	MC3	0.50	10.53	10.83	10.23	9.20	9.47	8.93	12.80	13.19	12.42
3	MC3	0.30	10.62	10.95	10.29	9.35	9.65	9.06	12.78	13.21	12.36
3	MC3	0.10	10.68	11.04	10.33	9.46	9.78	9.15	12.77	13.22	12.32
3	Terminus	0.00	10.68	11.04	10.33	9.46	9.78	9.15	12.77	13.22	12.32
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.67	8.54	6.30	6.35	6.24	11.44	11.52	11.35
4	MC Trib 3 Headwater	1.31	8.85	8.97	8.73	6.85	6.95	6.74	11.41	11.57	11.26
4	MC Trib 3 Headwater	1.12	9.05	9.22	8.89	7.28	7.43	7.14	11.39	11.60	11.19
4	MC Trib 3 Headwater	0.93	9.21	9.42	9.01	7.62	7.80	7.44	11.38	11.63	11.13
4	MC5	0.73	9.34	9.59	9.10	7.86	8.08	7.65	11.34	11.64	11.04
4	MC5	0.52	9.45	9.73	9.17	8.06	8.31	7.82	11.30	11.64	10.97
4	MC5	0.31	9.54	9.85	9.23	8.22	8.50	7.95	11.27	11.64	10.91
4	MC5	0.10	9.61	9.95	9.28	8.36	8.66	8.06	11.24	11.64	10.85
4	Terminus	0.00	9.61	9.95	9.28	8.36	8.66	8.06	11.24	11.64	10.85

Air Temperature Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+5	-5	Calibration	+5	-5	Calibration	+5	-5
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.71	8.63	6.22	6.26	6.19	11.85	11.91	11.80
5	East Fork MC Headwater	4.11	9.00	9.07	8.93	6.66	6.72	6.60	12.16	12.26	12.06
5	East Fork MC Headwater	3.92	9.28	9.39	9.18	7.01	7.10	6.92	12.43	12.57	12.29
5	East Fork MC Headwater	3.72	9.53	9.66	9.40	7.30	7.42	7.19	12.68	12.86	12.51
5	East Fork MC Headwater	3.52	9.75	9.91	9.59	7.54	7.67	7.40	12.92	13.13	12.71
5	East Fork MC Headwater	3.33	9.94	10.12	9.77	7.74	7.90	7.59	13.13	13.37	12.90
5	East Fork MC Headwater	3.13	10.12	10.32	9.92	7.92	8.09	7.75	13.33	13.59	13.07
5	East Fork MC Headwater	2.93	10.27	10.49	10.06	8.07	8.26	7.88	13.51	13.80	13.23
5	East Fork MC Headwater	2.73	10.41	10.65	10.18	8.21	8.41	8.00	13.68	13.99	13.38
5	East Fork MC Headwater	2.54	10.54	10.80	10.29	8.32	8.55	8.11	13.84	14.17	13.52
5	East Fork MC Headwater	2.34	10.66	10.93	10.40	8.43	8.67	8.20	13.99	14.34	13.65
5	East Fork MC Headwater	2.14	10.77	11.05	10.49	8.52	8.77	8.28	14.13	14.49	13.77
5	East Fork MC Headwater	1.95	10.86	11.16	10.57	8.61	8.87	8.35	14.26	14.64	13.88
5	East Fork MC Headwater	1.75	10.96	11.26	10.65	8.68	8.96	8.42	14.38	14.78	13.99
5	MC9	1.55	11.10	11.45	10.76	8.70	9.01	8.40	14.80	15.25	14.36
5	MC9	1.34	11.23	11.62	10.86	8.71	9.05	8.38	15.19	15.68	14.71
5	MC9	1.13	11.36	11.77	10.95	8.72	9.09	8.36	15.54	16.06	15.03
5	MC9	0.93	11.47	11.91	11.03	8.73	9.13	8.34	15.85	16.40	15.30
5	MC9	0.72	11.57	12.04	11.10	8.74	9.16	8.32	16.13	16.71	15.56
5	MC9	0.52	11.66	12.16	11.17	8.74	9.19	8.30	16.38	16.99	15.79
5	MC9	0.31	11.75	12.28	11.23	8.74	9.22	8.28	16.62	17.24	16.00
5	MC9	0.10	11.83	12.38	11.29	8.75	9.25	8.26	16.83	17.47	16.18
5	Terminus	0.00	11.83	12.38	11.29	8.75	9.25	8.26	16.83	17.47	16.18
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.51	9.99	8.84	9.07	8.61	12.20	12.53	11.88
6	Garnet Creek Headwater	1.51	10.70	11.06	10.35	9.42	9.74	9.10	12.45	12.89	12.01
6	Garnet Creek Headwater	1.29	10.88	11.30	10.47	9.59	9.97	9.22	12.58	13.10	12.08
6	Garnet Creek Headwater	1.07	10.96	11.43	10.51	9.65	10.06	9.23	12.67	13.24	12.12
6	Garnet Creek Headwater	0.85	11.01	11.51	10.51	9.65	10.10	9.20	12.74	13.35	12.15
6	GC1	0.65	11.10	11.62	10.59	9.65	10.12	9.18	12.87	13.50	12.25
6	GC1	0.46	11.17	11.71	10.63	9.64	10.13	9.15	12.99	13.64	12.34
6	GC1	0.28	11.22	11.78	10.66	9.62	10.13	9.11	13.09	13.76	12.51
6	GC1	0.09	11.25	11.83	10.68	9.59	10.12	9.07	13.23	13.87	12.65
6	Terminus	0.00	11.25	11.83	10.68	9.59	10.12	9.07	13.23	13.87	12.65
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.48	8.35	5.97	6.03	5.91	11.39	11.48	11.30
7	Fiddle Creek Headwater	2.53	8.52	8.65	8.39	6.30	6.41	6.18	11.31	11.48	11.15
7	Fiddle Creek Headwater	2.36	8.62	8.80	8.44	6.58	6.74	6.42	11.25	11.48	11.02
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.89	8.47	6.94	7.13	6.75	11.02	11.28	10.76
7	FC1 (at Fiddle Creek Trib	2.02	8.76	9.02	8.51	7.09	7.32	6.87	11.03	11.34	10.72
7	FC2	1.84	8.85	9.15	8.55	7.25	7.51	6.99	11.00	11.37	10.64
7	FC2	1.65	8.93	9.27	8.59	7.38	7.68	7.08	10.97	11.39	10.56
7	FC2	1.46	9.00	9.38	8.62	7.49	7.83	7.16	10.95	11.41	10.50
7	FC2	1.26	9.06	9.48	8.65	7.58	7.96	7.22	10.93	11.43	10.44
7	FC2	1.07	9.12	9.57	8.67	7.67	8.07	7.28	10.91	11.44	10.38
7	FC2	0.87	9.17	9.65	8.69	7.75	8.18	7.32	10.89	11.46	10.33
7	FC2	0.68	9.21	9.73	8.71	7.81	8.27	7.37	10.87	11.47	10.28
7	FC2	0.49	9.25	9.79	8.72	7.88	8.36	7.40	10.85	11.48	10.23
7	FC2	0.29	9.29	9.85	8.74	7.93	8.44	7.43	10.83	11.49	10.18
7	FC2	0.10	9.32	9.91	8.75	7.98	8.51	7.46	10.82	11.51	10.14
7	Terminus	0.00	9.32	9.91	8.75	7.98	8.51	7.46	10.82	11.51	10.14

Air Temperature Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+5	-5	Calibration	+5	-5	Calibration	+5	-5
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	10.29	9.80	8.75	8.96	8.53	11.64	11.96	11.33
8	Midnight Creek Headwater	2.69	10.47	10.82	10.14	9.37	9.67	9.07	11.71	12.14	11.29
8	Midnight Creek Headwater	2.49	10.64	11.04	10.24	9.57	9.93	9.22	11.75	12.25	11.26
8	Midnight Creek Headwater	2.29	10.71	11.16	10.28	9.64	10.04	9.25	11.78	12.34	11.23
8	Midnight Creek Headwater	2.09	10.75	11.23	10.27	9.65	10.09	9.23	11.80	12.40	11.24
8	Midnight Creek Headwater	1.89	10.76	11.27	10.26	9.64	10.11	9.19	11.83	12.46	11.28
8	Midnight Creek Headwater	1.69	10.76	11.30	10.23	9.62	10.11	9.13	11.86	12.51	11.31
8	Midnight Creek Headwater	1.50	10.75	11.32	10.20	9.58	10.10	9.08	11.89	12.55	11.32
8	Midnight Creek Headwater	1.30	10.74	11.33	10.17	9.55	10.08	9.02	11.90	12.59	11.31
8	Midnight Creek Headwater	1.10	10.73	11.34	10.13	9.51	10.06	8.96	11.91	12.62	11.30
8	Midnight Creek Headwater	0.90	10.72	11.34	10.10	9.47	10.04	8.91	11.91	12.65	11.29
8	Midnight Creek Headwater	0.70	10.70	11.34	10.07	9.43	10.02	8.85	11.91	12.67	11.26
8	Midnight Creek Headwater	0.50	10.68	11.34	10.03	9.40	10.00	8.80	11.92	12.69	11.24
8	Midnight Creek Headwater	0.30	10.67	11.34	10.00	9.36	9.98	8.75	11.92	12.71	11.21
8	Midnight Creek Headwater	0.10	10.65	11.34	9.97	9.32	9.96	8.70	11.92	12.73	11.18
8	Terminus	0.00	10.65	11.34	9.97	9.32	9.96	8.70	11.92	12.73	11.18

Cloud Cover Input																								
	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Calibration (0%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Cloud Cover Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	50%	100%	Calibration	50%	100%	Calibration	50%	100%
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.77	9.79	6.82	6.83	6.85	13.54	13.54	13.53
0	EFSFSR Headwater	7.26	9.76	9.78	9.82	6.96	6.98	7.03	13.44	13.44	13.43
0	EFSFSR Headwater	7.09	9.76	9.78	9.84	7.09	7.12	7.20	13.35	13.35	13.34
0	EFSFSR1	6.90	9.86	9.88	9.91	7.32	7.35	7.43	13.51	13.46	13.33
0	EFSFSR1	6.69	9.96	9.96	9.97	7.41	7.46	7.61	13.65	13.57	13.31
0	EFSFSR2	6.47	9.69	9.69	9.67	7.17	7.23	7.41	13.10	12.99	12.74
0	EFSFSR2	6.25	9.72	9.72	9.71	7.19	7.26	7.47	13.03	12.94	12.70
0	EFSFSR2	6.02	9.75	9.75	9.74	7.22	7.29	7.52	12.98	12.89	12.65
0	EFSFSR3	5.80	9.76	9.77	9.77	7.24	7.32	7.58	12.92	12.84	12.60
0	EFSFSR3	5.59	9.77	9.78	9.79	7.26	7.35	7.63	12.86	12.78	12.55
0	EFSFSR3	5.37	9.78	9.80	9.82	7.28	7.38	7.68	12.80	12.72	12.51
0	EFSFSR3	5.16	9.79	9.81	9.84	7.30	7.41	7.73	12.75	12.67	12.46
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	9.71	9.76	7.42	7.52	7.83	12.38	12.31	12.13
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	9.74	9.79	7.45	7.55	7.88	12.36	12.29	12.13
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	9.76	9.83	7.47	7.59	7.93	12.34	12.28	12.13
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	9.78	9.87	7.50	7.62	7.98	12.33	12.27	12.13
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	9.81	9.90	7.53	7.65	8.02	12.31	12.26	12.13
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	9.83	9.93	7.55	7.68	8.07	12.29	12.24	12.13
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	9.85	9.96	7.57	7.71	8.11	12.27	12.23	12.12
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	9.87	10.00	7.60	7.74	8.15	12.25	12.21	12.12
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	9.88	10.03	7.62	7.76	8.19	12.23	12.20	12.11
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	9.90	10.05	7.64	7.79	8.23	12.21	12.18	12.11
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	11.47	10.95	8.07	8.24	8.76	16.15	15.48	13.33
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	11.55	10.98	8.04	8.22	8.75	16.36	15.62	13.35
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	11.62	11.01	8.02	8.20	8.74	16.56	15.77	13.39
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	11.62	11.02	8.06	8.24	8.79	16.47	15.69	13.36
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	11.63	11.03	8.06	8.24	8.79	16.49	15.70	13.35
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	11.64	11.03	8.05	8.24	8.79	16.50	15.71	13.34
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	11.65	11.04	8.05	8.23	8.79	16.52	15.72	13.33
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	11.66	11.04	8.05	8.23	8.79	16.54	15.74	13.32
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	11.67	11.05	8.04	8.23	8.79	16.56	15.75	13.31
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	11.68	11.05	8.04	8.23	8.80	16.58	15.77	13.30
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	11.69	11.06	8.04	8.23	8.80	16.61	15.79	13.29
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	11.70	11.06	8.04	8.23	8.81	16.64	15.81	13.28
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	11.52	10.96	8.03	8.22	8.79	16.13	15.37	13.10
0	EFSFSR8	0.39	11.71	11.54	10.97	8.03	8.22	8.79	16.21	15.44	13.10
0	EFSFSR8	0.21	11.73	11.57	10.98	8.03	8.22	8.79	16.28	15.50	13.10
0	EFSFSR9 (at Midnight Cree	0.06	11.71	11.55	10.99	8.09	8.28	8.85	16.16	15.40	13.06
0	Terminus	0.00	11.71	11.55	10.99	8.09	8.28	8.85	16.16	15.40	13.06
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.56	8.53	6.07	6.08	6.09	11.75	11.70	11.57
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.80	8.75	6.37	6.41	6.52	11.98	11.89	11.64
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.01	8.94	6.59	6.65	6.80	12.20	12.07	11.72

Cloud Cover Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	50%	100%	Calibration	50%	100%	Calibration	50%	100%
1	Terminus	0.00	9.03	9.01	8.94	6.59	6.65	6.80	12.20	12.07	11.72
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.02	11.00	8.47	8.48	8.51	14.34	14.29	14.12
2	Meadow Creek Headwater	6.96	11.15	11.14	11.09	8.86	8.89	8.99	14.19	14.09	13.80
2	Meadow Creek Headwater	6.76	11.24	11.22	11.17	9.10	9.15	9.28	14.10	13.97	13.58
2	Meadow Creek Headwater	6.56	11.31	11.29	11.22	9.27	9.32	9.48	14.05	13.88	13.42
2	Meadow Creek Headwater	6.36	11.36	11.34	11.27	9.39	9.45	9.63	14.02	13.83	13.30
2	Meadow Creek Headwater	6.16	11.41	11.39	11.30	9.47	9.54	9.75	14.01	13.80	13.20
2	Meadow Creek Headwater	5.96	11.44	11.42	11.33	9.54	9.61	9.84	14.02	13.78	13.12
2	MC1	5.76	11.50	11.47	11.36	9.58	9.66	9.91	14.08	13.80	13.07
2	MC1	5.57	11.55	11.51	11.39	9.62	9.70	9.96	14.14	13.83	13.03
2	MC1	5.38	11.59	11.55	11.41	9.65	9.73	10.00	14.19	13.87	12.99
2	MC1	5.18	11.62	11.58	11.43	9.66	9.76	10.04	14.24	13.91	12.96
2	MC1	4.99	11.65	11.61	11.44	9.68	9.78	10.07	14.28	13.94	12.94
2	MC1	4.80	11.68	11.63	11.46	9.69	9.79	10.09	14.33	13.97	12.92
2	MC2 (at MC Trib 2)	4.62	11.30	11.29	11.22	9.59	9.69	9.98	13.76	13.47	12.61
2	MC2 (at MC Trib 2)	4.45	11.27	11.26	11.21	9.58	9.68	9.98	13.73	13.45	12.58
2	MC4 (at MC Trib 3)	4.27	10.74	10.76	10.79	9.17	9.26	9.55	12.82	12.65	12.23
2	MC4 (at MC Trib 3)	4.09	10.80	10.82	10.84	9.19	9.29	9.58	12.94	12.75	12.27
2	MC4 (at MC Trib 3)	3.91	10.86	10.87	10.88	9.21	9.31	9.61	13.05	12.84	12.31
2	MC4 (at MC Trib 3)	3.73	10.92	10.92	10.92	9.22	9.33	9.64	13.16	12.93	12.34
2	MC4 (at MC Trib 3)	3.55	10.97	10.97	10.96	9.24	9.35	9.67	13.26	13.02	12.38
2	MC6	3.36	11.29	11.25	11.08	9.16	9.27	9.62	14.19	13.81	12.66
2	MC6	3.15	11.59	11.50	11.19	9.07	9.20	9.58	15.14	14.59	12.96
2	MC6	2.95	11.88	11.75	11.30	8.98	9.12	9.53	16.02	15.34	13.26
2	MC6	2.75	12.15	11.98	11.40	8.90	9.05	9.49	16.85	16.04	13.54
2	MC6	2.54	12.41	12.20	11.49	8.82	8.98	9.45	17.61	16.69	13.81
2	MC7	2.35	12.60	12.36	11.56	8.75	8.91	9.41	18.25	17.24	14.03
2	MC7	2.16	12.78	12.52	11.63	8.68	8.85	9.37	18.84	17.75	14.25
2	MC7	1.98	12.96	12.67	11.69	8.62	8.80	9.33	19.40	18.22	14.46
2	MC7	1.79	13.13	12.81	11.75	8.56	8.74	9.30	19.91	18.66	14.66
2	MC7	1.60	13.29	12.95	11.81	8.50	8.69	9.27	20.39	19.07	14.84
2	MC8 (at East Fork MC)	1.41	13.00	12.69	11.65	8.56	8.74	9.27	19.63	18.41	14.50
2	MC8 (at East Fork MC)	1.22	13.07	12.75	11.69	8.57	8.75	9.28	19.79	18.55	14.57
2	MC8 (at East Fork MC)	1.03	13.14	12.81	11.72	8.58	8.76	9.29	19.94	18.67	14.64
2	MC8 (at East Fork MC)	0.84	13.20	12.87	11.75	8.58	8.76	9.30	20.08	18.80	14.70
2	MC8 (at East Fork MC)	0.65	13.26	12.92	11.78	8.59	8.77	9.32	20.21	18.92	14.76
2	MC8 (at East Fork MC)	0.46	13.33	12.98	11.81	8.60	8.78	9.33	20.34	19.03	14.82
2	MC10	0.27	13.34	12.99	11.82	8.59	8.78	9.33	20.33	19.01	14.82
2	MC10	0.09	13.35	13.00	11.83	8.59	8.78	9.34	20.31	19.00	14.83
2	Terminus	0.00	13.35	13.00	11.83	8.59	8.78	9.34	20.31	19.00	14.83
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.27	9.27	7.32	7.34	7.40	12.00	11.93	11.70
3	MC Trib 2 Headwater	1.08	9.82	9.82	9.82	8.18	8.22	8.34	12.34	12.22	11.83

Cloud Cover Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	50%	100%	Calibration	50%	100%	Calibration	50%	100%
3	MC Trib 2 Headwater	0.89	10.16	10.17	10.17	8.67	8.72	8.87	12.61	12.45	11.94
3	MC Trib 2 Headwater	0.70	10.40	10.41	10.41	8.98	9.04	9.22	12.87	12.63	12.03
3	MC3	0.50	10.53	10.54	10.57	9.20	9.27	9.47	12.80	12.61	12.05
3	MC3	0.30	10.62	10.64	10.69	9.35	9.42	9.65	12.78	12.61	12.08
3	MC3	0.10	10.68	10.71	10.78	9.46	9.54	9.77	12.77	12.60	12.10
3	Terminus	0.00	10.68	10.71	10.78	9.46	9.54	9.77	12.77	12.60	12.10
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.62	8.66	6.30	6.31	6.35	11.44	11.45	11.48
4	MC Trib 3 Headwater	1.31	8.85	8.88	8.95	6.85	6.87	6.95	11.41	11.43	11.50
4	MC Trib 3 Headwater	1.12	9.05	9.09	9.19	7.28	7.32	7.44	11.39	11.42	11.51
4	MC Trib 3 Headwater	0.93	9.21	9.26	9.39	7.62	7.67	7.81	11.38	11.42	11.53
4	MC5	0.73	9.34	9.39	9.55	7.86	7.92	8.09	11.34	11.39	11.53
4	MC5	0.52	9.45	9.51	9.69	8.06	8.13	8.31	11.30	11.36	11.54
4	MC5	0.31	9.54	9.60	9.81	8.22	8.29	8.50	11.27	11.34	11.54
4	MC5	0.10	9.61	9.69	9.91	8.36	8.43	8.66	11.24	11.32	11.54
4	Terminus	0.00	9.61	9.69	9.91	8.36	8.43	8.66	11.24	11.32	11.54
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.66	8.61	6.22	6.21	6.18	11.85	11.80	11.63
5	East Fork MC Headwater	4.11	9.00	8.97	8.88	6.66	6.67	6.68	12.16	12.06	11.75
5	East Fork MC Headwater	3.92	9.28	9.24	9.12	7.01	7.03	7.08	12.43	12.29	11.86
5	East Fork MC Headwater	3.72	9.53	9.48	9.33	7.30	7.33	7.40	12.68	12.49	11.95
5	East Fork MC Headwater	3.52	9.75	9.69	9.51	7.54	7.57	7.67	12.92	12.69	12.04
5	East Fork MC Headwater	3.33	9.94	9.88	9.67	7.74	7.78	7.89	13.13	12.87	12.12
5	East Fork MC Headwater	3.13	10.12	10.05	9.81	7.92	7.96	8.09	13.33	13.04	12.19
5	East Fork MC Headwater	2.93	10.27	10.20	9.94	8.07	8.12	8.26	13.51	13.19	12.25
5	East Fork MC Headwater	2.73	10.41	10.33	10.06	8.21	8.26	8.41	13.68	13.34	12.30
5	East Fork MC Headwater	2.54	10.54	10.45	10.16	8.32	8.38	8.55	13.84	13.47	12.36
5	East Fork MC Headwater	2.34	10.66	10.57	10.25	8.43	8.49	8.66	13.99	13.59	12.40
5	East Fork MC Headwater	2.14	10.77	10.67	10.34	8.52	8.59	8.77	14.13	13.71	12.45
5	East Fork MC Headwater	1.95	10.86	10.76	10.42	8.61	8.67	8.87	14.26	13.82	12.49
5	East Fork MC Headwater	1.75	10.96	10.85	10.49	8.68	8.75	8.95	14.38	13.92	12.53
5	MC9	1.55	11.10	10.98	10.58	8.70	8.78	9.00	14.80	14.21	12.61
5	MC9	1.34	11.23	11.10	10.66	8.71	8.80	9.05	15.19	14.54	12.68
5	MC9	1.13	11.36	11.21	10.74	8.72	8.81	9.09	15.54	14.83	12.75
5	MC9	0.93	11.47	11.31	10.80	8.73	8.83	9.12	15.85	15.10	12.82
5	MC9	0.72	11.57	11.41	10.87	8.74	8.84	9.16	16.13	15.34	12.91
5	MC9	0.52	11.66	11.49	10.92	8.74	8.85	9.18	16.38	15.55	13.00
5	MC9	0.31	11.75	11.57	10.97	8.74	8.86	9.21	16.62	15.75	13.09
5	MC9	0.10	11.83	11.64	11.02	8.75	8.87	9.23	16.83	15.93	13.17
5	Terminus	0.00	11.83	11.64	11.02	8.75	8.87	9.23	16.83	15.93	13.17
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.27	10.32	8.84	8.90	9.07	12.20	12.14	11.95
6	Garnet Creek Headwater	1.51	10.70	10.73	10.80	9.42	9.50	9.73	12.45	12.37	12.12
6	Garnet Creek Headwater	1.29	10.88	10.91	11.00	9.59	9.69	9.96	12.58	12.50	12.22

Cloud Cover Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	50%	100%	Calibration	50%	100%	Calibration	50%	100%
6	Garnet Creek Headwater	1.07	10.96	11.00	11.09	9.65	9.75	10.05	12.67	12.58	12.28
6	Garnet Creek Headwater	0.85	11.01	11.05	11.15	9.65	9.76	10.09	12.74	12.65	12.32
6	GC1	0.65	11.10	11.13	11.21	9.65	9.76	10.11	12.87	12.76	12.38
6	GC1	0.46	11.17	11.19	11.24	9.64	9.76	10.12	12.99	12.86	12.43
6	GC1	0.28	11.22	11.24	11.27	9.62	9.74	10.11	13.09	12.94	12.47
6	GC1	0.09	11.25	11.27	11.29	9.59	9.72	10.10	13.23	13.02	12.51
6	Terminus	0.00	11.25	11.27	11.29	9.59	9.72	10.10	13.23	13.02	12.51
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.43	8.47	5.97	5.99	6.03	11.39	11.40	11.45
7	Fiddle Creek Headwater	2.53	8.52	8.55	8.64	6.30	6.33	6.41	11.31	11.34	11.43
7	Fiddle Creek Headwater	2.36	8.62	8.66	8.78	6.58	6.62	6.75	11.25	11.29	11.42
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.73	8.87	6.94	6.99	7.14	11.02	11.06	11.19
7	FC1 (at Fiddle Creek Trib	2.02	8.76	8.81	8.98	7.09	7.15	7.32	11.03	11.08	11.21
7	FC2	1.84	8.85	8.91	9.10	7.25	7.31	7.52	11.00	11.06	11.22
7	FC2	1.65	8.93	9.00	9.21	7.38	7.45	7.68	10.97	11.04	11.24
7	FC2	1.46	9.00	9.08	9.31	7.49	7.57	7.83	10.95	11.02	11.25
7	FC2	1.26	9.06	9.15	9.40	7.58	7.68	7.96	10.93	11.01	11.26
7	FC2	1.07	9.12	9.21	9.48	7.67	7.77	8.07	10.91	10.99	11.26
7	FC2	0.87	9.17	9.27	9.56	7.75	7.85	8.18	10.89	10.98	11.26
7	FC2	0.68	9.21	9.32	9.62	7.81	7.93	8.27	10.87	10.97	11.27
7	FC2	0.49	9.25	9.36	9.69	7.88	8.00	8.36	10.85	10.95	11.26
7	FC2	0.29	9.29	9.40	9.74	7.93	8.06	8.43	10.83	10.94	11.26
7	FC2	0.10	9.32	9.44	9.79	7.98	8.11	8.50	10.82	10.92	11.26
7	Terminus	0.00	9.32	9.44	9.79	7.98	8.11	8.50	10.82	10.92	11.26
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	10.08	10.20	8.75	8.80	8.97	11.64	11.67	11.74
8	Midnight Creek Headwater	2.69	10.47	10.53	10.68	9.37	9.44	9.67	11.71	11.75	11.85
8	Midnight Creek Headwater	2.49	10.64	10.70	10.89	9.57	9.66	9.93	11.75	11.79	11.91
8	Midnight Creek Headwater	2.29	10.71	10.78	10.99	9.64	9.74	10.04	11.78	11.82	11.95
8	Midnight Creek Headwater	2.09	10.75	10.82	11.04	9.65	9.76	10.08	11.80	11.85	11.98
8	Midnight Creek Headwater	1.89	10.76	10.84	11.08	9.64	9.76	10.10	11.83	11.87	12.00
8	Midnight Creek Headwater	1.69	10.76	10.85	11.09	9.62	9.74	10.10	11.86	11.89	12.02
8	Midnight Creek Headwater	1.50	10.75	10.84	11.10	9.58	9.71	10.09	11.89	11.90	12.04
8	Midnight Creek Headwater	1.30	10.74	10.84	11.11	9.55	9.68	10.07	11.90	11.92	12.05
8	Midnight Creek Headwater	1.10	10.73	10.83	11.10	9.51	9.64	10.05	11.91	11.93	12.06
8	Midnight Creek Headwater	0.90	10.72	10.81	11.10	9.47	9.61	10.03	11.91	11.94	12.07
8	Midnight Creek Headwater	0.70	10.70	10.80	11.10	9.43	9.58	10.01	11.91	11.95	12.08
8	Midnight Creek Headwater	0.50	10.68	10.79	11.09	9.40	9.54	9.99	11.92	11.95	12.09
8	Midnight Creek Headwater	0.30	10.67	10.77	11.08	9.36	9.51	9.97	11.92	11.96	12.09
8	Midnight Creek Headwater	0.10	10.65	10.76	11.08	9.32	9.48	9.94	11.92	11.96	12.10
8	Terminus	0.00	10.65	10.76	11.08	9.32	9.48	9.94	11.92	11.96	12.10

Diffuse Temperature Input				
		Diffuse Temperature (dec C)		
Reach	Reach Label	Calibration	+ 2 deg C	- 2 deg C
Reach 1	EFSFSR	11.90	13.90	9.90
Reach 2	EFSFSR	11.90	13.90	9.90
Reach 3	EFSFSR Trib 4	11.90	13.90	9.90
Reach 4	EFSFSR	11.90	13.90	9.90
Reach 5	EFSFSR	11.90	13.90	9.90
Reach 6	EFSFSR	13.90	15.90	11.90
Reach 7	Meadow Creek	11.90	13.90	9.90
Reach 8	Meadow Creek	11.90	13.90	9.90
Reach 9	Meadow Creek Trib 2	11.90	13.90	9.90
Reach 10	Meadow Creek Trib 2	11.90	13.90	9.90
Reach 11	Meadow Creek	11.90	13.90	9.90
Reach 12	Meadow Creek Trib 3	11.90	13.90	9.90
Reach 13	Meadow Creek Trib 3	11.90	13.90	9.90
Reach 14	Meadow Creek	13.90	15.90	11.90
Reach 15	Meadow Creek	13.90	15.90	11.90
Reach 16	Meadow Creek	13.90	15.90	11.90
Reach 17	East Fork Meadow Creek	11.90	13.90	9.90
Reach 18	East Fork Meadow Creek	11.90	13.90	9.90
Reach 19	Meadow Creek	13.90	15.90	11.90
Reach 20	Meadow Creek	13.90	15.90	11.90
Reach 21	EFSFSR	13.90	15.90	11.90
Reach 22	Garnet Creek	11.90	13.90	9.90
Reach 23	Garnet Creek	11.90	13.90	9.90
Reach 24	EFSFSR	11.90	13.90	9.90
Reach 25	Fiddle Creek	11.90	13.90	9.90
Reach 26	Fiddle Creek	11.90	13.90	9.90
Reach 27	Fiddle Creek	11.90	13.90	9.90
Reach 28	EFSFSR	11.90	13.90	9.90
Reach 29	EFSFSR	11.90	13.90	9.90
Reach 30	Midnight Creek	11.90	13.90	9.90
Reach 31	EFSFSR	11.90	13.90	9.90

Diffuse Temperature Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+2	-2	Calibration	+2	-2	Calibration	+2	-2
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.80	9.72	6.82	6.86	6.78	13.54	13.58	13.50
0	EFSFSR Headwater	7.26	9.76	9.84	9.68	6.96	7.04	6.88	13.44	13.52	13.36
0	EFSFSR Headwater	7.09	9.76	9.88	9.65	7.09	7.21	6.98	13.35	13.47	13.24
0	EFSFSR1	6.90	9.86	10.02	9.70	7.32	7.48	7.16	13.51	13.66	13.35
0	EFSFSR1	6.69	9.96	10.16	9.76	7.41	7.61	7.20	13.65	13.84	13.45
0	EFSFSR2	6.47	9.69	9.93	9.45	7.17	7.41	6.92	13.10	13.33	12.87
0	EFSFSR2	6.25	9.72	9.98	9.46	7.19	7.46	6.93	13.03	13.29	12.78
0	EFSFSR2	6.02	9.75	10.04	9.47	7.22	7.50	6.93	12.98	13.25	12.71
0	EFSFSR3	5.80	9.76	10.07	9.46	7.24	7.55	6.93	12.92	13.21	12.63
0	EFSFSR3	5.59	9.77	10.10	9.45	7.26	7.59	6.93	12.86	13.16	12.55
0	EFSFSR3	5.37	9.78	10.13	9.44	7.28	7.63	6.94	12.80	13.13	12.48
0	EFSFSR3	5.16	9.79	10.15	9.43	7.30	7.67	6.94	12.75	13.09	12.41
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	10.04	9.35	7.42	7.77	7.06	12.38	12.70	12.05
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	10.07	9.36	7.45	7.81	7.08	12.36	12.70	12.02
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	10.10	9.36	7.47	7.85	7.09	12.34	12.70	11.99
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	10.13	9.37	7.50	7.89	7.11	12.33	12.69	11.96
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	10.16	9.37	7.53	7.93	7.12	12.31	12.68	11.93
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	10.19	9.38	7.55	7.97	7.13	12.29	12.68	11.90
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	10.22	9.38	7.57	8.00	7.15	12.27	12.67	11.87
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	10.24	9.39	7.60	8.04	7.16	12.25	12.66	11.85
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	10.27	9.39	7.62	8.07	7.17	12.23	12.65	11.82
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	10.29	9.40	7.64	8.10	7.18	12.21	12.63	11.79
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	12.31	10.94	8.07	8.79	7.35	16.15	16.76	15.55
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	12.38	11.03	8.04	8.76	7.32	16.36	16.96	15.75
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	12.46	11.12	8.02	8.73	7.30	16.56	17.15	15.96
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	12.48	11.09	8.06	8.80	7.32	16.47	17.09	15.85
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	12.49	11.10	8.06	8.79	7.32	16.49	17.10	15.86
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	12.50	11.11	8.05	8.79	7.31	16.50	17.12	15.88
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	12.51	11.12	8.05	8.78	7.31	16.52	17.14	15.89
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	12.53	11.14	8.05	8.78	7.31	16.54	17.16	15.91
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	12.54	11.15	8.04	8.78	7.30	16.56	17.18	15.93
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	12.55	11.16	8.04	8.78	7.30	16.58	17.20	15.96
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	12.56	11.17	8.04	8.78	7.30	16.61	17.23	15.98
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	12.57	11.18	8.04	8.78	7.30	16.64	17.26	16.01
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	12.38	10.98	8.03	8.77	7.29	16.13	16.76	15.50
0	EFSFSR8	0.39	11.71	12.40	11.01	8.03	8.77	7.29	16.21	16.84	15.57
0	EFSFSR8	0.21	11.73	12.43	11.03	8.03	8.77	7.29	16.28	16.91	15.65
0	EFSFSR9 (at Midnight Cree	0.06	11.71	12.44	10.98	8.09	8.86	7.32	16.16	16.81	15.50
0	Terminus	0.00	11.71	12.44	10.98	8.09	8.86	7.32	16.16	16.81	15.50
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.67	8.47	6.07	6.16	5.97	11.75	11.85	11.66
1	EFSRSR Trib 4 Headwater	0.32	8.81	9.00	8.63	6.37	6.56	6.19	11.98	12.16	11.80
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.29	8.77	6.59	6.85	6.33	12.20	12.45	11.95

Diffuse Temperature Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+2	-2	Calibration	+2	-2	Calibration	+2	-2
1	Terminus	0.00	9.03	9.29	8.77	6.59	6.85	6.33	12.20	12.45	11.95
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.33	10.73	8.47	8.77	8.17	14.34	14.63	14.05
2	Meadow Creek Headwater	6.96	11.15	11.66	10.64	8.86	9.37	8.34	14.19	14.69	13.69
2	Meadow Creek Headwater	6.76	11.24	11.91	10.57	9.10	9.78	8.42	14.10	14.75	13.45
2	Meadow Creek Headwater	6.56	11.31	12.09	10.52	9.27	10.06	8.47	14.05	14.80	13.29
2	Meadow Creek Headwater	6.36	11.36	12.24	10.48	9.39	10.28	8.49	14.02	14.86	13.17
2	Meadow Creek Headwater	6.16	11.41	12.36	10.46	9.47	10.44	8.50	14.01	14.92	13.10
2	Meadow Creek Headwater	5.96	11.44	12.45	10.43	9.54	10.57	8.51	14.02	14.99	13.06
2	MC1	5.76	11.50	12.56	10.44	9.58	10.66	8.50	14.08	15.08	13.07
2	MC1	5.57	11.55	12.64	10.45	9.62	10.74	8.50	14.14	15.18	13.09
2	MC1	5.38	11.59	12.72	10.45	9.65	10.80	8.49	14.19	15.26	13.11
2	MC1	5.18	11.62	12.78	10.46	9.66	10.85	8.48	14.24	15.33	13.14
2	MC1	4.99	11.65	12.83	10.47	9.68	10.89	8.46	14.28	15.40	13.17
2	MC1	4.80	11.68	12.88	10.47	9.69	10.92	8.45	14.33	15.45	13.19
2	MC2 (at MC Trib 2)	4.62	11.30	12.53	10.07	9.59	10.86	8.33	13.76	14.92	12.60
2	MC2 (at MC Trib 2)	4.45	11.27	12.51	10.03	9.58	10.85	8.31	13.73	14.89	12.57
2	MC4 (at MC Trib 3)	4.27	10.74	11.85	9.63	9.17	10.30	8.04	12.82	13.86	11.77
2	MC4 (at MC Trib 3)	4.09	10.80	11.91	9.69	9.19	10.32	8.05	12.94	13.98	11.89
2	MC4 (at MC Trib 3)	3.91	10.86	11.97	9.75	9.21	10.34	8.07	13.05	14.09	12.00
2	MC4 (at MC Trib 3)	3.73	10.92	12.03	9.80	9.22	10.36	8.08	13.16	14.20	12.11
2	MC4 (at MC Trib 3)	3.55	10.97	12.08	9.85	9.24	10.38	8.10	13.26	14.30	12.21
2	MC6	3.36	11.29	12.38	10.19	9.16	10.28	8.03	14.19	15.20	13.17
2	MC6	3.15	11.59	12.66	10.51	9.07	10.17	7.96	15.14	16.13	14.14
2	MC6	2.95	11.88	12.93	10.82	8.98	10.07	7.89	16.02	16.99	15.05
2	MC6	2.75	12.15	13.18	11.11	8.90	9.97	7.82	16.85	17.78	15.90
2	MC6	2.54	12.41	13.42	11.39	8.82	9.88	7.76	17.61	18.52	16.69
2	MC7	2.35	12.60	13.60	11.60	8.75	9.79	7.70	18.25	19.14	17.35
2	MC7	2.16	12.78	13.76	11.80	8.68	9.71	7.64	18.84	19.71	17.97
2	MC7	1.98	12.96	13.92	11.99	8.62	9.63	7.59	19.40	20.24	18.54
2	MC7	1.79	13.13	14.07	12.17	8.56	9.56	7.54	19.91	20.74	19.07
2	MC7	1.60	13.29	14.22	12.35	8.50	9.49	7.50	20.39	21.19	19.57
2	MC8 (at East Fork MC)	1.41	13.00	13.96	12.03	8.56	9.58	7.54	19.63	20.48	18.78
2	MC8 (at East Fork MC)	1.22	13.07	14.03	12.10	8.57	9.59	7.55	19.79	20.63	18.94
2	MC8 (at East Fork MC)	1.03	13.14	14.09	12.17	8.58	9.59	7.55	19.94	20.78	19.09
2	MC8 (at East Fork MC)	0.84	13.20	14.16	12.24	8.58	9.60	7.56	20.08	20.91	19.23
2	MC8 (at East Fork MC)	0.65	13.26	14.22	12.30	8.59	9.60	7.57	20.21	21.05	19.37
2	MC8 (at East Fork MC)	0.46	13.33	14.28	12.37	8.60	9.61	7.58	20.34	21.17	19.50
2	MC10	0.27	13.34	14.29	12.38	8.59	9.60	7.58	20.33	21.16	19.49
2	MC10	0.09	13.35	14.29	12.39	8.59	9.60	7.58	20.31	21.13	19.47
2	Terminus	0.00	13.35	14.29	12.39	8.59	9.60	7.58	20.31	21.13	19.47
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.77	8.76	7.32	7.83	6.81	12.00	12.50	11.51
3	MC Trib 2 Headwater	1.08	9.82	10.60	9.03	8.18	8.98	7.39	12.34	13.11	11.58

Diffuse Temperature Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+2	-2	Calibration	+2	-2	Calibration	+2	-2
3	MC Trib 2 Headwater	0.89	10.16	11.12	9.20	8.67	9.64	7.69	12.61	13.54	11.68
3	MC Trib 2 Headwater	0.70	10.40	11.48	9.32	8.98	10.07	7.88	12.87	13.90	11.83
3	MC3	0.50	10.53	11.69	9.36	9.20	10.38	8.01	12.80	13.92	11.68
3	MC3	0.30	10.62	11.85	9.38	9.35	10.60	8.10	12.78	13.95	11.60
3	MC3	0.10	10.68	11.96	9.40	9.46	10.76	8.16	12.77	13.98	11.55
3	Terminus	0.00	10.68	11.96	9.40	9.46	10.76	8.16	12.77	13.98	11.55
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.80	8.40	6.30	6.50	6.10	11.44	11.63	11.24
4	MC Trib 3 Headwater	1.31	8.85	9.21	8.49	6.85	7.21	6.49	11.41	11.76	11.06
4	MC Trib 3 Headwater	1.12	9.05	9.53	8.56	7.28	7.77	6.79	11.39	11.87	10.91
4	MC Trib 3 Headwater	0.93	9.21	9.80	8.62	7.62	8.22	7.02	11.38	11.96	10.80
4	MC5	0.73	9.34	10.02	8.66	7.86	8.55	7.18	11.34	12.00	10.67
4	MC5	0.52	9.45	10.20	8.70	8.06	8.82	7.30	11.30	12.04	10.57
4	MC5	0.31	9.54	10.35	8.72	8.22	9.05	7.40	11.27	12.06	10.47
4	MC5	0.10	9.61	10.48	8.75	8.36	9.24	7.48	11.24	12.09	10.39
4	Terminus	0.00	9.61	10.48	8.75	8.36	9.24	7.48	11.24	12.09	10.39
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.82	8.52	6.22	6.37	6.07	11.85	12.00	11.71
5	East Fork MC Headwater	4.11	9.00	9.27	8.73	6.66	6.93	6.39	12.16	12.42	11.89
5	East Fork MC Headwater	3.92	9.28	9.66	8.90	7.01	7.39	6.63	12.43	12.80	12.06
5	East Fork MC Headwater	3.72	9.53	10.00	9.06	7.30	7.78	6.83	12.68	13.15	12.22
5	East Fork MC Headwater	3.52	9.75	10.30	9.20	7.54	8.09	6.98	12.92	13.46	12.38
5	East Fork MC Headwater	3.33	9.94	10.56	9.32	7.74	8.37	7.11	13.13	13.74	12.52
5	East Fork MC Headwater	3.13	10.12	10.80	9.43	7.92	8.61	7.23	13.33	13.99	12.66
5	East Fork MC Headwater	2.93	10.27	11.01	9.53	8.07	8.82	7.32	13.51	14.23	12.80
5	East Fork MC Headwater	2.73	10.41	11.20	9.63	8.21	9.00	7.41	13.68	14.45	12.92
5	East Fork MC Headwater	2.54	10.54	11.37	9.71	8.32	9.17	7.48	13.84	14.65	13.04
5	East Fork MC Headwater	2.34	10.66	11.53	9.79	8.43	9.31	7.55	13.99	14.83	13.15
5	East Fork MC Headwater	2.14	10.77	11.67	9.86	8.52	9.44	7.60	14.13	15.00	13.25
5	East Fork MC Headwater	1.95	10.86	11.80	9.92	8.61	9.56	7.65	14.26	15.16	13.35
5	East Fork MC Headwater	1.75	10.96	11.92	9.98	8.68	9.67	7.70	14.38	15.31	13.45
5	MC9	1.55	11.10	12.09	10.11	8.70	9.70	7.69	14.80	15.74	13.86
5	MC9	1.34	11.23	12.23	10.23	8.71	9.73	7.69	15.19	16.14	14.24
5	MC9	1.13	11.36	12.37	10.34	8.72	9.76	7.68	15.54	16.49	14.58
5	MC9	0.93	11.47	12.49	10.44	8.73	9.78	7.68	15.85	16.80	14.89
5	MC9	0.72	11.57	12.60	10.53	8.74	9.80	7.67	16.13	17.09	15.16
5	MC9	0.52	11.66	12.70	10.62	8.74	9.82	7.66	16.38	17.35	15.41
5	MC9	0.31	11.75	12.80	10.69	8.74	9.83	7.66	16.62	17.58	15.64
5	MC9	0.10	11.83	12.88	10.77	8.75	9.84	7.65	16.83	17.80	15.85
5	Terminus	0.00	11.83	12.88	10.77	8.75	9.84	7.65	16.83	17.80	15.85
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	11.29	9.20	8.84	9.90	7.77	12.20	13.21	11.19
6	Garnet Creek Headwater	1.51	10.70	11.98	9.41	9.42	10.72	8.10	12.45	13.67	11.22
6	Garnet Creek Headwater	1.29	10.88	12.25	9.50	9.59	10.99	8.18	12.58	13.88	11.28

Diffuse Temperature Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	+2	-2	Calibration	+2	-2	Calibration	+2	-2
6	Garnet Creek Headwater	1.07	10.96	12.38	9.54	9.65	11.09	8.19	12.67	14.00	11.34
6	Garnet Creek Headwater	0.85	11.01	12.44	9.57	9.65	11.11	8.17	12.74	14.09	11.39
6	GC1	0.65	11.10	12.54	9.65	9.65	11.13	8.16	12.87	14.22	11.52
6	GC1	0.46	11.17	12.61	9.71	9.64	11.12	8.14	12.99	14.33	11.63
6	GC1	0.28	11.22	12.66	9.76	9.62	11.10	8.12	13.09	14.51	11.74
6	GC1	0.09	11.25	12.70	9.80	9.59	11.08	8.09	13.23	14.66	11.83
6	Terminus	0.00	11.25	12.70	9.80	9.59	11.08	8.09	13.23	14.66	11.83
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.51	8.31	5.97	6.07	5.87	11.39	11.48	11.29
7	Fiddle Creek Headwater	2.53	8.52	8.70	8.34	6.30	6.48	6.11	11.31	11.49	11.13
7	Fiddle Creek Headwater	2.36	8.62	8.88	8.36	6.58	6.84	6.32	11.25	11.50	10.99
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.98	8.38	6.94	7.24	6.63	11.02	11.31	10.72
7	FC1 (at Fiddle Creek Trib	2.02	8.76	9.12	8.40	7.09	7.45	6.73	11.03	11.38	10.68
7	FC2	1.84	8.85	9.27	8.43	7.25	7.67	6.82	11.00	11.41	10.59
7	FC2	1.65	8.93	9.40	8.45	7.38	7.86	6.89	10.97	11.44	10.51
7	FC2	1.46	9.00	9.52	8.47	7.49	8.02	6.95	10.95	11.46	10.43
7	FC2	1.26	9.06	9.63	8.49	7.58	8.17	7.00	10.93	11.48	10.37
7	FC2	1.07	9.12	9.73	8.51	7.67	8.29	7.05	10.91	11.50	10.31
7	FC2	0.87	9.17	9.81	8.52	7.75	8.41	7.09	10.89	11.51	10.26
7	FC2	0.68	9.21	9.89	8.53	7.81	8.51	7.12	10.87	11.53	10.21
7	FC2	0.49	9.25	9.96	8.54	7.88	8.60	7.15	10.85	11.53	10.16
7	FC2	0.29	9.29	10.03	8.55	7.93	8.68	7.18	10.83	11.54	10.12
7	FC2	0.10	9.32	10.08	8.56	7.98	8.76	7.20	10.82	11.55	10.08
7	Terminus	0.00	9.32	10.08	8.56	7.98	8.76	7.20	10.82	11.55	10.08
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	11.06	9.03	8.75	9.77	7.72	11.64	12.61	10.67
8	Midnight Creek Headwater	2.69	10.47	11.73	9.21	9.37	10.65	8.08	11.71	12.91	10.50
8	Midnight Creek Headwater	2.49	10.64	12.00	9.28	9.57	10.95	8.18	11.75	13.04	10.46
8	Midnight Creek Headwater	2.29	10.71	12.12	9.30	9.64	11.07	8.20	11.78	13.10	10.45
8	Midnight Creek Headwater	2.09	10.75	12.18	9.31	9.65	11.11	8.19	11.80	13.15	10.46
8	Midnight Creek Headwater	1.89	10.76	12.20	9.31	9.64	11.12	8.16	11.83	13.23	10.48
8	Midnight Creek Headwater	1.69	10.76	12.20	9.31	9.62	11.10	8.13	11.86	13.28	10.50
8	Midnight Creek Headwater	1.50	10.75	12.20	9.30	9.58	11.06	8.09	11.89	13.31	10.52
8	Midnight Creek Headwater	1.30	10.74	12.18	9.29	9.55	11.03	8.06	11.90	13.33	10.53
8	Midnight Creek Headwater	1.10	10.73	12.16	9.28	9.51	10.99	8.02	11.91	13.33	10.55
8	Midnight Creek Headwater	0.90	10.72	12.14	9.27	9.47	10.94	7.99	11.91	13.33	10.57
8	Midnight Creek Headwater	0.70	10.70	12.12	9.26	9.43	10.90	7.95	11.91	13.32	10.58
8	Midnight Creek Headwater	0.50	10.68	12.10	9.25	9.40	10.86	7.92	11.92	13.31	10.60
8	Midnight Creek Headwater	0.30	10.67	12.08	9.24	9.36	10.82	7.89	11.92	13.29	10.61
8	Midnight Creek Headwater	0.10	10.65	12.05	9.23	9.32	10.78	7.86	11.92	13.26	10.62
8	Terminus	0.00	10.65	12.05	9.23	9.32	10.78	7.86	11.92	13.26	10.62

Diffuse Flow Input				
		Diffuse Flow (m3/s)		
Reach	Reach Label	Calibration	- 50%	+ 50%
Reach 1	EFSFSR	0.0060	0.0030	0.0090
Reach 2	EFSFSR	0.0050	0.0025	0.0075
Reach 3	EFSFSR Trib 4	0.0070	0.0035	0.0105
Reach 4	EFSFSR	0.0070	0.0035	0.0105
Reach 5	EFSFSR	0.0100	0.0050	0.0150
Reach 6	EFSFSR	0.0210	0.0105	0.0315
Reach 7	Meadow Creek	0.0180	0.0090	0.0270
Reach 8	Meadow Creek	0.0150	0.0075	0.0225
Reach 9	Meadow Creek Trib 2	0.0100	0.0050	0.0150
Reach 10	Meadow Creek Trib 2	0.0080	0.0040	0.0120
Reach 11	Meadow Creek	0.0040	0.0020	0.0060
Reach 12	Meadow Creek Trib 3	0.0100	0.0050	0.0150
Reach 13	Meadow Creek Trib 3	0.0100	0.0050	0.0150
Reach 14	Meadow Creek	0.0090	0.0045	0.0135
Reach 15	Meadow Creek	0.0070	0.0035	0.0105
Reach 16	Meadow Creek	0.0060	0.0030	0.0090
Reach 17	East Fork Meadow Creek	0.0180	0.0090	0.0270
Reach 18	East Fork Meadow Creek	0.0110	0.0055	0.0165
Reach 19	Meadow Creek	0.0080	0.0040	0.0120
Reach 20	Meadow Creek	0.0020	0.0010	0.0030
Reach 21	EFSFSR	0.0040	0.0020	0.0060
Reach 22	Garnet Creek	0.0070	0.0035	0.0105
Reach 23	Garnet Creek	0.0050	0.0025	0.0075
Reach 24	EFSFSR	0.0110	0.0055	0.0165
Reach 25	Fiddle Creek	0.0030	0.0015	0.0045
Reach 26	Fiddle Creek	0.0020	0.0010	0.0030
Reach 27	Fiddle Creek	0.0120	0.0060	0.0180
Reach 28	EFSFSR	0.0010	0.0005	0.0015
Reach 29	EFSFSR	0.0020	0.0010	0.0030
Reach 30	Midnight Creek	0.0190	0.0095	0.0285
Reach 31	EFSFSR	0.0010	0.0005	0.0015

Diffuse Flow Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.74	9.77	6.82	6.83	6.81	13.54	13.50	13.55
0	EFSFSR Headwater	7.26	9.76	9.72	9.78	6.96	6.99	6.95	13.44	13.38	13.47
0	EFSFSR Headwater	7.09	9.76	9.71	9.79	7.09	7.12	7.08	13.35	13.27	13.39
0	EFSFSR1	6.90	9.86	9.83	9.88	7.32	7.25	7.29	13.51	13.51	13.50
0	EFSFSR1	6.69	9.96	9.95	9.96	7.41	7.28	7.45	13.65	13.80	13.61
0	EFSFSR2	6.47	9.69	9.71	9.67	7.17	7.02	7.22	13.10	13.29	13.02
0	EFSFSR2	6.25	9.72	9.75	9.71	7.19	7.02	7.26	13.03	13.20	12.97
0	EFSFSR2	6.02	9.75	9.78	9.74	7.22	7.01	7.30	12.98	13.13	12.93
0	EFSFSR3	5.80	9.76	9.78	9.76	7.24	7.02	7.33	12.92	13.04	12.88
0	EFSFSR3	5.59	9.77	9.78	9.77	7.26	7.02	7.37	12.86	12.96	12.83
0	EFSFSR3	5.37	9.78	9.77	9.79	7.28	7.02	7.40	12.80	12.88	12.78
0	EFSFSR3	5.16	9.79	9.77	9.80	7.30	7.03	7.43	12.75	12.81	12.73
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	9.67	9.71	7.42	7.14	7.54	12.38	12.44	12.36
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	9.68	9.73	7.45	7.15	7.57	12.36	12.41	12.35
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	9.68	9.75	7.47	7.17	7.61	12.34	12.37	12.34
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	9.69	9.78	7.50	7.18	7.64	12.33	12.34	12.33
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	9.70	9.80	7.53	7.19	7.68	12.31	12.31	12.32
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	9.70	9.82	7.55	7.21	7.71	12.29	12.27	12.31
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	9.71	9.84	7.57	7.22	7.74	12.27	12.24	12.30
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	9.71	9.86	7.60	7.23	7.77	12.25	12.20	12.28
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	9.72	9.88	7.62	7.24	7.80	12.23	12.17	12.27
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	9.72	9.90	7.64	7.25	7.82	12.21	12.14	12.26
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	11.91	11.48	8.07	7.57	8.34	16.15	17.21	15.56
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	12.02	11.55	8.04	7.54	8.31	16.36	17.46	15.73
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	12.13	11.62	8.02	7.52	8.29	16.56	17.70	15.91
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	12.11	11.62	8.06	7.56	8.34	16.47	17.58	15.83
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	12.12	11.63	8.06	7.55	8.33	16.49	17.59	15.85
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	12.14	11.64	8.05	7.55	8.33	16.50	17.61	15.86
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	12.15	11.65	8.05	7.55	8.32	16.52	17.62	15.88
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	12.16	11.67	8.05	7.55	8.32	16.54	17.64	15.89
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	12.17	11.68	8.04	7.55	8.32	16.56	17.66	15.90
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	12.19	11.69	8.04	7.55	8.32	16.58	17.68	15.92
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	12.20	11.70	8.04	7.55	8.32	16.61	17.70	15.94
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	12.21	11.71	8.04	7.56	8.32	16.64	17.72	15.97
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	11.97	11.53	8.03	7.57	8.30	16.13	17.08	15.53
0	EFSFSR8	0.39	11.71	12.00	11.55	8.03	7.57	8.30	16.21	17.18	15.61
0	EFSFSR8	0.21	11.73	12.04	11.57	8.03	7.57	8.30	16.28	17.28	15.67
0	EFSFSR9 (at Midnight Cree	0.06	11.71	11.99	11.56	8.09	7.63	8.36	16.16	17.13	15.59
0	Terminus	0.00	11.71	11.99	11.56	8.09	7.63	8.36	16.16	17.13	15.59
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.61	8.55	6.07	6.08	6.04	11.75	11.88	11.70
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.89	8.78	6.37	6.34	6.38	11.98	12.23	11.88
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.13	8.98	6.59	6.50	6.62	12.20	12.56	12.05

Diffuse Flow Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%
1	Terminus	0.00	9.03	9.13	8.98	6.59	6.50	6.62	12.20	12.56	12.05
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.03	11.03	8.47	8.43	8.47	14.34	14.43	14.30
2	Meadow Creek Headwater	6.96	11.15	11.15	11.15	8.86	8.75	8.89	14.19	14.35	14.12
2	Meadow Creek Headwater	6.76	11.24	11.24	11.24	9.10	8.93	9.17	14.10	14.33	14.00
2	Meadow Creek Headwater	6.56	11.31	11.31	11.31	9.27	9.04	9.36	14.05	14.34	13.92
2	Meadow Creek Headwater	6.36	11.36	11.36	11.36	9.39	9.12	9.50	14.02	14.40	13.87
2	Meadow Creek Headwater	6.16	11.41	11.40	11.41	9.47	9.17	9.61	14.01	14.49	13.83
2	Meadow Creek Headwater	5.96	11.44	11.43	11.45	9.54	9.20	9.69	14.02	14.57	13.81
2	MC1	5.76	11.50	11.50	11.50	9.58	9.22	9.75	14.08	14.65	13.83
2	MC1	5.57	11.55	11.55	11.54	9.62	9.23	9.80	14.14	14.73	13.86
2	MC1	5.38	11.59	11.60	11.58	9.65	9.23	9.83	14.19	14.80	13.90
2	MC1	5.18	11.62	11.64	11.61	9.66	9.23	9.86	14.24	14.87	13.93
2	MC1	4.99	11.65	11.67	11.64	9.68	9.23	9.89	14.28	14.93	13.97
2	MC1	4.80	11.68	11.70	11.67	9.69	9.22	9.90	14.33	14.99	14.00
2	MC2 (at MC Trib 2)	4.62	11.30	11.26	11.31	9.59	9.15	9.79	13.76	14.27	13.48
2	MC2 (at MC Trib 2)	4.45	11.27	11.21	11.29	9.58	9.12	9.78	13.73	14.22	13.47
2	MC4 (at MC Trib 3)	4.27	10.74	10.65	10.78	9.17	8.77	9.35	12.82	13.09	12.68
2	MC4 (at MC Trib 3)	4.09	10.80	10.72	10.83	9.19	8.77	9.37	12.94	13.25	12.78
2	MC4 (at MC Trib 3)	3.91	10.86	10.79	10.89	9.21	8.78	9.40	13.05	13.40	12.87
2	MC4 (at MC Trib 3)	3.73	10.92	10.85	10.94	9.22	8.78	9.42	13.16	13.54	12.96
2	MC4 (at MC Trib 3)	3.55	10.97	10.91	10.99	9.24	8.79	9.44	13.26	13.68	13.05
2	MC6	3.36	11.29	11.36	11.25	9.16	8.66	9.38	14.19	15.06	13.80
2	MC6	3.15	11.59	11.78	11.50	9.07	8.53	9.31	15.14	16.37	14.54
2	MC6	2.95	11.88	12.17	11.74	8.98	8.41	9.25	16.02	17.54	15.28
2	MC6	2.75	12.15	12.53	11.97	8.90	8.30	9.19	16.85	18.59	15.97
2	MC6	2.54	12.41	12.87	12.18	8.82	8.19	9.13	17.61	19.54	16.62
2	MC7	2.35	12.60	13.12	12.35	8.75	8.10	9.07	18.25	20.31	17.18
2	MC7	2.16	12.78	13.35	12.51	8.68	8.01	9.01	18.84	21.00	17.70
2	MC7	1.98	12.96	13.56	12.66	8.62	7.94	8.96	19.40	21.62	18.19
2	MC7	1.79	13.13	13.76	12.81	8.56	7.87	8.91	19.91	22.17	18.66
2	MC7	1.60	13.29	13.95	12.95	8.50	7.81	8.87	20.39	22.67	19.10
2	MC8 (at East Fork MC)	1.41	13.00	13.62	12.69	8.56	7.93	8.90	19.63	21.75	18.44
2	MC8 (at East Fork MC)	1.22	13.07	13.70	12.75	8.57	7.94	8.90	19.79	21.91	18.59
2	MC8 (at East Fork MC)	1.03	13.14	13.78	12.81	8.58	7.95	8.91	19.94	22.07	18.73
2	MC8 (at East Fork MC)	0.84	13.20	13.85	12.87	8.58	7.96	8.92	20.08	22.21	18.86
2	MC8 (at East Fork MC)	0.65	13.26	13.93	12.93	8.59	7.97	8.92	20.21	22.33	18.99
2	MC8 (at East Fork MC)	0.46	13.33	14.00	12.98	8.60	7.99	8.93	20.34	22.45	19.11
2	MC10	0.27	13.34	14.00	13.00	8.59	7.98	8.93	20.33	22.36	19.12
2	MC10	0.09	13.35	14.00	13.01	8.59	7.99	8.93	20.31	22.27	19.13
2	Terminus	0.00	13.35	14.00	13.01	8.59	7.99	8.93	20.31	22.27	19.13
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.28	9.23	7.32	7.30	7.26	12.00	12.20	11.91
3	MC Trib 2 Headwater	1.08	9.82	9.82	9.77	8.18	8.05	8.17	12.34	12.67	12.18

Diffuse Flow Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%
3	MC Trib 2 Headwater	0.89	10.16	10.16	10.12	8.67	8.47	8.69	12.61	13.09	12.40
3	MC Trib 2 Headwater	0.70	10.40	10.39	10.37	8.98	8.73	9.03	12.87	13.38	12.59
3	MC3	0.50	10.53	10.48	10.51	9.20	8.90	9.28	12.80	13.23	12.57
3	MC3	0.30	10.62	10.54	10.62	9.35	9.02	9.45	12.78	13.16	12.57
3	MC3	0.10	10.68	10.58	10.70	9.46	9.09	9.58	12.77	13.09	12.58
3	Terminus	0.00	10.68	10.58	10.70	9.46	9.09	9.58	12.77	13.09	12.58
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.58	8.61	6.30	6.31	6.29	11.44	11.39	11.45
4	MC Trib 3 Headwater	1.31	8.85	8.80	8.87	6.85	6.86	6.84	11.41	11.34	11.44
4	MC Trib 3 Headwater	1.12	9.05	8.98	9.08	7.28	7.24	7.28	11.39	11.30	11.43
4	MC Trib 3 Headwater	0.93	9.21	9.12	9.25	7.62	7.52	7.64	11.38	11.27	11.42
4	MC5	0.73	9.34	9.23	9.39	7.86	7.72	7.92	11.34	11.20	11.40
4	MC5	0.52	9.45	9.31	9.51	8.06	7.88	8.13	11.30	11.14	11.37
4	MC5	0.31	9.54	9.38	9.60	8.22	8.01	8.31	11.27	11.09	11.35
4	MC5	0.10	9.61	9.44	9.69	8.36	8.11	8.46	11.24	11.04	11.33
4	Terminus	0.00	9.61	9.44	9.69	8.36	8.11	8.46	11.24	11.04	11.33
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.72	8.65	6.22	6.25	6.19	11.85	12.01	11.78
5	East Fork MC Headwater	4.11	9.00	9.10	8.96	6.66	6.67	6.65	12.16	12.46	12.03
5	East Fork MC Headwater	3.92	9.28	9.42	9.22	7.01	7.00	7.01	12.43	12.86	12.25
5	East Fork MC Headwater	3.72	9.53	9.69	9.46	7.30	7.25	7.31	12.68	13.22	12.45
5	East Fork MC Headwater	3.52	9.75	9.94	9.66	7.54	7.46	7.56	12.92	13.55	12.64
5	East Fork MC Headwater	3.33	9.94	10.15	9.85	7.74	7.64	7.77	13.13	13.85	12.81
5	East Fork MC Headwater	3.13	10.12	10.35	10.01	7.92	7.80	7.96	13.33	14.13	12.98
5	East Fork MC Headwater	2.93	10.27	10.52	10.16	8.07	7.93	8.12	13.51	14.38	13.13
5	East Fork MC Headwater	2.73	10.41	10.67	10.30	8.21	8.05	8.27	13.68	14.61	13.27
5	East Fork MC Headwater	2.54	10.54	10.81	10.42	8.32	8.15	8.40	13.84	14.83	13.40
5	East Fork MC Headwater	2.34	10.66	10.94	10.53	8.43	8.23	8.51	13.99	15.04	13.53
5	East Fork MC Headwater	2.14	10.77	11.06	10.63	8.52	8.31	8.61	14.13	15.25	13.64
5	East Fork MC Headwater	1.95	10.86	11.16	10.73	8.61	8.38	8.70	14.26	15.44	13.75
5	East Fork MC Headwater	1.75	10.96	11.26	10.81	8.68	8.44	8.79	14.38	15.62	13.85
5	MC9	1.55	11.10	11.43	10.95	8.70	8.42	8.82	14.80	16.16	14.14
5	MC9	1.34	11.23	11.58	11.07	8.71	8.40	8.85	15.19	16.62	14.48
5	MC9	1.13	11.36	11.72	11.18	8.72	8.38	8.88	15.54	17.03	14.79
5	MC9	0.93	11.47	11.84	11.28	8.73	8.36	8.90	15.85	17.38	15.07
5	MC9	0.72	11.57	11.96	11.38	8.74	8.34	8.92	16.13	17.69	15.32
5	MC9	0.52	11.66	12.06	11.47	8.74	8.32	8.94	16.38	17.96	15.55
5	MC9	0.31	11.75	12.15	11.55	8.74	8.30	8.95	16.62	18.21	15.76
5	MC9	0.10	11.83	12.24	11.62	8.75	8.29	8.96	16.83	18.42	15.96
5	Terminus	0.00	11.83	12.24	11.62	8.75	8.29	8.96	16.83	18.42	15.96
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.18	10.05	8.84	8.57	8.61	12.20	12.38	12.05
6	Garnet Creek Headwater	1.51	10.70	10.59	10.57	9.42	9.01	9.34	12.45	12.67	12.28
6	Garnet Creek Headwater	1.29	10.88	10.74	10.80	9.59	9.11	9.62	12.58	12.83	12.41

Diffuse Flow Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%	Calibration	- 50%	+ 50%
6	Garnet Creek Headwater	1.07	10.96	10.80	10.92	9.65	9.11	9.74	12.67	12.93	12.49
6	Garnet Creek Headwater	0.85	11.01	10.83	10.99	9.65	9.07	9.80	12.74	13.00	12.56
6	GC1	0.65	11.10	10.94	11.09	9.65	9.05	9.83	12.87	13.17	12.67
6	GC1	0.46	11.17	11.02	11.17	9.64	9.02	9.85	12.99	13.32	12.76
6	GC1	0.28	11.22	11.07	11.22	9.62	8.98	9.85	13.09	13.45	12.85
6	GC1	0.09	11.25	11.11	11.26	9.59	8.95	9.84	13.23	13.56	12.94
6	Terminus	0.00	11.25	11.11	11.26	9.59	8.95	9.84	13.23	13.56	12.94
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.39	8.42	5.97	5.99	5.96	11.39	11.33	11.41
7	Fiddle Creek Headwater	2.53	8.52	8.47	8.54	6.30	6.32	6.27	11.31	11.22	11.35
7	Fiddle Creek Headwater	2.36	8.62	8.54	8.64	6.58	6.58	6.55	11.25	11.12	11.30
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.59	8.71	6.94	6.86	6.92	11.02	10.90	11.07
7	FC1 (at Fiddle Creek Trib	2.02	8.76	8.66	8.80	7.09	6.97	7.11	11.03	10.89	11.09
7	FC2	1.84	8.85	8.73	8.89	7.25	7.09	7.29	11.00	10.84	11.08
7	FC2	1.65	8.93	8.80	8.98	7.38	7.18	7.44	10.97	10.80	11.06
7	FC2	1.46	9.00	8.86	9.05	7.49	7.26	7.56	10.95	10.76	11.04
7	FC2	1.26	9.06	8.90	9.12	7.58	7.33	7.68	10.93	10.73	11.02
7	FC2	1.07	9.12	8.95	9.18	7.67	7.39	7.77	10.91	10.71	11.01
7	FC2	0.87	9.17	8.99	9.24	7.75	7.44	7.86	10.89	10.68	10.99
7	FC2	0.68	9.21	9.02	9.29	7.81	7.48	7.94	10.87	10.67	10.98
7	FC2	0.49	9.25	9.05	9.34	7.88	7.52	8.01	10.85	10.71	10.97
7	FC2	0.29	9.29	9.07	9.38	7.93	7.55	8.08	10.83	10.74	10.95
7	FC2	0.10	9.32	9.10	9.42	7.98	7.58	8.14	10.82	10.75	10.93
7	Terminus	0.00	9.32	9.10	9.42	7.98	7.58	8.14	10.82	10.75	10.93
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	9.93	9.87	8.75	8.50	8.50	11.64	11.62	11.61
8	Midnight Creek Headwater	2.69	10.47	10.31	10.36	9.37	8.98	9.26	11.71	11.70	11.67
8	Midnight Creek Headwater	2.49	10.64	10.43	10.59	9.57	9.11	9.57	11.75	11.75	11.71
8	Midnight Creek Headwater	2.29	10.71	10.48	10.70	9.64	9.12	9.72	11.78	11.78	11.73
8	Midnight Creek Headwater	2.09	10.75	10.49	10.77	9.65	9.09	9.78	11.80	11.81	11.75
8	Midnight Creek Headwater	1.89	10.76	10.48	10.80	9.64	9.04	9.81	11.83	11.84	11.77
8	Midnight Creek Headwater	1.69	10.76	10.46	10.83	9.62	8.99	9.82	11.86	11.86	11.79
8	Midnight Creek Headwater	1.50	10.75	10.44	10.84	9.58	8.94	9.82	11.89	11.87	11.80
8	Midnight Creek Headwater	1.30	10.74	10.42	10.84	9.55	8.88	9.80	11.90	11.88	11.82
8	Midnight Creek Headwater	1.10	10.73	10.39	10.84	9.51	8.83	9.78	11.91	11.88	11.84
8	Midnight Creek Headwater	0.90	10.72	10.37	10.83	9.47	8.78	9.76	11.91	11.88	11.86
8	Midnight Creek Headwater	0.70	10.70	10.34	10.83	9.43	8.73	9.74	11.91	11.88	11.87
8	Midnight Creek Headwater	0.50	10.68	10.32	10.82	9.40	8.68	9.71	11.92	11.88	11.88
8	Midnight Creek Headwater	0.30	10.67	10.29	10.81	9.36	8.64	9.69	11.92	11.87	11.88
8	Midnight Creek Headwater	0.10	10.65	10.27	10.80	9.32	8.59	9.66	11.92	11.87	11.89
8	Terminus	0.00	10.65	10.27	10.80	9.32	8.59	9.66	11.92	11.87	11.89

Diffuse Flow Input	
	Sediment Thermal Thickness
Calibration	10 cm
Decrease	5 cm
Increase	15 cm

Sediment Depth Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	5 cm	15 cm	Calibration	5 cm	15 cm	Calibration	5 cm	15 cm
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.76	9.76	6.82	6.81	6.83	13.54	13.58	13.53
0	EFSFSR Headwater	7.26	9.76	9.76	9.76	6.96	6.94	6.99	13.44	13.52	13.42
0	EFSFSR Headwater	7.09	9.76	9.76	9.76	7.09	7.06	7.13	13.35	13.47	13.33
0	EFSFSR1	6.90	9.86	9.86	9.86	7.32	7.27	7.37	13.51	13.67	13.47
0	EFSFSR1	6.69	9.96	9.96	9.96	7.41	7.34	7.46	13.65	13.85	13.63
0	EFSFSR2	6.47	9.69	9.69	9.69	7.17	7.09	7.23	13.10	13.31	13.07
0	EFSFSR2	6.25	9.72	9.72	9.72	7.19	7.10	7.26	13.03	13.27	13.00
0	EFSFSR2	6.02	9.75	9.75	9.75	7.22	7.12	7.29	12.98	13.23	12.93
0	EFSFSR3	5.80	9.76	9.76	9.77	7.24	7.13	7.32	12.92	13.19	12.86
0	EFSFSR3	5.59	9.77	9.77	9.78	7.26	7.14	7.35	12.86	13.15	12.80
0	EFSFSR3	5.37	9.78	9.78	9.78	7.28	7.16	7.38	12.80	13.10	12.73
0	EFSFSR3	5.16	9.79	9.79	9.79	7.30	7.17	7.40	12.75	13.06	12.67
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	9.69	9.69	7.42	7.28	7.51	12.38	12.67	12.30
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	9.71	9.71	7.45	7.31	7.54	12.36	12.66	12.28
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	9.73	9.73	7.47	7.33	7.57	12.34	12.65	12.26
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	9.75	9.75	7.50	7.35	7.60	12.33	12.64	12.24
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	9.76	9.77	7.53	7.37	7.63	12.31	12.63	12.22
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	9.78	9.78	7.55	7.39	7.66	12.29	12.61	12.20
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	9.79	9.80	7.57	7.41	7.68	12.27	12.60	12.18
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	9.81	9.82	7.60	7.42	7.71	12.25	12.58	12.16
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	9.82	9.83	7.62	7.44	7.73	12.23	12.56	12.13
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	9.84	9.85	7.64	7.46	7.76	12.21	12.55	12.11
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	11.61	11.63	8.07	7.86	8.25	16.15	16.61	16.09
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	11.70	11.71	8.04	7.83	8.23	16.36	16.82	16.30
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	11.78	11.79	8.02	7.79	8.21	16.56	17.04	16.50
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	11.77	11.79	8.06	7.84	8.26	16.47	16.94	16.41
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	11.78	11.80	8.06	7.83	8.25	16.49	16.96	16.43
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	11.79	11.81	8.05	7.82	8.25	16.50	16.98	16.45
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	11.81	11.82	8.05	7.81	8.25	16.52	17.00	16.47
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	11.82	11.83	8.05	7.80	8.25	16.54	17.02	16.50
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	11.83	11.85	8.04	7.80	8.25	16.56	17.05	16.53
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	11.84	11.86	8.04	7.79	8.25	16.58	17.07	16.56
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	11.85	11.87	8.04	7.79	8.25	16.61	17.10	16.59
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	11.86	11.88	8.04	7.79	8.25	16.64	17.14	16.62
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	11.67	11.68	8.03	7.79	8.24	16.13	16.60	16.12
0	EFSFSR8	0.39	11.71	11.69	11.71	8.03	7.78	8.24	16.21	16.68	16.20
0	EFSFSR8	0.21	11.73	11.72	11.73	8.03	7.78	8.24	16.28	16.76	16.28
0	EFSFSR9 (at Midnight Cree	0.06	11.71	11.70	11.71	8.09	7.84	8.30	16.16	16.63	16.16
0	Terminus	0.00	11.71	11.70	11.71	8.09	7.84	8.30	16.16	16.63	16.16
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.57	8.57	6.07	6.05	6.09	11.75	11.81	11.74
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.81	8.81	6.37	6.33	6.41	11.98	12.09	11.95
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.03	9.03	6.59	6.53	6.64	12.20	12.36	12.15

Sediment Depth Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	5 cm	15 cm	Calibration	5 cm	15 cm	Calibration	5 cm	15 cm
1	Terminus	0.00	9.03	9.03	9.03	6.59	6.53	6.64	12.20	12.36	12.15
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.03	11.03	8.47	8.45	8.49	14.34	14.41	14.32
2	Meadow Creek Headwater	6.96	11.15	11.15	11.15	8.86	8.82	8.89	14.19	14.31	14.16
2	Meadow Creek Headwater	6.76	11.24	11.24	11.24	9.10	9.05	9.14	14.10	14.25	14.06
2	Meadow Creek Headwater	6.56	11.31	11.31	11.31	9.27	9.21	9.32	14.05	14.22	14.01
2	Meadow Creek Headwater	6.36	11.36	11.36	11.36	9.39	9.32	9.44	14.02	14.20	13.98
2	Meadow Creek Headwater	6.16	11.41	11.41	11.41	9.47	9.40	9.53	14.01	14.21	13.99
2	Meadow Creek Headwater	5.96	11.44	11.44	11.44	9.54	9.46	9.60	14.02	14.22	14.04
2	MC1	5.76	11.50	11.50	11.50	9.58	9.51	9.65	14.08	14.28	14.08
2	MC1	5.57	11.55	11.54	11.55	9.62	9.54	9.69	14.14	14.35	14.13
2	MC1	5.38	11.59	11.58	11.59	9.65	9.56	9.72	14.19	14.40	14.18
2	MC1	5.18	11.62	11.62	11.62	9.66	9.58	9.74	14.24	14.46	14.22
2	MC1	4.99	11.65	11.65	11.65	9.68	9.59	9.75	14.28	14.50	14.26
2	MC1	4.80	11.68	11.68	11.68	9.69	9.59	9.76	14.33	14.55	14.30
2	MC2 (at MC Trib 2)	4.62	11.30	11.30	11.30	9.59	9.51	9.66	13.76	13.96	13.74
2	MC2 (at MC Trib 2)	4.45	11.27	11.27	11.27	9.58	9.50	9.65	13.73	13.93	13.71
2	MC4 (at MC Trib 3)	4.27	10.74	10.74	10.74	9.17	9.09	9.23	12.82	12.99	12.81
2	MC4 (at MC Trib 3)	4.09	10.80	10.80	10.80	9.19	9.11	9.25	12.94	13.11	12.93
2	MC4 (at MC Trib 3)	3.91	10.86	10.86	10.86	9.21	9.12	9.26	13.05	13.22	13.04
2	MC4 (at MC Trib 3)	3.73	10.92	10.91	10.92	9.22	9.14	9.28	13.16	13.33	13.15
2	MC4 (at MC Trib 3)	3.55	10.97	10.97	10.97	9.24	9.15	9.30	13.26	13.44	13.26
2	MC6	3.36	11.29	11.29	11.29	9.16	9.06	9.22	14.19	14.39	14.20
2	MC6	3.15	11.59	11.59	11.59	9.07	8.96	9.15	15.14	15.35	15.14
2	MC6	2.95	11.88	11.87	11.88	8.98	8.87	9.07	16.02	16.26	16.01
2	MC6	2.75	12.15	12.14	12.15	8.90	8.78	9.01	16.85	17.12	16.81
2	MC6	2.54	12.41	12.40	12.41	8.82	8.69	8.94	17.61	17.91	17.56
2	MC7	2.35	12.60	12.59	12.60	8.75	8.60	8.89	18.25	18.59	18.18
2	MC7	2.16	12.78	12.78	12.79	8.68	8.52	8.83	18.84	19.22	18.76
2	MC7	1.98	12.96	12.95	12.96	8.62	8.45	8.79	19.40	19.81	19.29
2	MC7	1.79	13.13	13.11	13.13	8.56	8.37	8.75	19.91	20.37	19.79
2	MC7	1.60	13.29	13.27	13.29	8.50	8.30	8.71	20.39	20.89	20.24
2	MC8 (at East Fork MC)	1.41	13.00	12.99	13.00	8.56	8.39	8.76	19.63	20.12	19.51
2	MC8 (at East Fork MC)	1.22	13.07	13.05	13.07	8.57	8.39	8.77	19.79	20.29	19.66
2	MC8 (at East Fork MC)	1.03	13.14	13.12	13.14	8.58	8.39	8.78	19.94	20.45	19.81
2	MC8 (at East Fork MC)	0.84	13.20	13.18	13.20	8.58	8.39	8.79	20.08	20.61	19.94
2	MC8 (at East Fork MC)	0.65	13.26	13.25	13.27	8.59	8.39	8.81	20.21	20.76	20.08
2	MC8 (at East Fork MC)	0.46	13.33	13.31	13.33	8.60	8.39	8.82	20.34	20.90	20.20
2	MC10	0.27	13.34	13.32	13.34	8.59	8.38	8.82	20.33	20.90	20.18
2	MC10	0.09	13.35	13.33	13.35	8.59	8.38	8.83	20.31	20.89	20.16
2	Terminus	0.00	13.35	13.33	13.35	8.59	8.38	8.83	20.31	20.89	20.16
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.26	9.27	7.32	7.30	7.34	12.00	12.08	11.99
3	MC Trib 2 Headwater	1.08	9.82	9.81	9.82	8.18	8.15	8.21	12.34	12.46	12.32

Sediment Depth Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	5 cm	15 cm	Calibration	5 cm	15 cm	Calibration	5 cm	15 cm
3	MC Trib 2 Headwater	0.89	10.16	10.16	10.16	8.67	8.62	8.70	12.61	12.75	12.63
3	MC Trib 2 Headwater	0.70	10.40	10.40	10.40	8.98	8.93	9.01	12.87	12.98	12.89
3	MC3	0.50	10.53	10.53	10.53	9.20	9.15	9.24	12.80	12.97	12.82
3	MC3	0.30	10.62	10.62	10.62	9.35	9.30	9.39	12.78	12.95	12.79
3	MC3	0.10	10.68	10.68	10.68	9.46	9.41	9.50	12.77	12.93	12.77
3	Terminus	0.00	10.68	10.68	10.68	9.46	9.41	9.50	12.77	12.93	12.77
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.60	8.60	6.30	6.28	6.31	11.44	11.48	11.43
4	MC Trib 3 Headwater	1.31	8.85	8.85	8.85	6.85	6.82	6.87	11.41	11.48	11.39
4	MC Trib 3 Headwater	1.12	9.05	9.05	9.05	7.28	7.25	7.32	11.39	11.49	11.37
4	MC Trib 3 Headwater	0.93	9.21	9.21	9.21	7.62	7.57	7.65	11.38	11.49	11.35
4	MC5	0.73	9.34	9.34	9.34	7.86	7.81	7.90	11.34	11.47	11.31
4	MC5	0.52	9.45	9.45	9.45	8.06	8.00	8.10	11.30	11.44	11.27
4	MC5	0.31	9.54	9.54	9.54	8.22	8.16	8.26	11.27	11.42	11.24
4	MC5	0.10	9.61	9.61	9.61	8.36	8.29	8.39	11.24	11.39	11.21
4	Terminus	0.00	9.61	9.61	9.61	8.36	8.29	8.39	11.24	11.39	11.21
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.67	8.67	6.22	6.21	6.23	11.85	11.88	11.84
5	East Fork MC Headwater	4.11	9.00	9.00	9.00	6.66	6.64	6.67	12.16	12.21	12.14
5	East Fork MC Headwater	3.92	9.28	9.28	9.28	7.01	6.98	7.03	12.43	12.51	12.41
5	East Fork MC Headwater	3.72	9.53	9.53	9.53	7.30	7.27	7.33	12.68	12.78	12.66
5	East Fork MC Headwater	3.52	9.75	9.75	9.75	7.54	7.50	7.57	12.92	13.02	12.89
5	East Fork MC Headwater	3.33	9.94	9.94	9.94	7.74	7.70	7.77	13.13	13.25	13.10
5	East Fork MC Headwater	3.13	10.12	10.12	10.12	7.92	7.87	7.95	13.33	13.46	13.29
5	East Fork MC Headwater	2.93	10.27	10.27	10.27	8.07	8.02	8.11	13.51	13.66	13.47
5	East Fork MC Headwater	2.73	10.41	10.41	10.41	8.21	8.15	8.25	13.68	13.84	13.64
5	East Fork MC Headwater	2.54	10.54	10.54	10.54	8.32	8.27	8.37	13.84	14.00	13.80
5	East Fork MC Headwater	2.34	10.66	10.66	10.66	8.43	8.37	8.48	13.99	14.16	13.94
5	East Fork MC Headwater	2.14	10.77	10.76	10.77	8.52	8.46	8.57	14.13	14.31	14.07
5	East Fork MC Headwater	1.95	10.86	10.86	10.87	8.61	8.55	8.66	14.26	14.45	14.21
5	East Fork MC Headwater	1.75	10.96	10.95	10.96	8.68	8.62	8.74	14.38	14.59	14.36
5	MC9	1.55	11.10	11.10	11.10	8.70	8.63	8.76	14.80	15.02	14.79
5	MC9	1.34	11.23	11.23	11.23	8.71	8.64	8.78	15.19	15.43	15.18
5	MC9	1.13	11.36	11.35	11.36	8.72	8.64	8.80	15.54	15.80	15.52
5	MC9	0.93	11.47	11.46	11.47	8.73	8.65	8.82	15.85	16.13	15.83
5	MC9	0.72	11.57	11.56	11.57	8.74	8.65	8.83	16.13	16.43	16.11
5	MC9	0.52	11.66	11.66	11.66	8.74	8.65	8.84	16.38	16.71	16.36
5	MC9	0.31	11.75	11.74	11.75	8.74	8.65	8.85	16.62	16.97	16.59
5	MC9	0.10	11.83	11.82	11.83	8.75	8.65	8.86	16.83	17.20	16.80
5	Terminus	0.00	11.83	11.82	11.83	8.75	8.65	8.86	16.83	17.20	16.80
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.24	10.25	8.84	8.80	8.87	12.20	12.28	12.17
6	Garnet Creek Headwater	1.51	10.70	10.70	10.70	9.42	9.37	9.46	12.45	12.54	12.41
6	Garnet Creek Headwater	1.29	10.88	10.88	10.88	9.59	9.54	9.64	12.58	12.68	12.53

Sediment Depth Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature	
		(km)	deg C			deg C			deg C	
Tributary	Reach Label		Calibration	5 cm	15 cm	Calibration	5 cm	15 cm	Calibration	5 cm	15 cm
6	Garnet Creek Headwater	1.07	10.96	10.96	10.96	9.65	9.59	9.70	12.67	12.78	12.62
6	Garnet Creek Headwater	0.85	11.01	11.00	11.01	9.65	9.59	9.70	12.74	12.85	12.70
6	GC1	0.65	11.10	11.10	11.10	9.65	9.59	9.71	12.87	12.99	12.80
6	GC1	0.46	11.17	11.16	11.17	9.64	9.57	9.70	12.99	13.11	12.93
6	GC1	0.28	11.22	11.21	11.22	9.62	9.54	9.68	13.09	13.22	13.13
6	GC1	0.09	11.25	11.25	11.25	9.59	9.51	9.66	13.23	13.36	13.28
6	Terminus	0.00	11.25	11.25	11.25	9.59	9.51	9.66	13.23	13.36	13.28
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.41	8.41	5.97	5.96	5.99	11.39	11.43	11.38
7	Fiddle Creek Headwater	2.53	8.52	8.52	8.52	6.30	6.27	6.32	11.31	11.40	11.29
7	Fiddle Creek Headwater	2.36	8.62	8.62	8.62	6.58	6.54	6.62	11.25	11.37	11.22
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.68	8.68	6.94	6.88	6.98	11.02	11.15	10.99
7	FC1 (at Fiddle Creek Trib	2.02	8.76	8.76	8.76	7.09	7.02	7.13	11.03	11.18	11.00
7	FC2	1.84	8.85	8.85	8.85	7.25	7.17	7.29	11.00	11.17	10.97
7	FC2	1.65	8.93	8.93	8.93	7.38	7.29	7.42	10.97	11.16	10.94
7	FC2	1.46	9.00	9.00	9.00	7.49	7.40	7.53	10.95	11.15	10.91
7	FC2	1.26	9.06	9.06	9.06	7.58	7.49	7.63	10.93	11.13	10.89
7	FC2	1.07	9.12	9.12	9.12	7.67	7.57	7.72	10.91	11.12	10.86
7	FC2	0.87	9.17	9.17	9.17	7.75	7.64	7.80	10.89	11.10	10.84
7	FC2	0.68	9.21	9.21	9.21	7.81	7.71	7.87	10.87	11.09	10.82
7	FC2	0.49	9.25	9.25	9.25	7.88	7.77	7.93	10.85	11.07	10.81
7	FC2	0.29	9.29	9.29	9.29	7.93	7.82	7.98	10.83	11.06	10.82
7	FC2	0.10	9.32	9.32	9.32	7.98	7.87	8.03	10.82	11.04	10.85
7	Terminus	0.00	9.32	9.32	9.32	7.98	7.87	8.03	10.82	11.04	10.85
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	10.05	10.05	8.75	8.71	8.77	11.64	11.71	11.62
8	Midnight Creek Headwater	2.69	10.47	10.47	10.47	9.37	9.32	9.40	11.71	11.79	11.68
8	Midnight Creek Headwater	2.49	10.64	10.64	10.64	9.57	9.52	9.60	11.75	11.82	11.71
8	Midnight Creek Headwater	2.29	10.71	10.71	10.72	9.64	9.59	9.68	11.78	11.85	11.74
8	Midnight Creek Headwater	2.09	10.75	10.75	10.75	9.65	9.60	9.69	11.80	11.88	11.76
8	Midnight Creek Headwater	1.89	10.76	10.76	10.76	9.64	9.59	9.68	11.83	11.93	11.83
8	Midnight Creek Headwater	1.69	10.76	10.76	10.76	9.62	9.56	9.66	11.86	11.98	11.88
8	Midnight Creek Headwater	1.50	10.75	10.75	10.76	9.58	9.52	9.63	11.89	12.01	11.92
8	Midnight Creek Headwater	1.30	10.74	10.74	10.74	9.55	9.48	9.60	11.90	12.03	11.94
8	Midnight Creek Headwater	1.10	10.73	10.73	10.73	9.51	9.44	9.56	11.91	12.04	11.95
8	Midnight Creek Headwater	0.90	10.72	10.71	10.72	9.47	9.40	9.53	11.91	12.05	11.95
8	Midnight Creek Headwater	0.70	10.70	10.70	10.70	9.43	9.36	9.49	11.91	12.07	11.95
8	Midnight Creek Headwater	0.50	10.68	10.68	10.68	9.40	9.32	9.46	11.92	12.08	11.94
8	Midnight Creek Headwater	0.30	10.67	10.66	10.67	9.36	9.28	9.42	11.92	12.09	11.93
8	Midnight Creek Headwater	0.10	10.65	10.64	10.65	9.32	9.24	9.39	11.92	12.10	11.92
8	Terminus	0.00	10.65	10.64	10.65	9.32	9.24	9.39	11.92	12.10	11.92

		Shade Input																							
Reach	Reach Label	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Reach 1	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	99.0%	98.1%	98.2%	96.7%	87.1%	82.0%	91.9%	94.4%	94.5%	90.0%	86.8%	89.3%	91.2%	97.0%	98.4%	99.3%	100.0%	100.0%	100.0%
Reach 2	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	98.7%	92.3%	81.0%	75.3%	71.8%	69.8%	67.8%	63.4%	57.5%	58.0%	51.0%	60.8%	75.5%	91.3%	98.3%	98.8%	100.0%	100.0%	100.0%
Reach 3	EFSFSR Trib 4	100.0%	100.0%	100.0%	100.0%	100.0%	99.2%	98.7%	94.9%	84.3%	82.5%	77.2%	56.6%	44.3%	52.0%	64.1%	70.2%	77.4%	86.7%	98.1%	98.8%	99.2%	100.0%	100.0%	100.0%
Reach 4	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	98.1%	95.9%	89.4%	87.3%	82.1%	71.9%	61.2%	53.2%	68.1%	80.5%	85.1%	90.4%	95.7%	97.9%	98.4%	98.4%	100.0%	100.0%	100.0%
Reach 5	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	98.9%	95.1%	79.3%	77.9%	68.4%	73.2%	85.2%	82.8%	88.0%	91.1%	92.1%	95.3%	98.3%	98.8%	98.9%	100.0%	100.0%	100.0%
Reach 6	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	99.0%	98.8%	92.9%	87.8%	85.8%	82.5%	81.3%	85.7%	91.0%	92.1%	93.3%	93.6%	93.4%	91.3%	97.5%	98.8%	100.0%	100.0%	100.0%
Reach 7	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	98.6%	94.1%	84.0%	79.5%	71.2%	64.8%	55.9%	53.1%	60.8%	67.4%	73.0%	85.1%	96.8%	98.7%	99.1%	100.0%	100.0%	100.0%
Reach 8	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	98.7%	98.3%	96.7%	76.4%	66.1%	59.0%	48.0%	38.5%	54.7%	62.1%	63.8%	68.2%	76.2%	96.2%	98.3%	98.6%	100.0%	100.0%	100.0%
Reach 9	Meadow Creek Trib 2	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.1%	93.9%	93.0%	90.1%	87.0%	83.0%	79.7%	65.3%	55.9%	65.6%	79.2%	92.8%	96.9%	99.5%	99.6%	100.0%	100.0%	100.0%
Reach 10	Meadow Creek Trib 2	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.2%	97.8%	91.7%	89.9%	91.5%	89.9%	89.2%	89.0%	80.9%	81.2%	84.8%	94.6%	98.9%	99.3%	99.5%	100.0%	100.0%	100.0%
Reach 11	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.0%	99.0%	98.7%	98.1%	97.8%	97.4%	96.1%	88.5%	81.7%	81.4%	80.6%	95.4%	97.8%	99.0%	99.0%	99.0%	100.0%	100.0%	100.0%
Reach 12	Meadow Creek Trib 3	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%	99.2%	98.7%	97.9%	95.8%	97.3%	95.4%	95.6%	97.9%	97.8%	97.9%	96.4%	97.7%	97.9%	99.4%	99.7%	100.0%	100.0%	100.0%
Reach 13	Meadow Creek Trib 3	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**99.7%**	**99.7%**	**99.5%**	**98.8%**	**95.7%**	**94.7%**	**96.8%**	**96.5%**	**98.1%**	**98.4%**	**98.7%**	**98.8%**	**99.3%**	**99.2%**	**99.2%**	**99.6%**	**100.0%**	**100.0%**	**100.0%**
Reach 14	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	97.8%	90.6%	74.4%	65.2%	65.6%	66.4%	63.7%	60.5%	57.1%	52.4%	59.9%	69.2%	77.2%	85.5%	95.4%	98.0%	100.0%	100.0%	100.0%
Reach 15	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	93.1%	56.0%	12.0%	5.1%	3.9%	4.1%	4.0%	4.2%	4.2%	4.0%	4.2%	4.9%	8.9%	27.6%	73.7%	93.7%	100.0%	100.0%	100.0%
Reach 16	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	94.0%	88.5%	48.3%	23.7%	11.9%	7.9%	7.7%	5.8%	4.9%	4.7%	5.0%	9.4%	29.2%	74.3%	93.9%	94.1%	100.0%	100.0%	100.0%
Reach 17	East Fork Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	97.9%	96.1%	79.9%	55.3%	47.8%	43.1%	38.4%	31.5%	27.4%	32.9%	36.2%	42.2%	49.5%	84.8%	96.4%	98.2%	100.0%	100.0%	100.0%
Reach 18	East Fork Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	96.3%	95.5%	82.5%	66.3%	56.7%	41.0%	26.8%	16.2%	22.2%	29.7%	41.7%	53.2%	68.7%	86.5%	96.1%	96.4%	100.0%	100.0%	100.0%
Reach 19	Meadow Creek	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**93.1%**	**64.8%**	**37.8%**	**25.5%**	**12.9%**	**6.3%**	**3.9%**	**3.6%**	**3.9%**	**3.8%**	**4.8%**	**6.7%**	**12.7%**	**42.5%**	**92.4%**	**93.3%**	**100.0%**	**100.0%**	**100.0%**
Reach 20	Meadow Creek	100.0%	100.0%	100.0%	100.0%	100.0%	96.9%	96.8%	82.9%	60.0%	51.3%	42.5%	33.7%	27.6%	31.4%	42.3%	46.5%	52.3%	65.1%	88.7%	96.6%	97.1%	100.0%	100.0%	100.0%
Reach 21	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	95.4%	95.4%	85.9%	67.9%	52.3%	33.5%	13.9%	10.0%	14.7%	23.8%	35.0%	43.2%	61.5%	93.1%	94.9%	95.1%	100.0%	100.0%	100.0%
Reach 22	Garnet Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.1%	98.1%	96.6%	92.3%	88.7%	86.3%	84.6%	78.2%	77.9%	88.2%	82.5%	79.6%	78.6%	89.9%	93.6%	99.2%	100.0%	100.0%	100.0%
Reach 23	Garnet Creek	100.0%	100.0%	100.0%	100.0%	100.0%	97.8%	97.7%	87.9%	74.3%	70.1%	70.6%	67.8%	62.0%	77.6%	78.1%	76.6%	74.2%	73.2%	88.5%	98.0%	98.3%	100.0%	100.0%	100.0%
Reach 24	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	96.7%	96.5%	96.1%	86.2%	67.9%	46.5%	31.6%	26.4%	26.1%	37.5%	50.9%	70.5%	83.9%	94.7%	96.5%	96.6%	100.0%	100.0%	100.0%
Reach 25	Fiddle Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%	99.6%	98.7%	98.4%	97.8%	95.2%	97.9%	98.7%	98.7%	97.8%	98.0%	99.0%	98.9%	99.2%	99.3%	99.7%	100.0%	100.0%	100.0%
Reach 26	Fiddle Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%	99.0%	99.0%	98.9%	97.2%	96.7%	96.5%	96.8%	95.1%	94.3%	92.0%	93.4%	99.2%	99.5%	99.7%	99.7%	100.0%	100.0%	100.0%
Reach 27	Fiddle Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.5%	97.2%	99.1%	99.0%	98.8%	98.4%	97.5%	92.0%	83.7%	92.7%	96.7%	98.5%	99.5%	99.5%	99.5%	100.0%	100.0%	100.0%
Reach 28	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	96.8%	96.8%	96.8%	73.6%	16.7%	7.4%	18.2%	30.2%	40.1%	63.7%	80.7%	87.2%	92.4%	96.8%	96.8%	96.8%	100.0%	100.0%	100.0%
Reach 29	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	96.0%	96.0%	94.0%	77.0%	62.8%	39.1%	9.7%	6.5%	6.8%	10.6%	24.8%	47.0%	65.7%	92.2%	95.9%	96.0%	100.0%	100.0%	100.0%
Reach 30	Midnight Creek	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	99.2%	98.1%	94.2%	90.4%	84.4%	82.2%	88.5%	92.6%	93.1%	94.2%	94.6%	94.2%	98.8%	99.2%	99.5%	100.0%	100.0%	100.0%
Reach 31	EFSFSR	100.0%	100.0%	100.0%	100.0%	100.0%	93.9%	93.7%	84.7%	48.4%	4.8%	4.8%	3.9%	5.6%	11.0%	16.2%	21.3%	25.0%	41.9%	93.5%	93.5%	93.8%	100.0%	100.0%	100.0%

Note: Calibration input provided in table. Bold rows indicate the maximum and minimum shade values applied for all reaches in sensitivity analyses.

Shade Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	Max	Min	Calibration	Max	Min	Calibration	Max	Min
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.74	10.01	6.82	6.80	7.05	13.54	13.46	14.18
0	EFSFSR Headwater	7.26	9.76	9.72	10.25	6.96	6.94	7.24	13.44	13.29	14.69
0	EFSFSR Headwater	7.09	9.76	9.70	10.48	7.09	7.07	7.32	13.35	13.14	15.16
0	EFSFSR1	6.90	9.86	9.68	10.75	7.32	7.21	7.38	13.51	12.97	15.72
0	EFSFSR1	6.69	9.96	9.66	11.01	7.41	7.34	7.43	13.65	12.81	16.26
0	EFSFSR2	6.47	9.69	9.29	10.87	7.17	7.15	7.20	13.10	12.18	16.25
0	EFSFSR2	6.25	9.72	9.27	11.06	7.19	7.18	7.22	13.03	12.09	16.71
0	EFSFSR2	6.02	9.75	9.26	11.25	7.22	7.20	7.24	12.98	12.00	17.15
0	EFSFSR3	5.80	9.76	9.25	11.43	7.24	7.23	7.27	12.92	11.92	17.54
0	EFSFSR3	5.59	9.77	9.24	11.60	7.26	7.26	7.29	12.86	11.84	17.91
0	EFSFSR3	5.37	9.78	9.23	11.76	7.28	7.28	7.31	12.80	11.76	18.26
0	EFSFSR3	5.16	9.79	9.22	11.91	7.30	7.30	7.34	12.75	11.69	18.59
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	9.16	11.77	7.42	7.41	7.45	12.38	11.39	18.10
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	9.18	11.92	7.45	7.44	7.48	12.36	11.36	18.41
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	9.19	12.07	7.47	7.47	7.51	12.34	11.34	18.71
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	9.20	12.21	7.50	7.49	7.53	12.33	11.31	18.99
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	9.22	12.34	7.53	7.52	7.56	12.31	11.28	19.26
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	9.23	12.47	7.55	7.54	7.59	12.29	11.25	19.52
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	9.24	12.59	7.57	7.57	7.62	12.27	11.22	19.76
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	9.25	12.71	7.60	7.59	7.64	12.25	11.20	19.99
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	9.26	12.83	7.62	7.61	7.67	12.23	11.17	20.21
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	9.27	12.94	7.64	7.63	7.70	12.21	11.14	20.42
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	9.50	13.83	8.07	8.02	8.17	16.15	10.99	21.66
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	9.47	13.92	8.04	7.99	8.16	16.36	10.94	21.87
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	9.44	14.02	8.02	7.96	8.14	16.56	10.90	22.06
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	9.46	14.03	8.06	8.00	8.19	16.47	10.89	22.04
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	9.46	14.06	8.06	8.00	8.19	16.49	10.87	22.08
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	9.45	14.09	8.05	7.99	8.19	16.50	10.86	22.13
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	9.44	14.11	8.05	7.99	8.19	16.52	10.84	22.17
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	9.43	14.14	8.05	7.98	8.19	16.54	10.82	22.21
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	9.42	14.16	8.04	7.98	8.20	16.56	10.80	22.25
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	9.41	14.19	8.04	7.97	8.20	16.58	10.79	22.28
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	9.41	14.21	8.04	7.97	8.21	16.61	10.77	22.32
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	9.40	14.24	8.04	7.97	8.22	16.64	10.75	22.35
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	9.37	14.13	8.03	7.96	8.21	16.13	10.72	22.12
0	EFSFSR8	0.39	11.71	9.37	14.15	8.03	7.96	8.21	16.21	10.70	22.16
0	EFSFSR8	0.21	11.73	9.36	14.17	8.03	7.96	8.22	16.28	10.69	22.19
0	EFSFSR9 (at Midnight Cree	0.06	11.71	9.40	14.19	8.09	8.02	8.28	16.16	10.69	22.14
0	Terminus	0.00	11.71	9.40	14.19	8.09	8.02	8.28	16.16	10.69	22.14
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.40	8.91	6.07	5.99	6.21	11.75	11.37	12.72
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.49	9.45	6.37	6.31	6.45	11.98	11.27	13.80
1	EFSRSR Trib 4 Headwater	0.11	9.03	8.58	9.94	6.59	6.58	6.64	12.20	11.19	14.78

Shade Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	Max	Min	Calibration	Max	Min	Calibration	Max	Min
1	Terminus	0.00	9.03	8.58	9.94	6.59	6.58	6.64	12.20	11.19	14.78
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	10.86	11.36	8.47	8.40	8.56	14.34	13.89	15.25
2	Meadow Creek Headwater	6.96	11.15	10.86	11.74	8.86	8.83	8.90	14.19	13.42	15.80
2	Meadow Creek Headwater	6.76	11.24	10.85	12.03	9.10	9.09	9.12	14.10	13.08	16.26
2	Meadow Creek Headwater	6.56	11.31	10.84	12.26	9.27	9.26	9.28	14.05	12.83	16.65
2	Meadow Creek Headwater	6.36	11.36	10.83	12.45	9.39	9.38	9.40	14.02	12.62	16.98
2	Meadow Creek Headwater	6.16	11.41	10.82	12.61	9.47	9.47	9.48	14.01	12.45	17.27
2	Meadow Creek Headwater	5.96	11.44	10.80	12.75	9.54	9.53	9.55	14.02	12.31	17.53
2	MC1	5.76	11.50	10.79	12.87	9.58	9.58	9.60	14.08	12.19	17.76
2	MC1	5.57	11.55	10.78	12.97	9.62	9.62	9.63	14.14	12.09	17.96
2	MC1	5.38	11.59	10.76	13.06	9.65	9.64	9.66	14.19	12.00	18.15
2	MC1	5.18	11.62	10.75	13.14	9.66	9.66	9.68	14.24	11.92	18.32
2	MC1	4.99	11.65	10.73	13.22	9.68	9.67	9.70	14.28	11.85	18.48
2	MC1	4.80	11.68	10.72	13.28	9.69	9.68	9.71	14.33	11.79	18.63
2	MC2 (at MC Trib 2)	4.62	11.30	10.58	13.04	9.59	9.59	9.61	13.76	11.60	18.25
2	MC2 (at MC Trib 2)	4.45	11.27	10.56	13.11	9.58	9.58	9.60	13.73	11.57	18.43
2	MC4 (at MC Trib 3)	4.27	10.74	10.24	12.66	9.17	9.16	9.19	12.82	11.44	17.92
2	MC4 (at MC Trib 3)	4.09	10.80	10.26	12.76	9.19	9.18	9.21	12.94	11.45	18.13
2	MC4 (at MC Trib 3)	3.91	10.86	10.27	12.85	9.21	9.20	9.23	13.05	11.45	18.34
2	MC4 (at MC Trib 3)	3.73	10.92	10.29	12.94	9.22	9.21	9.25	13.16	11.45	18.53
2	MC4 (at MC Trib 3)	3.55	10.97	10.30	13.03	9.24	9.23	9.27	13.26	11.46	18.72
2	MC6	3.36	11.29	10.24	13.24	9.16	9.14	9.18	14.19	11.39	19.33
2	MC6	3.15	11.59	10.19	13.44	9.07	9.05	9.10	15.14	11.33	19.91
2	MC6	2.95	11.88	10.13	13.63	8.98	8.96	9.02	16.02	11.27	20.43
2	MC6	2.75	12.15	10.07	13.81	8.90	8.88	8.95	16.85	11.21	20.92
2	MC6	2.54	12.41	10.02	13.97	8.82	8.79	8.88	17.61	11.16	21.37
2	MC7	2.35	12.60	9.97	14.12	8.75	8.72	8.82	18.25	11.11	21.75
2	MC7	2.16	12.78	9.93	14.26	8.68	8.65	8.76	18.84	11.06	22.10
2	MC7	1.98	12.96	9.88	14.39	8.62	8.58	8.71	19.40	11.02	22.42
2	MC7	1.79	13.13	9.84	14.52	8.56	8.51	8.66	19.91	10.98	22.71
2	MC7	1.60	13.29	9.80	14.64	8.50	8.44	8.62	20.39	10.95	22.97
2	MC8 (at East Fork MC)	1.41	13.00	9.81	14.27	8.56	8.51	8.66	19.63	10.95	22.15
2	MC8 (at East Fork MC)	1.22	13.07	9.81	14.32	8.57	8.51	8.67	19.79	10.95	22.22
2	MC8 (at East Fork MC)	1.03	13.14	9.81	14.36	8.58	8.51	8.68	19.94	10.95	22.29
2	MC8 (at East Fork MC)	0.84	13.20	9.81	14.41	8.58	8.51	8.69	20.08	10.95	22.35
2	MC8 (at East Fork MC)	0.65	13.26	9.81	14.45	8.59	8.52	8.70	20.21	10.95	22.41
2	MC8 (at East Fork MC)	0.46	13.33	9.82	14.49	8.60	8.52	8.71	20.34	10.94	22.47
2	MC10	0.27	13.34	9.81	14.53	8.59	8.52	8.72	20.33	10.94	22.53
2	MC10	0.09	13.35	9.81	14.57	8.59	8.51	8.72	20.31	10.93	22.59
2	Terminus	0.00	13.35	9.81	14.57	8.59	8.51	8.72	20.31	10.93	22.59
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.12	9.76	7.32	7.28	7.42	12.00	11.43	13.16
3	MC Trib 2 Headwater	1.08	9.82	9.58	10.63	8.18	8.18	8.21	12.34	11.42	14.24

Shade Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	Max	Min	Calibration	Max	Min	Calibration	Max	Min
3	MC Trib 2 Headwater	0.89	10.16	9.86	11.20	8.67	8.66	8.68	12.61	11.41	15.04
3	MC Trib 2 Headwater	0.70	10.40	10.05	11.61	8.98	8.98	8.99	12.87	11.40	15.67
3	MC3	0.50	10.53	10.18	11.94	9.20	9.20	9.21	12.80	11.39	16.21
3	MC3	0.30	10.62	10.28	12.19	9.35	9.35	9.36	12.78	11.38	16.65
3	MC3	0.10	10.68	10.35	12.40	9.46	9.46	9.47	12.77	11.37	17.02
3	Terminus	0.00	10.68	10.35	12.40	9.46	9.46	9.47	12.77	11.37	17.02
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.60	8.98	6.30	6.29	6.50	11.44	11.41	12.43
4	MC Trib 3 Headwater	1.31	8.85	8.84	9.54	6.85	6.84	7.00	11.41	11.37	13.21
4	MC Trib 3 Headwater	1.12	9.05	9.04	10.01	7.28	7.28	7.37	11.39	11.34	13.87
4	MC Trib 3 Headwater	0.93	9.21	9.20	10.40	7.62	7.62	7.66	11.38	11.31	14.45
4	MC5	0.73	9.34	9.33	10.76	7.86	7.86	7.90	11.34	11.28	15.02
4	MC5	0.52	9.45	9.44	11.06	8.06	8.06	8.09	11.30	11.25	15.52
4	MC5	0.31	9.54	9.53	11.33	8.22	8.22	8.25	11.27	11.23	15.97
4	MC5	0.10	9.61	9.61	11.56	8.36	8.36	8.38	11.24	11.20	16.37
4	Terminus	0.00	9.61	9.61	11.56	8.36	8.36	8.38	11.24	11.20	16.37
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.52	8.75	6.22	6.10	6.29	11.85	11.46	12.07
5	East Fork MC Headwater	4.11	9.00	8.72	9.15	6.66	6.53	6.74	12.16	11.44	12.57
5	East Fork MC Headwater	3.92	9.28	8.89	9.50	7.01	6.89	7.06	12.43	11.42	13.01
5	East Fork MC Headwater	3.72	9.53	9.04	9.81	7.30	7.20	7.33	12.68	11.40	13.39
5	East Fork MC Headwater	3.52	9.75	9.17	10.08	7.54	7.47	7.56	12.92	11.39	13.76
5	East Fork MC Headwater	3.33	9.94	9.28	10.32	7.74	7.71	7.76	13.13	11.38	14.09
5	East Fork MC Headwater	3.13	10.12	9.38	10.53	7.92	7.89	7.93	13.33	11.37	14.41
5	East Fork MC Headwater	2.93	10.27	9.46	10.73	8.07	8.05	8.08	13.51	11.36	14.69
5	East Fork MC Headwater	2.73	10.41	9.54	10.91	8.21	8.19	8.22	13.68	11.35	14.96
5	East Fork MC Headwater	2.54	10.54	9.61	11.07	8.32	8.31	8.33	13.84	11.34	15.20
5	East Fork MC Headwater	2.34	10.66	9.67	11.22	8.43	8.42	8.44	13.99	11.34	15.42
5	East Fork MC Headwater	2.14	10.77	9.73	11.35	8.52	8.52	8.53	14.13	11.33	15.63
5	East Fork MC Headwater	1.95	10.86	9.78	11.48	8.61	8.60	8.62	14.26	11.32	15.83
5	East Fork MC Headwater	1.75	10.96	9.82	11.60	8.68	8.68	8.69	14.38	11.31	16.03
5	MC9	1.55	11.10	9.83	11.82	8.70	8.69	8.71	14.80	11.26	16.59
5	MC9	1.34	11.23	9.83	12.02	8.71	8.70	8.72	15.19	11.22	17.10
5	MC9	1.13	11.36	9.83	12.21	8.72	8.71	8.73	15.54	11.18	17.57
5	MC9	0.93	11.47	9.84	12.38	8.73	8.72	8.74	15.85	11.14	17.99
5	MC9	0.72	11.57	9.83	12.54	8.74	8.72	8.75	16.13	11.10	18.37
5	MC9	0.52	11.66	9.83	12.69	8.74	8.73	8.76	16.38	11.06	18.71
5	MC9	0.31	11.75	9.83	12.82	8.74	8.73	8.76	16.62	11.02	19.02
5	MC9	0.10	11.83	9.83	12.95	8.75	8.72	8.76	16.83	10.99	19.30
5	Terminus	0.00	11.83	9.83	12.95	8.75	8.72	8.76	16.83	10.99	19.30
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.00	11.51	8.84	8.84	8.85	12.20	11.46	15.60
6	Garnet Creek Headwater	1.51	10.70	10.36	12.41	9.42	9.41	9.43	12.45	11.45	17.15
6	Garnet Creek Headwater	1.29	10.88	10.49	12.86	9.59	9.59	9.61	12.58	11.44	18.05

Shade Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	Max	Min	Calibration	Max	Min	Calibration	Max	Min
6	Garnet Creek Headwater	1.07	10.96	10.53	13.15	9.65	9.64	9.67	12.67	11.43	18.67
6	Garnet Creek Headwater	0.85	11.01	10.54	13.35	9.65	9.64	9.68	12.74	11.42	19.13
6	GC1	0.65	11.10	10.55	13.47	9.65	9.64	9.69	12.87	11.41	19.40
6	GC1	0.46	11.17	10.54	13.57	9.64	9.62	9.68	12.99	11.41	19.63
6	GC1	0.28	11.22	10.53	13.66	9.62	9.60	9.67	13.09	11.40	19.84
6	GC1	0.09	11.25	10.52	13.74	9.59	9.57	9.65	13.23	11.39	20.02
6	Terminus	0.00	11.25	10.52	13.74	9.59	9.57	9.65	13.23	11.39	20.02
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.41	8.81	5.97	5.98	6.19	11.39	11.39	12.43
7	Fiddle Creek Headwater	2.53	8.52	8.52	9.27	6.30	6.30	6.49	11.31	11.31	13.26
7	Fiddle Creek Headwater	2.36	8.62	8.62	9.68	6.58	6.58	6.70	11.25	11.25	14.01
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.68	9.91	6.94	6.93	7.00	11.02	10.97	14.20
7	FC1 (at Fiddle Creek Trib	2.02	8.76	8.75	10.23	7.09	7.09	7.13	11.03	10.95	14.82
7	FC2	1.84	8.85	8.83	10.57	7.25	7.24	7.28	11.00	10.91	15.47
7	FC2	1.65	8.93	8.90	10.87	7.38	7.37	7.41	10.97	10.88	16.05
7	FC2	1.46	9.00	8.96	11.15	7.49	7.49	7.52	10.95	10.85	16.59
7	FC2	1.26	9.06	9.02	11.40	7.58	7.58	7.61	10.93	10.83	17.07
7	FC2	1.07	9.12	9.07	11.63	7.67	7.67	7.70	10.91	10.80	17.52
7	FC2	0.87	9.17	9.11	11.84	7.75	7.74	7.78	10.89	10.77	17.92
7	FC2	0.68	9.21	9.15	12.04	7.81	7.81	7.85	10.87	10.74	18.28
7	FC2	0.49	9.25	9.19	12.22	7.88	7.87	7.92	10.85	10.72	18.61
7	FC2	0.29	9.29	9.22	12.38	7.93	7.93	7.98	10.83	10.69	18.91
7	FC2	0.10	9.32	9.25	12.53	7.98	7.98	8.03	10.82	10.66	19.18
7	Terminus	0.00	9.32	9.25	12.53	7.98	7.98	8.03	10.82	10.66	19.18
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	9.94	11.37	8.75	8.74	8.76	11.64	11.46	15.38
8	Midnight Creek Headwater	2.69	10.47	10.33	12.30	9.37	9.37	9.38	11.71	11.46	16.93
8	Midnight Creek Headwater	2.49	10.64	10.47	12.77	9.57	9.57	9.59	11.75	11.45	17.84
8	Midnight Creek Headwater	2.29	10.71	10.53	13.06	9.64	9.64	9.67	11.78	11.44	18.48
8	Midnight Creek Headwater	2.09	10.75	10.55	13.28	9.65	9.65	9.69	11.80	11.43	18.96
8	Midnight Creek Headwater	1.89	10.76	10.55	13.44	9.64	9.64	9.69	11.83	11.42	19.34
8	Midnight Creek Headwater	1.69	10.76	10.54	13.57	9.62	9.61	9.67	11.86	11.40	19.65
8	Midnight Creek Headwater	1.50	10.75	10.52	13.68	9.58	9.58	9.64	11.89	11.40	19.92
8	Midnight Creek Headwater	1.30	10.74	10.50	13.77	9.55	9.54	9.62	11.90	11.39	20.15
8	Midnight Creek Headwater	1.10	10.73	10.48	13.85	9.51	9.50	9.59	11.91	11.38	20.34
8	Midnight Creek Headwater	0.90	10.72	10.46	13.92	9.47	9.47	9.56	11.91	11.37	20.52
8	Midnight Creek Headwater	0.70	10.70	10.44	13.99	9.43	9.43	9.53	11.91	11.36	20.67
8	Midnight Creek Headwater	0.50	10.68	10.41	14.05	9.40	9.39	9.51	11.92	11.35	20.80
8	Midnight Creek Headwater	0.30	10.67	10.39	14.10	9.36	9.35	9.48	11.92	11.34	20.92
8	Midnight Creek Headwater	0.10	10.65	10.37	14.15	9.32	9.32	9.46	11.92	11.33	21.02
8	Terminus	0.00	10.65	10.37	14.15	9.32	9.32	9.46	11.92	11.33	21.02

ISS Input	
	Headwater Inorganic Solids
Calibration	0 mg/L
Increase to 5 mg/L	5 mg/L
Increase to 10 mg/L	10 mg/L

ISS Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature	
		(km)	deg C			deg C			deg C	
Tributary	Reach Label		Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L
0	EFSFSR	7.51	9.76	9.76	9.76	6.66	6.66	6.66	13.64	13.64	13.64
0	EFSFSR Headwater	7.43	9.76	9.76	9.76	6.82	6.82	6.82	13.54	13.54	13.54
0	EFSFSR Headwater	7.26	9.76	9.76	9.76	6.96	6.96	6.96	13.44	13.44	13.44
0	EFSFSR Headwater	7.09	9.76	9.76	9.76	7.09	7.09	7.09	13.35	13.35	13.35
0	EFSFSR1	6.90	9.86	9.86	9.86	7.32	7.32	7.32	13.51	13.51	13.51
0	EFSFSR1	6.69	9.96	9.96	9.96	7.41	7.41	7.41	13.65	13.65	13.65
0	EFSFSR2	6.47	9.69	9.69	9.69	7.17	7.17	7.17	13.10	13.10	13.10
0	EFSFSR2	6.25	9.72	9.72	9.72	7.19	7.19	7.19	13.03	13.03	13.03
0	EFSFSR2	6.02	9.75	9.75	9.75	7.22	7.22	7.22	12.98	12.98	12.98
0	EFSFSR3	5.80	9.76	9.76	9.76	7.24	7.24	7.24	12.92	12.92	12.92
0	EFSFSR3	5.59	9.77	9.77	9.77	7.26	7.26	7.26	12.86	12.86	12.86
0	EFSFSR3	5.37	9.78	9.78	9.78	7.28	7.28	7.28	12.80	12.80	12.80
0	EFSFSR3	5.16	9.79	9.79	9.79	7.30	7.30	7.30	12.75	12.75	12.75
0	EFSFSR4 (at Rabbit Creek)	4.95	9.69	9.69	9.69	7.42	7.42	7.42	12.38	12.38	12.38
0	EFSFSR4 (at Rabbit Creek)	4.76	9.71	9.71	9.71	7.45	7.45	7.45	12.36	12.36	12.36
0	EFSFSR4 (at Rabbit Creek)	4.57	9.73	9.73	9.73	7.47	7.47	7.47	12.34	12.34	12.34
0	EFSFSR4 (at Rabbit Creek)	4.38	9.75	9.75	9.75	7.50	7.50	7.50	12.33	12.33	12.33
0	EFSFSR4 (at Rabbit Creek)	4.19	9.77	9.77	9.77	7.53	7.53	7.53	12.31	12.31	12.31
0	EFSFSR4 (at Rabbit Creek)	4.00	9.78	9.78	9.78	7.55	7.55	7.55	12.29	12.29	12.29
0	EFSFSR4 (at Rabbit Creek)	3.81	9.80	9.80	9.80	7.57	7.57	7.57	12.27	12.27	12.27
0	EFSFSR4 (at Rabbit Creek)	3.62	9.82	9.82	9.82	7.60	7.60	7.60	12.25	12.25	12.25
0	EFSFSR4 (at Rabbit Creek)	3.43	9.83	9.83	9.83	7.62	7.62	7.62	12.23	12.23	12.23
0	EFSFSR4 (at Rabbit Creek)	3.24	9.85	9.85	9.85	7.64	7.64	7.64	12.21	12.21	12.21
0	EFSFSR5 (at Meadow Creek)	3.03	11.63	11.63	11.63	8.07	8.07	8.07	16.15	16.15	16.15
0	EFSFSR5 (at Meadow Creek)	2.81	11.71	11.71	11.71	8.04	8.04	8.04	16.36	16.36	16.36
0	EFSFSR5 (at Meadow Creek)	2.59	11.79	11.79	11.79	8.02	8.02	8.02	16.56	16.56	16.56
0	EFSFSR6 (at Garnet Creek)	2.38	11.79	11.79	11.79	8.06	8.06	8.06	16.47	16.47	16.47
0	EFSFSR6 (at Garnet Creek)	2.19	11.80	11.80	11.80	8.06	8.06	8.06	16.49	16.49	16.49
0	EFSFSR6 (at Garnet Creek)	1.99	11.81	11.81	11.81	8.05	8.05	8.05	16.50	16.50	16.50
0	EFSFSR6 (at Garnet Creek)	1.79	11.82	11.82	11.82	8.05	8.05	8.05	16.52	16.52	16.52
0	EFSFSR6 (at Garnet Creek)	1.60	11.83	11.83	11.83	8.05	8.05	8.05	16.54	16.54	16.54
0	EFSFSR6 (at Garnet Creek)	1.40	11.85	11.85	11.85	8.04	8.04	8.04	16.56	16.56	16.56
0	EFSFSR6 (at Garnet Creek)	1.20	11.86	11.86	11.86	8.04	8.04	8.04	16.58	16.58	16.58
0	EFSFSR6 (at Garnet Creek)	1.01	11.87	11.87	11.87	8.04	8.04	8.04	16.61	16.61	16.61
0	EFSFSR6 (at Garnet Creek)	0.81	11.88	11.88	11.88	8.04	8.04	8.04	16.64	16.64	16.64
0	EFSFSR7 (at Fiddle Creek)	0.60	11.68	11.68	11.68	8.03	8.03	8.03	16.13	16.13	16.13
0	EFSFSR8	0.39	11.71	11.71	11.71	8.03	8.03	8.03	16.21	16.21	16.21
0	EFSFSR8	0.21	11.73	11.73	11.73	8.03	8.03	8.03	16.28	16.28	16.28
0	EFSFSR9 (at Midnight Cree	0.06	11.71	11.71	11.71	8.09	8.09	8.09	16.16	16.16	16.16
0	Terminus	0.00	11.71	11.71	11.71	8.09	8.09	8.09	16.16	16.16	16.16
1	EFSFSR Trib 4	0.63	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
1	EFSRSR Trib 4 Headwater	0.53	8.57	8.57	8.57	6.07	6.07	6.07	11.75	11.75	11.75
1	EFSRSR Trib 4 Headwater	0.32	8.81	8.81	8.81	6.37	6.37	6.37	11.98	11.98	11.98
1	EFSRSR Trib 4 Headwater	0.11	9.03	9.03	9.03	6.59	6.59	6.59	12.20	12.20	12.20

ISS Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature	
		(km)	deg C			deg C			deg C	
Tributary	Reach Label		Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L
1	Terminus	0.00	9.03	9.03	9.03	6.59	6.59	6.59	12.20	12.20	12.20
2	Meadow Creek	7.26	10.86	10.86	10.86	7.76	7.76	7.76	14.58	14.58	14.58
2	Meadow Creek Headwater	7.16	11.03	11.03	11.03	8.47	8.47	8.47	14.34	14.34	14.34
2	Meadow Creek Headwater	6.96	11.15	11.15	11.15	8.86	8.86	8.86	14.19	14.19	14.19
2	Meadow Creek Headwater	6.76	11.24	11.24	11.24	9.10	9.10	9.10	14.10	14.10	14.10
2	Meadow Creek Headwater	6.56	11.31	11.31	11.31	9.27	9.27	9.27	14.05	14.05	14.05
2	Meadow Creek Headwater	6.36	11.36	11.36	11.36	9.39	9.39	9.39	14.02	14.02	14.02
2	Meadow Creek Headwater	6.16	11.41	11.41	11.41	9.47	9.47	9.47	14.01	14.01	14.01
2	Meadow Creek Headwater	5.96	11.44	11.44	11.44	9.54	9.54	9.54	14.02	14.02	14.02
2	MC1	5.76	11.50	11.50	11.50	9.58	9.58	9.58	14.08	14.08	14.08
2	MC1	5.57	11.55	11.55	11.55	9.62	9.62	9.62	14.14	14.14	14.14
2	MC1	5.38	11.59	11.59	11.59	9.65	9.65	9.65	14.19	14.19	14.19
2	MC1	5.18	11.62	11.62	11.62	9.66	9.66	9.66	14.24	14.24	14.24
2	MC1	4.99	11.65	11.65	11.65	9.68	9.68	9.68	14.28	14.28	14.28
2	MC1	4.80	11.68	11.68	11.68	9.69	9.69	9.69	14.33	14.33	14.33
2	MC2 (at MC Trib 2)	4.62	11.30	11.30	11.30	9.59	9.59	9.59	13.76	13.76	13.76
2	MC2 (at MC Trib 2)	4.45	11.27	11.27	11.27	9.58	9.58	9.58	13.73	13.73	13.73
2	MC4 (at MC Trib 3)	4.27	10.74	10.74	10.74	9.17	9.17	9.17	12.82	12.82	12.82
2	MC4 (at MC Trib 3)	4.09	10.80	10.80	10.80	9.19	9.19	9.19	12.94	12.94	12.94
2	MC4 (at MC Trib 3)	3.91	10.86	10.86	10.86	9.21	9.21	9.21	13.05	13.05	13.05
2	MC4 (at MC Trib 3)	3.73	10.92	10.92	10.92	9.22	9.22	9.22	13.16	13.16	13.16
2	MC4 (at MC Trib 3)	3.55	10.97	10.97	10.97	9.24	9.24	9.24	13.26	13.26	13.26
2	MC6	3.36	11.29	11.29	11.29	9.16	9.16	9.16	14.19	14.19	14.19
2	MC6	3.15	11.59	11.59	11.59	9.07	9.07	9.07	15.14	15.14	15.14
2	MC6	2.95	11.88	11.88	11.88	8.98	8.98	8.98	16.02	16.02	16.02
2	MC6	2.75	12.15	12.15	12.15	8.90	8.90	8.90	16.85	16.85	16.85
2	MC6	2.54	12.41	12.41	12.41	8.82	8.82	8.82	17.61	17.61	17.61
2	MC7	2.35	12.60	12.60	12.60	8.75	8.75	8.75	18.25	18.25	18.25
2	MC7	2.16	12.78	12.78	12.78	8.68	8.68	8.68	18.84	18.84	18.84
2	MC7	1.98	12.96	12.96	12.96	8.62	8.62	8.62	19.40	19.40	19.40
2	MC7	1.79	13.13	13.13	13.13	8.56	8.56	8.56	19.91	19.91	19.91
2	MC7	1.60	13.29	13.29	13.29	8.50	8.50	8.50	20.39	20.39	20.39
2	MC8 (at East Fork MC)	1.41	13.00	13.00	13.00	8.56	8.56	8.56	19.63	19.63	19.63
2	MC8 (at East Fork MC)	1.22	13.07	13.07	13.07	8.57	8.57	8.57	19.79	19.79	19.79
2	MC8 (at East Fork MC)	1.03	13.14	13.14	13.14	8.58	8.58	8.58	19.94	19.94	19.94
2	MC8 (at East Fork MC)	0.84	13.20	13.20	13.20	8.58	8.58	8.58	20.08	20.08	20.08
2	MC8 (at East Fork MC)	0.65	13.26	13.26	13.26	8.59	8.59	8.59	20.21	20.21	20.21
2	MC8 (at East Fork MC)	0.46	13.33	13.33	13.33	8.60	8.60	8.60	20.34	20.34	20.34
2	MC10	0.27	13.34	13.34	13.34	8.59	8.59	8.59	20.33	20.33	20.33
2	MC10	0.09	13.35	13.35	13.35	8.59	8.59	8.59	20.31	20.31	20.31
2	Terminus	0.00	13.35	13.35	13.35	8.59	8.59	8.59	20.31	20.31	20.31
3	Meadow Creek Trib 2	1.36	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
3	MC Trib 2 Headwater	1.27	9.27	9.27	9.27	7.32	7.32	7.32	12.00	12.00	12.00
3	MC Trib 2 Headwater	1.08	9.82	9.82	9.82	8.18	8.18	8.18	12.34	12.34	12.34

ISS Output										
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature	
		(km)	deg C			deg C			deg C	
Tributary	Reach Label		Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L
3	MC Trib 2 Headwater	0.89	10.16	10.16	10.16	8.67	8.67	8.67	12.61	12.61	12.61
3	MC Trib 2 Headwater	0.70	10.40	10.40	10.40	8.98	8.98	8.98	12.87	12.87	12.87
3	MC3	0.50	10.53	10.53	10.53	9.20	9.20	9.20	12.80	12.80	12.80
3	MC3	0.30	10.62	10.62	10.62	9.35	9.35	9.35	12.78	12.78	12.78
3	MC3	0.10	10.68	10.68	10.68	9.46	9.46	9.46	12.77	12.77	12.77
3	Terminus	0.00	10.68	10.68	10.68	9.46	9.46	9.46	12.77	12.77	12.77
4	Meadow Creek Trib 3	1.59	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
4	MC Trib 3 Headwater	1.50	8.60	8.60	8.60	6.30	6.30	6.30	11.44	11.44	11.44
4	MC Trib 3 Headwater	1.31	8.85	8.85	8.85	6.85	6.85	6.85	11.41	11.41	11.41
4	MC Trib 3 Headwater	1.12	9.05	9.05	9.05	7.28	7.28	7.28	11.39	11.39	11.39
4	MC Trib 3 Headwater	0.93	9.21	9.21	9.21	7.62	7.62	7.62	11.38	11.38	11.38
4	MC5	0.73	9.34	9.34	9.34	7.86	7.86	7.86	11.34	11.34	11.34
4	MC5	0.52	9.45	9.45	9.45	8.06	8.06	8.06	11.30	11.30	11.30
4	MC5	0.31	9.54	9.54	9.54	8.22	8.22	8.22	11.27	11.27	11.27
4	MC5	0.10	9.61	9.61	9.61	8.36	8.36	8.36	11.24	11.24	11.24
4	Terminus	0.00	9.61	9.61	9.61	8.36	8.36	8.36	11.24	11.24	11.24
5	East Fork Meadow Creek	4.41	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
5	East Fork MC Headwater	4.31	8.67	8.67	8.67	6.22	6.22	6.22	11.85	11.85	11.85
5	East Fork MC Headwater	4.11	9.00	9.00	9.00	6.66	6.66	6.66	12.16	12.16	12.16
5	East Fork MC Headwater	3.92	9.28	9.28	9.28	7.01	7.01	7.01	12.43	12.43	12.43
5	East Fork MC Headwater	3.72	9.53	9.53	9.53	7.30	7.30	7.30	12.68	12.68	12.68
5	East Fork MC Headwater	3.52	9.75	9.75	9.75	7.54	7.54	7.54	12.92	12.92	12.92
5	East Fork MC Headwater	3.33	9.94	9.94	9.94	7.74	7.74	7.74	13.13	13.13	13.13
5	East Fork MC Headwater	3.13	10.12	10.12	10.12	7.92	7.92	7.92	13.33	13.33	13.33
5	East Fork MC Headwater	2.93	10.27	10.27	10.27	8.07	8.07	8.07	13.51	13.51	13.51
5	East Fork MC Headwater	2.73	10.41	10.41	10.41	8.21	8.21	8.21	13.68	13.68	13.68
5	East Fork MC Headwater	2.54	10.54	10.54	10.54	8.32	8.32	8.32	13.84	13.84	13.84
5	East Fork MC Headwater	2.34	10.66	10.66	10.66	8.43	8.43	8.43	13.99	13.99	13.99
5	East Fork MC Headwater	2.14	10.77	10.77	10.77	8.52	8.52	8.52	14.13	14.13	14.13
5	East Fork MC Headwater	1.95	10.86	10.86	10.86	8.61	8.61	8.61	14.26	14.26	14.26
5	East Fork MC Headwater	1.75	10.96	10.96	10.96	8.68	8.68	8.68	14.38	14.38	14.38
5	MC9	1.55	11.10	11.10	11.10	8.70	8.70	8.70	14.80	14.80	14.80
5	MC9	1.34	11.23	11.23	11.23	8.71	8.71	8.71	15.19	15.19	15.19
5	MC9	1.13	11.36	11.36	11.36	8.72	8.72	8.72	15.54	15.54	15.54
5	MC9	0.93	11.47	11.47	11.47	8.73	8.73	8.73	15.85	15.85	15.85
5	MC9	0.72	11.57	11.57	11.57	8.74	8.74	8.74	16.13	16.13	16.13
5	MC9	0.52	11.66	11.66	11.66	8.74	8.74	8.74	16.38	16.38	16.38
5	MC9	0.31	11.75	11.75	11.75	8.74	8.74	8.74	16.62	16.62	16.62
5	MC9	0.10	11.83	11.83	11.83	8.75	8.75	8.75	16.83	16.83	16.83
5	Terminus	0.00	11.83	11.83	11.83	8.75	8.75	8.75	16.83	16.83	16.83
6	Garnet Creek	1.84	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
6	Garnet Creek Headwater	1.73	10.25	10.25	10.25	8.84	8.84	8.84	12.20	12.20	12.20
6	Garnet Creek Headwater	1.51	10.70	10.70	10.70	9.42	9.42	9.42	12.45	12.45	12.45
6	Garnet Creek Headwater	1.29	10.88	10.88	10.88	9.59	9.59	9.59	12.58	12.58	12.58

ISS Output											
		Distance	Average Temperature			Minimum Temperature			Maximum Temperature		
		(km)	deg C			deg C			deg C		
Tributary	Reach Label		Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L	Calibration	5 mg/L	10 mg/L
6	Garnet Creek Headwater	1.07	10.96	10.96	10.96	9.65	9.65	9.65	12.67	12.67	12.67
6	Garnet Creek Headwater	0.85	11.01	11.01	11.01	9.65	9.65	9.65	12.74	12.74	12.74
6	GC1	0.65	11.10	11.10	11.10	9.65	9.65	9.65	12.87	12.87	12.87
6	GC1	0.46	11.17	11.17	11.17	9.64	9.64	9.64	12.99	12.99	12.99
6	GC1	0.28	11.22	11.22	11.22	9.62	9.62	9.62	13.09	13.09	13.09
6	GC1	0.09	11.25	11.25	11.25	9.59	9.59	9.59	13.23	13.23	13.23
6	Terminus	0.00	11.25	11.25	11.25	9.59	9.59	9.59	13.23	13.23	13.23
7	Fiddle Creek	2.79	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
7	Fiddle Creek Headwater	2.70	8.41	8.41	8.41	5.97	5.97	5.97	11.39	11.39	11.39
7	Fiddle Creek Headwater	2.53	8.52	8.52	8.52	6.30	6.30	6.30	11.31	11.31	11.31
7	Fiddle Creek Headwater	2.36	8.62	8.62	8.62	6.58	6.58	6.58	11.25	11.25	11.25
7	FC1 (at Fiddle Creek Trib	2.19	8.68	8.68	8.68	6.94	6.94	6.94	11.02	11.02	11.02
7	FC1 (at Fiddle Creek Trib	2.02	8.76	8.76	8.76	7.09	7.09	7.09	11.03	11.03	11.03
7	FC2	1.84	8.85	8.85	8.85	7.25	7.25	7.25	11.00	11.00	11.00
7	FC2	1.65	8.93	8.93	8.93	7.38	7.38	7.38	10.97	10.97	10.97
7	FC2	1.46	9.00	9.00	9.00	7.49	7.49	7.49	10.95	10.95	10.95
7	FC2	1.26	9.06	9.06	9.06	7.58	7.58	7.58	10.93	10.93	10.93
7	FC2	1.07	9.12	9.12	9.12	7.67	7.67	7.67	10.91	10.91	10.91
7	FC2	0.87	9.17	9.17	9.17	7.75	7.75	7.75	10.89	10.89	10.89
7	FC2	0.68	9.21	9.21	9.21	7.81	7.81	7.81	10.87	10.87	10.87
7	FC2	0.49	9.25	9.25	9.25	7.88	7.88	7.88	10.85	10.85	10.85
7	FC2	0.29	9.29	9.29	9.29	7.93	7.93	7.93	10.83	10.83	10.83
7	FC2	0.10	9.32	9.32	9.32	7.98	7.98	7.98	10.82	10.82	10.82
7	Terminus	0.00	9.32	9.32	9.32	7.98	7.98	7.98	10.82	10.82	10.82
8	Midnight Creek	2.99	8.29	8.29	8.29	5.60	5.60	5.60	11.49	11.49	11.49
8	Midnight Creek Headwater	2.89	10.05	10.05	10.05	8.75	8.75	8.75	11.64	11.64	11.64
8	Midnight Creek Headwater	2.69	10.47	10.47	10.47	9.37	9.37	9.37	11.71	11.71	11.71
8	Midnight Creek Headwater	2.49	10.64	10.64	10.64	9.57	9.57	9.57	11.75	11.75	11.75
8	Midnight Creek Headwater	2.29	10.71	10.71	10.71	9.64	9.64	9.64	11.78	11.78	11.78
8	Midnight Creek Headwater	2.09	10.75	10.75	10.75	9.65	9.65	9.65	11.80	11.80	11.80
8	Midnight Creek Headwater	1.89	10.76	10.76	10.76	9.64	9.64	9.64	11.83	11.83	11.83
8	Midnight Creek Headwater	1.69	10.76	10.76	10.76	9.62	9.62	9.62	11.86	11.86	11.86
8	Midnight Creek Headwater	1.50	10.75	10.75	10.75	9.58	9.58	9.58	11.89	11.89	11.89
8	Midnight Creek Headwater	1.30	10.74	10.74	10.74	9.55	9.55	9.55	11.90	11.90	11.90
8	Midnight Creek Headwater	1.10	10.73	10.73	10.73	9.51	9.51	9.51	11.91	11.91	11.91
8	Midnight Creek Headwater	0.90	10.72	10.72	10.72	9.47	9.47	9.47	11.91	11.91	11.91
8	Midnight Creek Headwater	0.70	10.70	10.70	10.70	9.43	9.43	9.43	11.91	11.91	11.91
8	Midnight Creek Headwater	0.50	10.68	10.68	10.68	9.40	9.40	9.40	11.92	11.92	11.92
8	Midnight Creek Headwater	0.30	10.67	10.67	10.67	9.36	9.36	9.36	11.92	11.92	11.92
8	Midnight Creek Headwater	0.10	10.65	10.65	10.65	9.32	9.32	9.32	11.92	11.92	11.92
8	Terminus	0.00	10.65	10.65	10.65	9.32	9.32	9.32	11.92	11.92	11.92

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
501 West Ocean Boulevard, Suite 4200
LONG BEACH, CA 90802

Refer to NMFS No: WCRO-2023-02924

https://doi.org/10.25923/6zyd-4t83

October 7, 2024

Mr. Matthew Davis
Forest Supervisor
Payette National Forest
500 North Mission Street, Building 2
McCall, Idaho 83638

Lt. Col. Kathryn Werback
U.S. Army Corps of Engineers
Walla Walla District
201 N. 3rd Avenue
Walla Walla, Washington 99362-1876

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Stibnite Gold Project, South Fork Salmon River HUC 17060208, Valley County, Idaho; Lemhi River HUC 17060204, Lemhi County, Idaho.

Dear Mr. Davis and Lt. Col. Werback:

Thank you for your letter of March 26, 2024, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for the Stibnite Gold Project. Thank you, also, for your request for consultation pursuant to the essential fish habitat (EFH) provisions in Section 305(b) of the Magnuson–Stevens Fishery Conservation and Management Act (MSA) [16 U.S.C. 1855(b)] for this action. Upon review, we determined your submittal was sufficient and initiated consultation on March 26, 2024. On July 25, 2024, the U.S. Forest Service (USFS) submitted additional information, modifying the proposed action.

In this biological opinion (opinion), NMFS concludes that the action, as proposed, is not likely to jeopardize the continued existence of Snake River (SR) spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) and SR Basin steelhead (*O. mykiss*). NMFS also determined the action will not destroy or adversely modify designated critical habitat for these species. Rationale for our conclusions is provided in the attached opinion.

The USFS and the U.S. Army Corps of Engineers (USACE) also determined that the proposed action may affect, but is not likely to adversely affect Southern Resident killer whale (*Orcinus orca*) and their designated critical habitat. NMFS concurs with this determination and provides the rationale for this determination in this opinion.

As required by section 7 of the ESA, NMFS provides an incidental take statement (ITS) with the opinion. The ITS describes reasonable and prudent measures (RPM) NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The take statement sets forth terms and conditions, including reporting requirements, that the USFS, USACE, Perpetua Resources, Inc., and any permittee who performs any portion of the action, must comply with in order to be exempt from the ESA take prohibition.

This document also includes the results of our analysis of the action's effects on EFH pursuant to section 305(b) of the MSA, and includes thirteen Conservation Recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. These Conservation Recommendations are similar, but not identical to the ESA terms and conditions. Section 305(b)(4)(B) of the MSA requires federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations. If the response is inconsistent with the EFH Conservation Recommendations, the USFS and USACE must explain why the recommendations will not be followed, including the justification for any disagreements over the effects of the action and the recommendations. In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many Conservation Recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, in your statutory reply to the EFH portion of this consultation, NMFS asks that you clearly identify the number of Conservation Recommendations accepted.

Please contact Bill Lind, Southern Snake Branch Office, at (208) 391-1282, Bill.lind@noaa.gov or Johnna Sandow, Northern Snake Branch Office, at (208) 378-5737, Johnna.sandow@noaa.gov if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Jennifer Quan
Regional Administrator
West Coast Region

Enclosure

cc: K. Knesek – PNF
R. Rymerson - PNF
C. Nalder – PNF
K. Urbanek - USACE
B. Wilson - USACE
K. Hendricks - USFWS
C. Wise - USFWS
M. Lopez - NPT
C. Colter – SBT
B. Gibson - SPT

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response

Stibnite Gold Project

NMFS Consultation Number: WCRO-2023-02924

Action Agencies: USDA Forest Service
U.S. Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	If Likely to Adversely Affect, Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	If Likely to Adversely Affect, Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha)*	Threatened	Yes	No	Yes	No
Snake River Basin steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Southern Resident Killer Whale (*Orcinus orca*)	Endangered	No	N/A	No	NA

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By: [signature]

Jennifer Quan
Regional Administrator
West Coast Region
National Marine Fisheries Service

Date: *October 7, 2024*

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

ACRONYMS

6PPD-q	N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine-quinone
7DADM	7-day Average of the Daily Maximum
AADT	Annual Average Daily Traffic
ACS	Aquatic Conservation Strategy
ADFG	Alaska Department of Fish and Game
AFD	Acre-feet/day
AMSL	Above Mean Sea Level
APLIC	Avian Power Line Interaction Committee
ASAOC	Administrative Settlement Agreement and Order on Consent
BA	Biological Assessment
BC	Blowout Creek
BCY	Bank Cubic Yards
BMI	Benthic Macroinvertebrates
BMP	Best Management Practice
BNF	Boise National Forest
BOR	Bureau of Reclamation
BRGI	Burntlog Route Geophysical Investigation
$CaCl_2$	Calcium Chloride
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CMP	Compensatory Stream and Wetland Mitigation Plan
CR	County Road
CUP	Conditional Use Permit
CWA	Clean Water Act
dB	Decibel
DCH	Designated Critical Habitat
DCPT	Dynamic Cone Penetrometer Testing
District	Stibnite-Yellow Pine Mining District
DRSF	Development Rock Storage Facility
DO	Dissolved Oxygen
DPS	Distinct Population Segment
DQA	Data Quality Act
dw	Dry Weight
EC_x	Effect Concentration eliciting an "X" percent response or Effect Concentration affecting "X" percent of the test population
ECA	Equivalent Clearcut Area
eDNA	Environmental Deoxyribonucleic Acid
EDF	Environmental Design Features
EFH	Essential Fish Habitat

EFMC	East Fork Meadow Creek
EFSFSR	East Fork South Fork Salmon River
EMMP	Environmental Monitoring and Management Plan
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FA	Functioning Appropriately
FAA	Federal Aviation Administration
FAR	Functioning at Risk
FC-RNRW	Frank Church River of No Return Wilderness
FMP	Fishery Management Plan
FOMP	Fishway Operations and Management Plan
FR	Forest Road
FT	Feet/foot
FPS	Feet Per Second
FUR	Functioning at Unacceptable Risk
FWS	U.S. Fish and Wildlife Service
GCL	Geosynthetic Clay Liner
GIS	Geographic Information System
GM	Growth Media
GMS	Growth Media Stockpile
GPD	Gallons Per Day
GPM	Gallons Per Minute
HAC	Hot Arsenic Cure
HAPC	Habitat Area of Particular Concern
HFP	Hangar Flats Pit
HUC	Hydrologic Unit Code
IARB	Interagency Agency Review Board
ICTRT	Interior Columbia Technical Recovery Team
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IDL	Idaho Department of Lands
IDWR	Idaho Department of Water Resources
IPC	Idaho Power Company
IDPES	Idaho Pollution Discharge Elimination System
IPS	Inches Per Second
IRMA	Initiative for Responsible Mining Assurance
ISAB	Independent Scientific Advisory Board
ITS	Incidental Take Statement
IWRB	Idaho Water Resource Board

kV	Kilovolt
kPA	Kilopascals
LC_x	Lethal Concentration Killing "X" Percent of Test Organisms
LRLT	Lemhi Regional Land Trust
LWD	Large Woody Debris
MBR	Membrane Bioreactor
MFSR	Middle Fork Salmon River
$MgCl_2$	Magnesium Chloride
mg/kg	Milligrams Per Kilogram
mg/l	Milligrams Per Liter
MMP	Modified Mine Plan
MPG	Major Population Group
MSA	Magnuson–Stevens Fishery Conservation and Management Act
MSGP	Multi-Sector General Permit
MSHA	Mine Safety and Health Administration
MTI	Metals Tolerant Index
MW	Megawatt
MWAM	Montana Wetland Assessment Method
MWMT	Maximum Weekly Maximum Temperatures
MY	Mine Year
NEPA	National Environmental Policy Act
NFS	National Forest System
ng/l	Nanograms Per Liter
NMFS	National Marine Fisheries Service
NPT	Nez Perce Tribe
NTU	Nephelometric Turbidity Units
opinion	Biological Opinion
OHV	Off-highway Vehicle
OHWM	Ordinary High-Water Mark
OSC	Idaho Governor's Office of Species Conservation
OSV	Over-snow Vehicle
PAB	Palustrine Aquatic Bed
PAG	Potentially Acid Generating
PAH	Petroleum Aromatic Hydrocarbons
PBF	Physical or Biological Feature
PCE	Primary Constituent Element
PDF	Project Design Features
PEM	Palustrine Emergent Marsh
PFAS	Polyflouryl Alkyl Substances
PFO	Palustrine Forested
Perpetua	Perpetua Resources Idaho, Inc.

PIT	Passive Integrated Transponder
PNF	Payette National Forest
POD	Points of Diversion
PPV	Peak Particle Velocity
PRISM	Parameter-elevation Regressions on Independent Slope Model
PSI	Pounds Per Square Inch
PSS	Palustrine Scrub-shrub
RCA	Riparian Conservation Area
RCP	Reclamation and Closure Plan
RM	River Mile
RO	Reverse Osmosis
ROD	Record of Decision
ROW	Right of Way
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
SBM	Seed Bank Material
SDRR	Storm Damage Risk Reduction
SGLF	Stibnite Gold Logistics Facility
SGP	Stibnite Gold Project
SFSR	South Fork Salmon River
SKRW	Southern Resident Killer Whale
SODA	Spent Ore Disposal Area
SOP	Standard Operating Procedures
SPLNT	Stream and Pit Lake Network Temperature
SPPC	Spill Prevention, Control and Countermeasure
SPPP	Stormwater Pollution Prevention Plan
SR	Snake River
SWWC	Site-wide Water Chemistry
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TMP	Transportation Management Plan
TSF	Tailings Storage Facility
TSS	Total Suspended Solids
µg/L	Micrograms Per Liter
U.S.C.	U.S. Code
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Service
USGCRP	U.S. Global Change Research Program
VHF	Very High Frequency

VSP	Viable Salmonid Population
WAD	Weak Acid Dissociable
W:D	Width to Depth Ratio
WCI	Watershed Condition Indicator
WEP	West End Pit
WET	Whole Effluent Toxicity
WOTUS	Waters of the United States
WRMP	Water Resources Monitoring Plan
WSR	Wild and Scenic River
WTP	Water Treatment Plant
ww	Wet Weight
YPP	Yellow Pine Pit

1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1. Background

National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson–Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available within 2 weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at the Snake Basin Office in Boise, Idaho.

1.2. Consultation History

Perpetua Resources Idaho, Inc. (Perpetua) proposed the Stibnite Gold Project (SGP or Project) in central Idaho. The mine at Stibnite occurs on private, state, and public lands administered by the Boise National Forest (BNF), Payette National Forest (PNF), and the Bureau of Reclamation (BOR) in Valley County, Idaho (Figure 1), while the Lemhi River restoration portion of the project occurs in Lemhi County, Idaho (Figure 2). The SGP is located in the Stibnite-Yellow Pine Mining District (District) in central Idaho, near the Frank Church River of No Return Wilderness (FC-RNRW) and along the Lemhi River downstream from Leadore, Idaho. A summary of the consultation history follows. For a more detailed description of early coordination efforts and the consultation history, please see Appendix A of the final biological assessment (BA) (Stantec 2024).

NMFS and the U.S. Fish and Wildlife Service (FWS) have been meeting with the action agencies monthly since 2018 in early coordination efforts. Regularly scheduled (monthly) consultation meetings were initiated on June 21, 2018, with participation of the U.S. Forest Service (USFS), AECOM (USFS contractor), Perpetua, FWS, NMFS, U.S. Army Corps of Engineers (USACE), and the U.S. Environmental Protection Agency (EPA). Meetings continued through March 2020, and covered a wide variety of topics related to analysis methodology, data, BA preparation, etc.

The PNF and USACE submitted their first draft BA on October 26, 2023. Upon review of the draft BA, NMFS issued an insufficiency letter on November 22, 2023, outlining information needed in order to provide a complete initiation package. The action agencies and their contractor Stantec later met with NMFS and the FWS via conference call to discuss their approach to BA revisions on January 22 and February 7, 2024. A revised BA was submitted to NMFS on March 26, 2024, and consultation was initiated at this time.

The BNF initiated informal consultation for the permitting of Perpetua's Burntlog Route Geophysical Investigation (BRGI) Project on February 24, 2022. NMFS issued a concurrence letter for the project on March 14, 2022 (NMFS No: WCRO-2022-00428). On July 11, 2024, the BNF withdrew approval for the BRGI. Approval for the BRGI will now be considered in the NEPA decision for the larger SGP. On July 25, 2024, NMFS received a letter from the PNF transmitting a revised BA, fully incorporating the BRGI project into the SGP proposed action.

The USFS, as the lead Federal agency, evaluated the mining project proposal under regulations found at 36 Code of Federal Regulations (CFR) 228 subpart A, submitting the BA in accordance with Section 7 of the ESA (16 United States Code [USC] 1536(c)) and Section 305(b) of the MSA. In addition, the USACE evaluated the SGP per its requirements under the Clean Water Act (CWA). The USFS' approval of the Plan of Restoration and Operations, and the USACE's issuance of the CWA 404 permit, provide the federal nexus to ESA consultation. The PNF designated Perpetua as the non-federal representative for the SGP on March 14, 2018. The PNF also granted Perpetua applicant status for the SGP on August 30, 2017.

In the BA, the action agencies determined that the proposed action "may affect," and is "likely to adversely affect Snake River (SR) spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), SR Basin steelhead (*O. mykiss*), and their designated critical habitats (DCH). The USFS also determined that the proposed action "may affect," but is "not likely to adversely affect" Southern Resident Killer Whale (SRKW) (*Orcinus orca*) and their DCH. Our concurrence is documented in the NLAA Determinations section (Section 2.21).

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures [RPMs]), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the Act. 89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015. We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this opinion and ITS would not have been any different under the 2019 regulations or pre-2019 regulations.

On August 8, 2024, NMFS provided a copy of the draft proposed action to the PNF. NMFS received an August 19, 2024 email from the PNF explaining they completed their review and the did not have any substantive comments or recommended changes for the propose action. We also shared a copy of the draft terms and conditions with the PNF, USACE, Nez Perce Tribe, Shoshone-Bannock Tribes, and Shoshone-Paiute Tribes on September 12, 2024.

In preparing this opinion, NMFS relied upon information from the BA (Stantec 2024) and its supporting documentation, published scientific literature, and various government documents (e.g., recovery plans, 5-year reviews, listing decisions, etc.). This information provided the basis for our determinations as to whether the PNF and USACE can ensure that their proposed action is not likely to jeopardize the continued existence of ESA-listed species, and is not likely to result in the destruction or adverse modification of DCH.

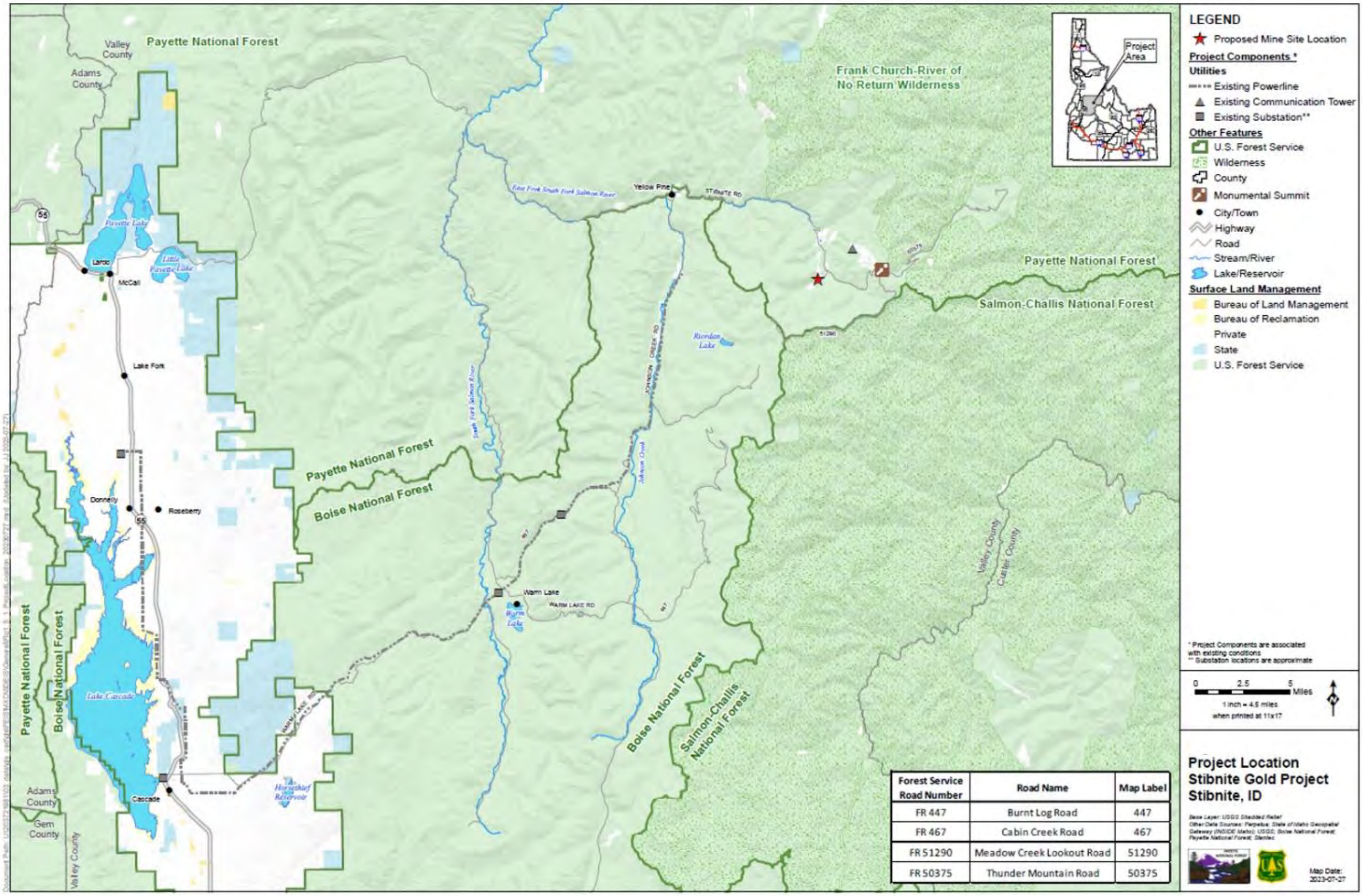


Figure 1. Stibnite Gold Project Location, Stibnite, Idaho.

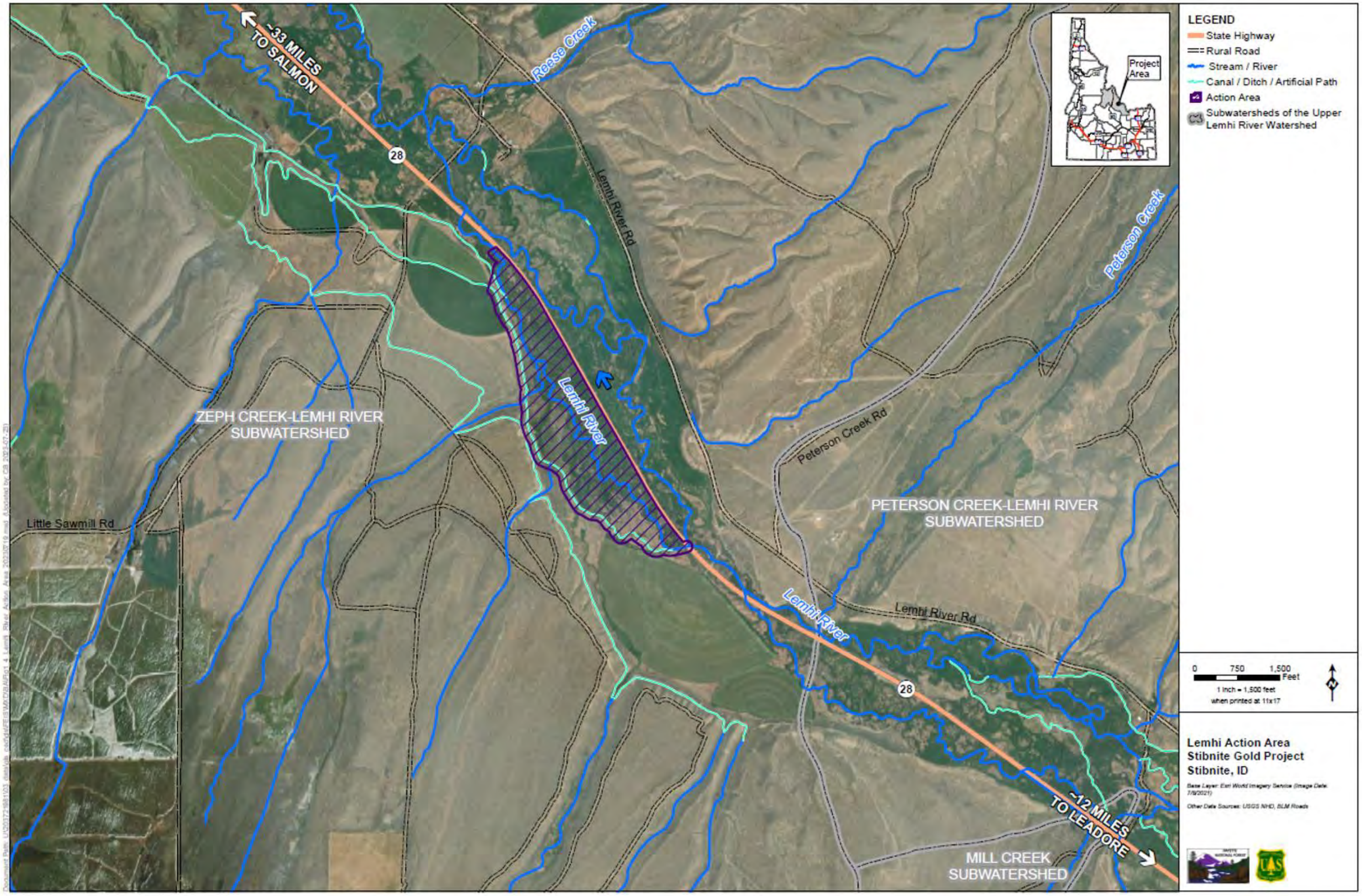


Figure 2. Lemhi River Restoration Project, Lemhi County, Idaho.

1.3. Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (see 50 CFR 402.02). Under the MSA, "Federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal agency (see 50 CFR 600.910).

This section of the opinion includes relevant excerpts of the proposed action as described in the BA (Stantec 2024), supplemented by additional information provided in the following support documents: Compensatory Stream and Wetland Mitigation Plan (CMP) (Tetra Tech 2023); Fisheries and Aquatic Resources Mitigation Plan (FMP) (Brown and Caldwell, Rio ASE, and BioAnalysts 2021); Fishway Operations and Management Plan (FOMP) (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021); and, the Stream Design Report (Rio ASE 2021).

1.3.1. Overview

The Proposed Action is based upon Perpetua's Modified Plan of Operations submitted in October 2021 for the SGP (Perpetua 2021a), referred to as the 2021 Modified Mine Plan (2021 MMP). Mine operations will occur on patented mining claims owned or controlled by Perpetua and on unpatented mining claims and other areas of federal public lands comprised of national forest system (NFS) lands that are administered by the PNF. Supporting infrastructure corridors (access and transmission line) are located on the BNF, Idaho Department of Lands (IDL), BOR, and non-federal lands. This document includes only sections of the proposed action relevant to effects on ESA-listed anadromous fish or their DCH. For a complete description of the proposed action, please see the BA (Stantec 2024).

Perpetua proposes to develop a mine operation that produces gold and silver doré, and antimony concentrates from ore deposits associated with their mining claims in the project area. The estimated recoverable mineral resource consists of: 4.2 million ounces of gold, 1.7 million ounces of silver, and 115 million pounds of antimony.

Development of the mineral resource will include construction of access and haul roads; construction of supporting infrastructure; open pit mining; ore processing; placement of tailings in a tailings storage facility (TSF); and placement of development rock. New access to the SGP will be provided by the proposed Burntlog Route, which will be a combination of widening the existing Burnt Log Road (Forest Road [FR] 447), Thunder Mountain Road (FR 50375), Meadow Creek Lookout Road (FR 51290), and constructing new connecting road segments of approximately 15 miles (Figure 3). Development of the Burntlog Route will entail 340.9 acres of new cut and fill activity (including borrow sources) along existing and newly constructed roadways.

To provide electric power for the SGP, an existing powerline will be upgraded and a new transmission line from a new Johnson Creek substation to the mine will be constructed. Additional off-site support facilities to be constructed along access corridors include the Stibnite Gold Logistics Facility (SGLF) and the Burntlog Access Route Maintenance Facility. The SGLF will house administrative offices, the assay laboratory, and a warehouse while the maintenance facility will be the headquarters for road maintenance and snow removal. The proposed facilities and access roads are shown on Figure 3 and Figure 4. The Operations Area Boundary shown on Figures 3 and 4 is the boundary within which Perpetua will control public access.

The proposed action includes activities that will result in permanent impacts to waters of the United States (WOTUS) including wetlands. Therefore, Perpetua has proposed a CMP as part of their CWA 404 permit. The CMP addresses compensatory mitigation for permanent impacts that will be accomplished through a combination of mitigation bank credits and the creation of new wetlands, streams, and enhancing and reclaiming existing wetlands and streams in the general vicinity of the impact areas. The CMP also addresses compensatory mitigation to reduce the temporal loss of aquatic functions and potential risks associated with actions described in the CMP.

As part of the CMP, Perpetua has proposed the Lemhi Regional Land Trust's (LRLT) Little Springs Conservation Easement and Restoration Project in an effort to use offsite mitigation to offset temporal losses to fish habitat in the SFSR drainage. The LRLT is negotiating a perpetual conservation easement for the property to ensure the restoration benefits and associated mitigation credits persist for at least the length of the predicted temporal loss for the SGP. This project reach is located on private ranch lands on the upper Lemhi River, approximately 12 miles northwest of Leadore, Idaho.

The components of the proposed action are described in the following sections in terms of overall land management and affected areas, and project phases: construction; operations; exploration; and closure and reclamation, including post-closure monitoring.

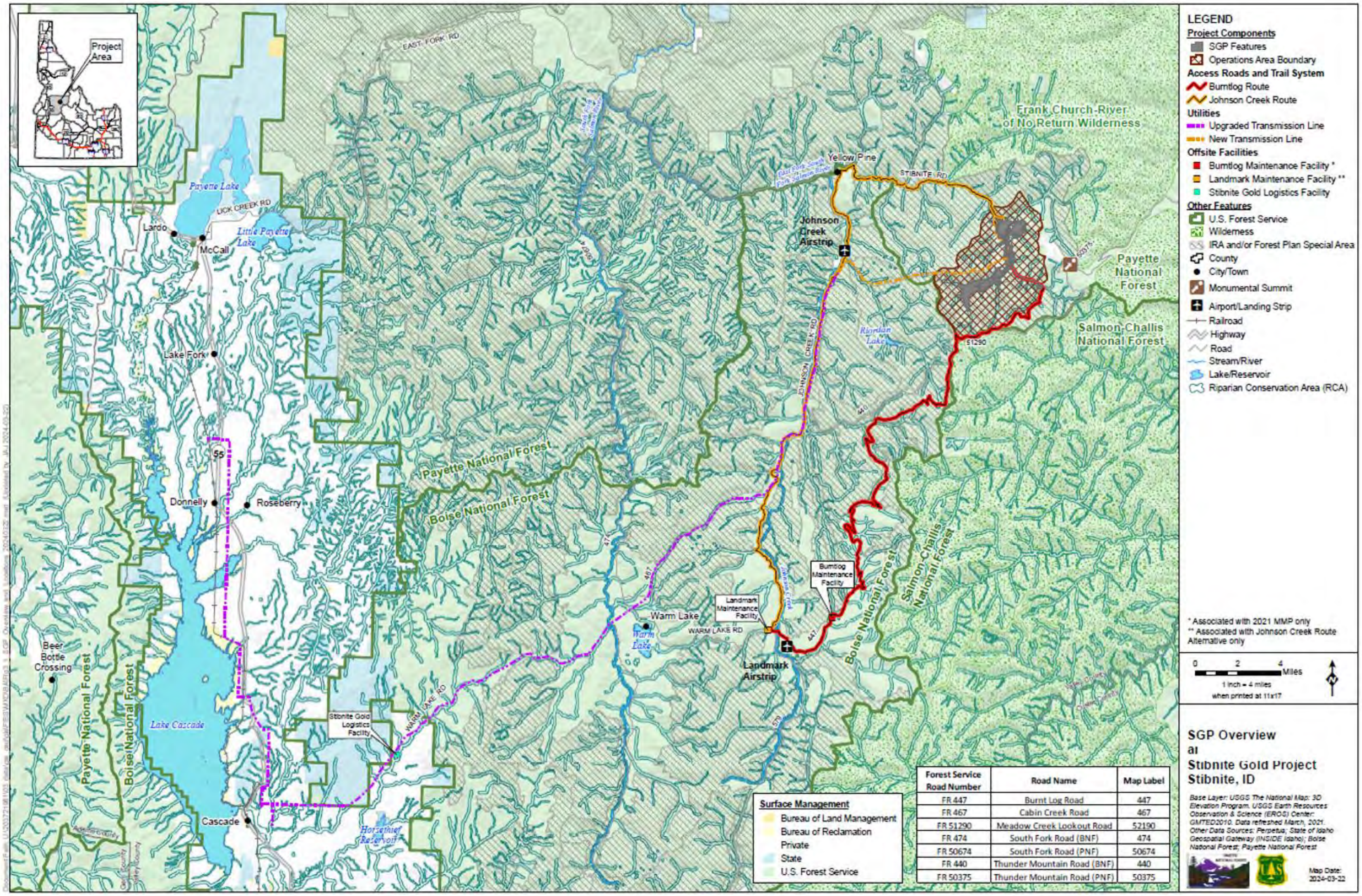


Figure 3. Project Overview and Location for the Stibnite Gold Project.

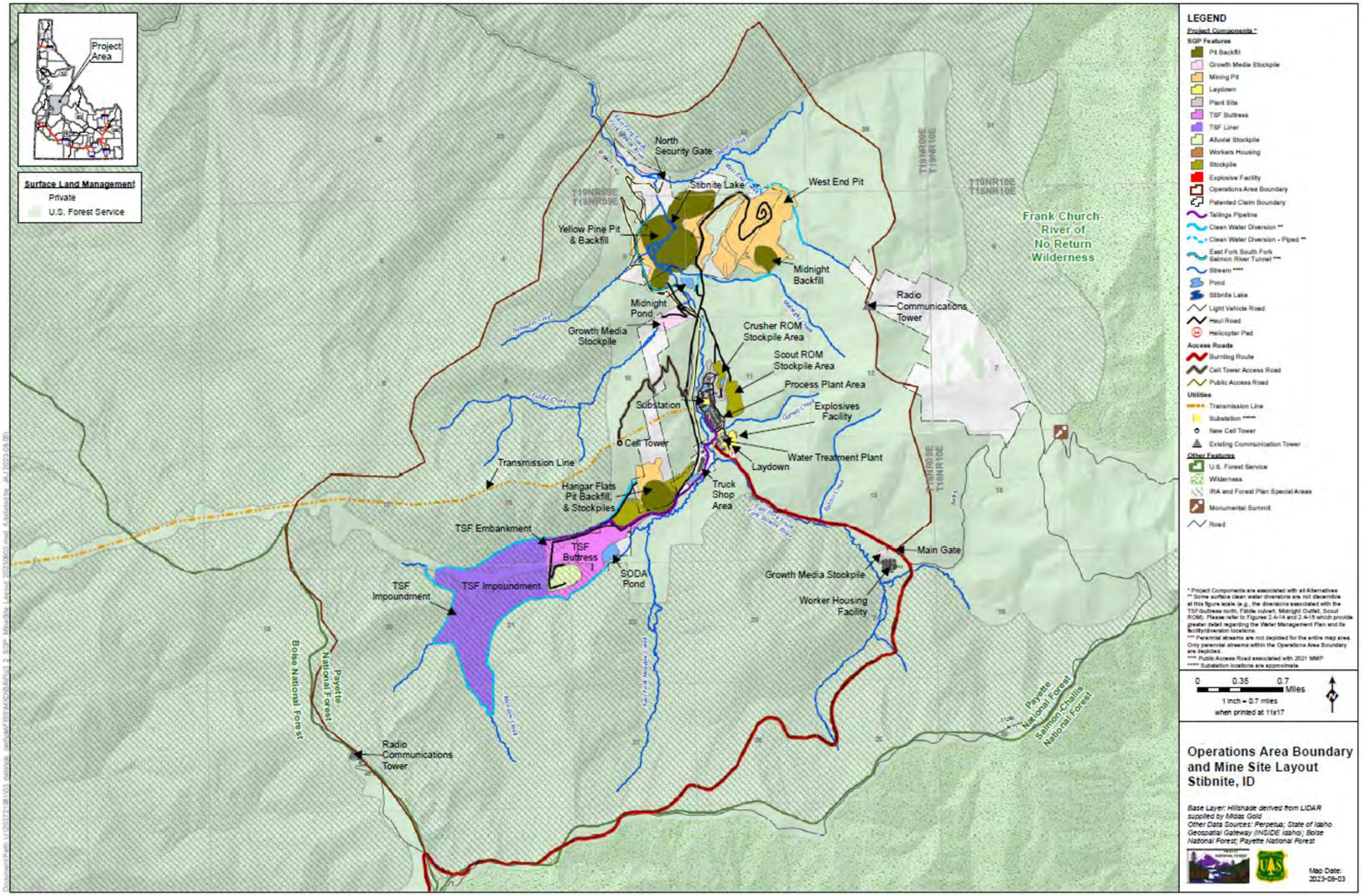


Figure 4. Operations Area Boundary and Mine Site Layout, Stibnite, Idaho.

1.4. Land Management and Affected Areas

Table 1 provides a summary of land management or ownership by estimated SGP component for the maximum affected area proposed and also includes acreages of new disturbance and re-disturbance by SGP component and ownership.

Table 1. Land Management and Acreage by Component for the Proposed Action.

Component		Perpetua Private	Other Private	PNF	BNF	SCNF[4]	BOR	IDL	Totals
Mine Site	New Disturbance	48.2	0	767.9 + 65[2]	0	0	0	0	881.1
	Re-disturbance	456.7	0	402.3	0	0	0	0	859.0
Off-site Facilities	New Disturbance	24.3	0	0	4.5	0	0	0	28.8
	Re-disturbance	0	0	0	0	0	0	0	0
Access Roads	New Disturbance	0	0	81.6	253.8	5.5	0	0	340.9
	Re-disturbance	1.9	4.5	26.9	102.5	8.7	0	0	144.5
Utilities[1]	New Disturbance	2.9	105.9	61.4	221.8	0	3.5	26.0	421.5
	Re-disturbance	1	174	19.4	350.6	0	9	36.1	590.1
Disturbance Totals	Total New Disturbance	75.4	105.9	910.9 + 65[2]	480.1	5.5	3.5	26.0	1,672.3
	Total Re-disturbance	459.6	178.5	448.6	453.1	8.7	9	36.1	1,593.6
Total New and Re-Disturbance		**535.0**	**284.4**	**1,424.5**	**933.2**	**14.2**	**12.5**	**62.1**	**3,265.9[3]**

Key: PNF – Payette National Forest; BNF – Boise National Forest; Salmon-Challis National Forest; BOR – Bureau of Reclamation; IDL – Idaho Department of Lands.

Notes: [1] Utilities affected areas include both existing utility corridors and access routes, and new utility corridors and access routes. Some existing utility access routes will be upgraded.

[2] Approximately 65 affected acres associated with temporary surface exploration pads and roads (SGP component) have an unknown land ownership because the exact locations of these exploration areas are not yet known; however, these are included in the PNF SGP subtotal.

[3] Items, subtotals, and totals may not add up to the grand total due to rounding.

[4] Approximately 14 acres of land is administered by the PNF but is within the boundary of the SCNF.

1.5. Phases and Timeline

The proposed action will take place over a period of approximately 20 to 25 years, not including the long-term, post-closure environmental monitoring or potential long-term water treatment. The phases of the SGP are described in subsequent sections and include: (1) construction (approximately 3 years; Mine Years (MY) -3 through -1); (2) mining and ore processing operations (approx. 15 years; MYs 1 through 15); (3) surface and underground exploration (approx. 17 years, beginning during construction and continuing concurrent with operations; MYs -2 through 15); and (4) closure and reclamation (MY 16+). Most activities in the Closure and Reclamation period will be completed within five years. However, closure water management and water treatment are expected to continue for as long as 25 years based on predictions for draindown and consolidation of the TSF (MYs 16 through 40) (Perpetua 2021a). The environmental monitoring phase will continue for as long as needed to demonstrate that the site has been fully reclaimed. Figure 5 provides an illustration of the timing of construction and operations activities and the initiation of the closure phase.

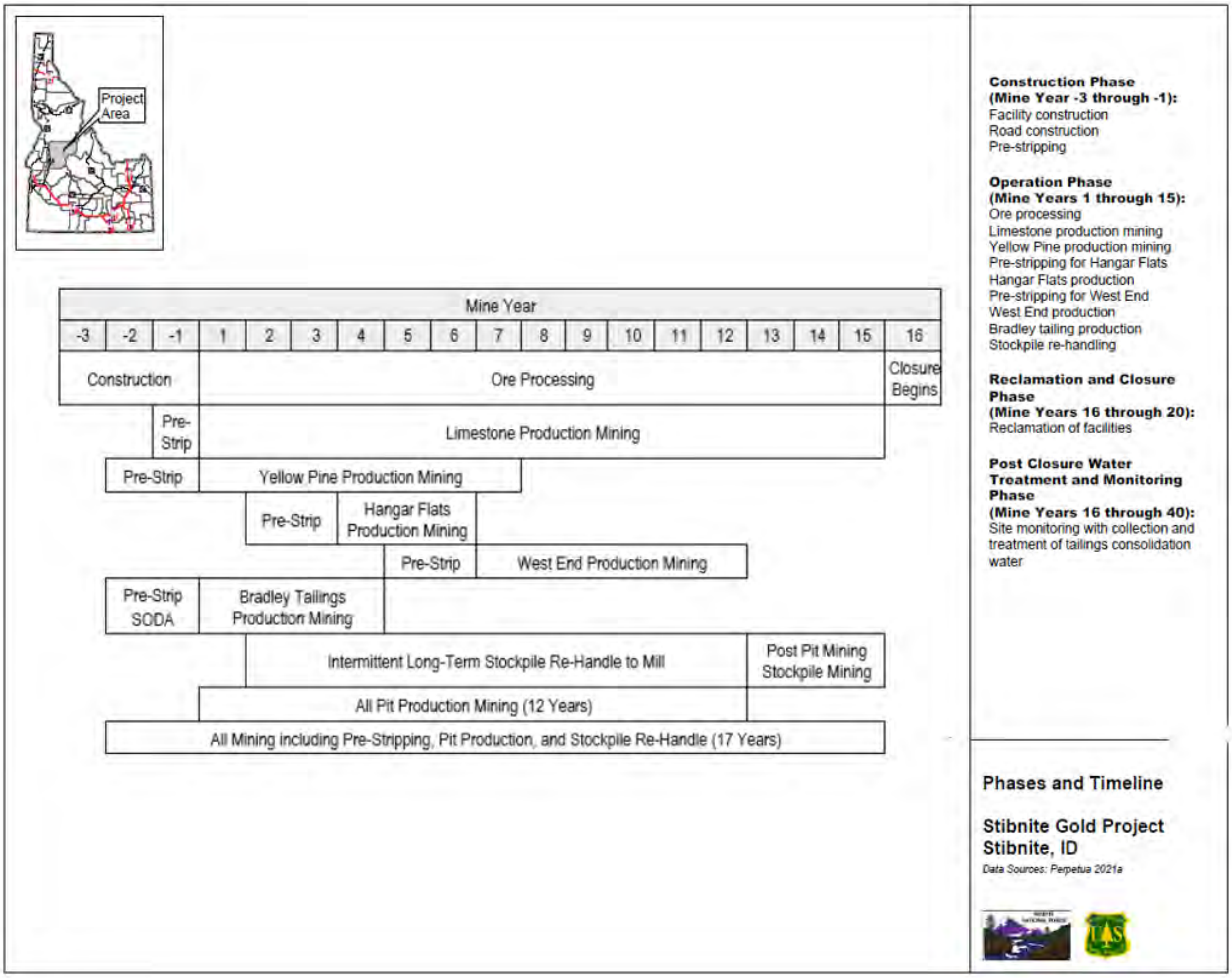


Figure 5. Stibnite Gold Project Phases and Timeline.

1.6. Site Preparation, Access, and Infrastructure

1.6.1. Overview

Preparing the proposed action will require construction of surface facilities, haul roads, and water management features. Environmental design features (EDF) for facilities associated with regulatory requirements are summarized in Table 2. Supporting infrastructure will include transmission lines, substations, communication sites, access roads, and a fish tunnel.

Additionally, removal of some features from past mining activities (legacy mining features) will be initiated during the construction phase. Perpetua will install 15 to 20 temporary trailers on private lands adjacent to the existing exploration camp (located in the proposed ore processing area) to accommodate construction crews; these temporary trailers will be used during site preparation and early construction until the worker housing facility is constructed.

Table 2. Summary of Design Criteria for Project Components.

Component Type	Project Components	Design Criteria	Regulation/Reference
Bridges and Culverts	Stream Crossings on Forest Service Land	100-year event unless risk tool indicates a different recurrence interval	Land and Resource Management Plan (LRMP) – FRST02
		Minimum culvert diameter 18 inches (in.) for less than 70 feet (ft.) or 24 in. for greater than 70 ft.	IDAPA 37.03.07 Sections 059.04a and 059.04e
		Culvert headwater to depth ratio	Forest Service Handbook (FSH) 7709.56b Chapter 64.5
		Fish passage unless protection of pure-stream native fish is required	LRMP – SWST08
		3- to 5-ft. freeboard for bridges depending on anticipated use and debris	FSH 7709.56b Chapter 62.2
		Span 120% of bankfull width for 1.5-year event	Feasibility Study design specification 170045-5200
	Stream Crossings on Private Lands	25-year event for drainages less than 50 square miles (sq. mi.); 1-ft. bridge clearance; minimum culvert diameter 18 in. for less than 70 ft. or 24 in. for >70 ft.; Fish passage unless protection of pure-stream native fish is required	IDAPA 37.03.07 Sections 059.04a and 059.04e
		Culvert headwater to depth ratio <0.8	FSH 7709.56b Chapter 64.5
		Span 120% of bankfull width for 1.5-year event	Feasibility Study design specification 170045-5200
	Culverts, Channels, or Ditches for Surface Water Flows from Haul Roads and Upland Areas	25-year event; minimum culvert diameter 18 in. for <70 ft. or 24 in. for >70 ft.; Process Plant site culverts have minimum 30-in. diameter	IDAPA 20.03.02 Section 140.05.c
		Culvert headwater to depth ratio <0.8	FSH 7709.56b Chapter 64.5
Contact Stormwater Collection Channels	TSF Buttress, Hecla Heap Removal, SODA/Bradley Tailings Removal	25-year event	N/A
	Process Plant Site, Truck Shop Area	100-year event; 1-ft. freeboard	Feasibility study design specification 170045-5200
Contact Stormwater Storage Ponds	Hangar Flats Pond, SODA Pond, Midnight Pond, West End Pond	Contain 100-year 24-hour event with average snowmelt with 3-ft. freeboard	IDAPA 37.03.06 Section 050.11

Component Type	Project Components	Design Criteria	Regulation/Reference
		Pass 100-year 24-hour event with 95th percentile snowmelt through spillway while maintaining 3-ft. freeboard	
	North Plant Pond, Central Plant Pond, North Truck Shop Pond, South Truck Shop Pond, Scout Pond	Contain 100-year 24-hour event with average snowmelt with 2-ft. freeboard Pass 500-year 24-hour event with average percentile snowmelt through spillway	Feasibility study design specification 170045-5200
In-Pit Sumps	Hangar Flats Pit, Yellow Pine Pit, West End Pit	Variable based on available in-pit space	N/A
Long-Term Stream Diversion Channel and Floodplain Corridor	Meadow Creek at Hangar Flats Pit	Bankfull 1.5-year event for channel capacity; 100-year event and 3-ft. freeboard; Top width 6 ft. if less than 6 ft. high, 8 ft. for 6 to 12 ft. high or sandy fill material, or 10 ft. if a road is included	Natural channel design
Process Water Impoundments	Tailings Storage Facility (TSF) Supernatant Pond	Meet the requirements for water storage reservoirs per the Rules for Safety of Dams Contain probable maximum flood or 100-year event (whichever is greater) with 2-ft. freeboard plus 2-ft. wave height	IDAPA 37.03.05 Section 050 IDAPA 37.03.06 Sections 050 and 065
	TSF Draindown Pond in the Truck Shop Area	Contain the volume of the TSF reclaim water pipeline and slurry pipeline plus the 100-year 24-hour storm event with snowmelt; 2-ft. freeboard	IDAPA 58.01.13 Section 200.02
Restored Stream Reaches and Floodplain Corridors	Restored Reaches without Rock Chutes	Bankfull 1.5-year event for channel capacity; average floodplain width for 100-year discharge is 1.25 times the maximum meander belt width for lined corridors and 2 times the meander belt width for unlined corridors	Natural channel design
	Rock Chutes on Meadow Creek, Hennessey Creek, and West End Creek	100-year event; 1-ft. freeboard	N/A
Stormwater Best Management Practices	Worker Housing Facility, Main Gate, Administrative Office, Burntlog Maintenance Facility, Stibnite Gold Logistics Facility	Idaho Department of Environmental Quality (IDEQ) Best Management Practices Manual	Valley County Comprehensive Plan (2010)

Component Type	Project Components	Design Criteria	Regulation/Reference
Stormwater Diversion Channels	TSF and TSF Buttress	100-year event; 1-ft. freeboard	IDAPA 37.03.05 Section 0045.06.b
	Process Plant Site	100-year event; 2-ft. freeboard	Feasibility Study design specification 170045-5200
TSF	Slope Stability	Minimum Factor of Safety for Static Load = 1.5	IDAPA 37.03.05 and 37.03.06
		Minimum Factor of Safety for Pseudo-Static (Earthquake) Load = 1.0	IDAPA 37.03.05 and 37.03.06
		Minimum Factor of Safety for Post-Earthquake Load = 1.2	FEMA 2005 Federal Guidelines for Dam Safety
		Operating Basis Earthquake = 2,500 years.	ICOLD 1995
		Maximum Credible Earthquake = magnitude 7	IDAPA 37.03.05 and 37.03.06
	Liner Subgrade Preparation	Approved alternative composite liner of 60-mil, single-sided, textured, linear low-density polyethylene (LLDPE) geomembrane line underlain by a geosynthetic clay liner (GCL) underlain by a minimum of 12 in. of liner bedding. Structurally stable subgrade to resist excessive differential settlement and uplift. Materials with appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients and contact with tailings and/or process solution. Materials with appropriate shear resistance to prevent sliding of the upper component in contact with the liner, including on slopes. Smooth rolled and compacted soil layer with: • no particles in excess of 0.75 in. in the uppermost six in. unless larger particles are consistent with the manufacturer's specifications for overlying line and approved by IDEQ;	IDAPA 58.01.13.200.06bii

Component Type	Project Components	Design Criteria	Regulation/Reference
		• no putrescible, frozen, or otherwise deleterious materials; • no angular, sharp material regardless of diameter; and, • soil placed within 2% of optimum moisture content to achieve specified compaction and hydraulic conductivity (i.e., 95% of maximum dry density and less than 10^{-6} cm/sec in combination with the GCL).	
TSF Continued	Underdrain System	Sized based on maximum cumulative flow calculated using Manning's equation.	Federal Highway Administration 2020 Hydraulic Toolbox 5.0
		Loading calculations based on culvert analysis and design structural analysis program.	Transportation Research Board 2007 CANDE-2007/2011
	Liner	Approved alternative composite liner of 60-mil, single-sided, textured, LLDPE geomembrane underlain by a GCL underlain by a minimum of 12 in. of liner bedding. Constructed per manufacturer and IDEQ's standards with protection against damage from sun exposure, ice, frost penetration, wildlife, wildfires, and contact with equipment and/or personnel. Material with an appropriate coefficient of friction against slide plus a factor of safety for each interface constructed on a slope. Material that meets the manufacturer's quality assurance/quality control performance specifications. Stable underlying earthworks meeting a minimum factor of safety. Geosynthetic overdrains to reduce hydraulic head on the liner. Tailings and supernatant pool management to reduce direct contact of the supernatant pool with the liner.	IDAPA 58.01.13.200.06bii
		Cyanidation Water Quality Monitoring Plan	IDAPA 58.01.13.204.01

Component Type	Project Components	Design Criteria	Regulation/Reference
Temporary Stream Diversion Channels	Meadow Creek at TSF and TSF Embankment	100-year event; 1-ft. freeboard	IDAPA 37.03.05 Section 0045.06.b
	West End Creek at West End Pit	100-year event; 1-ft. freeboard	N/A
	Hennessey Creek at Yellow Pine Pit	100-year event; 1-ft. freeboard	N/A
	Midnight Creek at Yellow Pine Pit	100-year event; 1-ft. freeboard	N/A
	East Fork Meadow Creek	100-year event; 1-ft. freeboard	N/A
	Fiddle Creek	100-year event; 1-ft. freeboard	N/A
	Garnet Creek at process plant site	100-year event; 1-ft. freeboard	N/A
	EFSFSR Tunnel	500-year event; 20% of tunnel height freeboard	N/A
Water Diversion	East Fork South Fork Salmon River (EFSFSR) Surface Water Diversion Groundwater Diversions	Surface water diversion from the EFSFSR is limited to 4.5 cubic feet per second (cfs); Diversions are conditional on flows in the EFSFSR, at the points of diversion (POD), of at least 5.0 cfs from October 1 – June 29 and 7.25 cfs from June 20 – September 30. Diversions are conditional on flows of at least 3.0 cfs in lower Meadow Creek Diversions cannot reduce flows in the EFSFSR by more than 20% when flows are less than 25 cfs downstream from Sugar Creek.	N/A

Prior to site preparation and construction of surface facilities, vegetation will be removed from operating areas. Trees, deadwood, shrubs, and slash not needed to construct windrows at the edge of Burntlog Route disturbance (to function as sediment barriers), will be chipped, and suitable soil will be separately salvaged and stockpiled (except for a small portion that will be 'live handled') for use as part of site reclamation and restoration. Portions of the salvaged soil will be blended with the chipped wood to create growth media (GM).

The existing potable water supply system at the exploration camp will be used and expanded for the construction camp. The existing system will be supplemented with deliveries of potable water, if needed. Supplemental water sources (i.e., water deliveries) will be used by personnel in remote construction areas. Sanitation during construction will be provided through the existing sewage treatment system adjacent to the exploration camp. In addition, portable sanitary facilities will be located throughout the SGP and at remote construction areas.

Construction of the Burntlog Route will occur from both ends of the route at the same time on a seasonal basis (May to November), but construction could occur outside of this time period if conditions allow (i.e., snow free). The southern portion workforce will be housed in three temporary trailer camps located within construction borrow sources or staging areas. The northern portion workforce will be housed at the temporary trailer construction camp at the SGP. Some construction workers could be housed in Cascade, Idaho.

1.6.2. Growth Media Stockpiles

Suitable GM within the area proposed for operations will be salvaged following vegetation clearing and moved to growth media stockpiles (GMS) either within the Fiddle Valley or at the Worker Housing Facility. Another short-term GMS will be located within the footprint of the TSF. Growth media from the new construction of the Burntlog Route will be stockpiled in the borrow source areas used for construction and widening of the route and in windrows along the edges of fill slopes. GMS will be stabilized, seeded, and mulched to protect the stockpile from wind and water erosion. A total of approximately 1,657,246 bank cubic yards (BCY) of suitable soils (GM and seed bank material [SBM]) will need to be salvaged from the SGP for reclamation. A total of approximately 860,373 BCY of GM, chipped wood blend, and SBM are available for salvage at the SGP.

To achieve the reclamation success criteria and offset the GM deficits, 1.5 million BCY of unconsolidated overburden (chiefly alluvial and glacial materials from the Yellow Pine Pit [YPP]) will be stored in the Fiddle GMS to allow use as cover material for reclamation of the TSF, TSF Buttress, and Hangar Flats Pit (HFP) backfill.

1.6.3. Access Roads

During the construction phase, site access to the SGP will cross 43 streams along existing roads, and crossing 28 streams along the Burntlog Route, including the existing Burntlog Route (Figure 6) (USFS 2023a). In addition to these stream crossings, approximately 6.5 miles (18 percent of its 36-mile length) of the Johnson Creek Route is located in close proximity to streams (i.e., within 100 feet). A total of 65 vehicle trips per day will occur during the construction phase (USFS 2023b). These trips will consist of 20 light vehicles and 45 heavy vehicles. The 65 trips will be along the Johnson Creek route.

During the mining and ore processing operations phase (approximately 15 years), a total of 50 vehicle trips per day are anticipated on average (year-round) utilizing the Burntlog Route. The 50 trips will consist of 17 light vehicles and 33 heavy vehicles. During the closure and reclamation phase, traffic along the Burntlog Route will be reduced to a total of 27 vehicle trips per day (year-round).

1.6.3.1. **Warm Lake Road**

Warm Lake Road (County Road [CR] 10-579) is a two-lane (one lane each direction), asphalt-paved roadway with lane markings and is open year-round to all vehicles from Idaho State Highway (SH) 55 to Warm Lake. Warm Lake Road starts in Cascade at an intersection with SH 55 and continues eastward for approximately 35 miles, ending at Johnson Creek Road (CR 10-

413) at Landmark. Warm Lake Road is under the jurisdiction of Valley County, but Valley County currently does not maintain Warm Lake Road in winter beyond Warm Lake Lodge. During years with adequate snowpack, an 8-mile segment of the Warm Lake Road route east of Warm Lake Lodge is used as an over snow vehicle (OSV) route, allowing access into Landmark and other areas.

The SGP will require year-round passenger and delivery truck access from the onset of construction through the life of the mine. Perpetua will conduct wintertime maintenance east of Warm Lake Lodge to ensure safe, year-round access to the sole route of ingress/egress to the SGP for all mine support traffic. This will include snow removal and road sanding, as appropriate, to maintain a safe driving surface. Commitments for wintertime maintenance of Warm Lake Road will be documented in a Road Maintenance Agreement with Valley County.

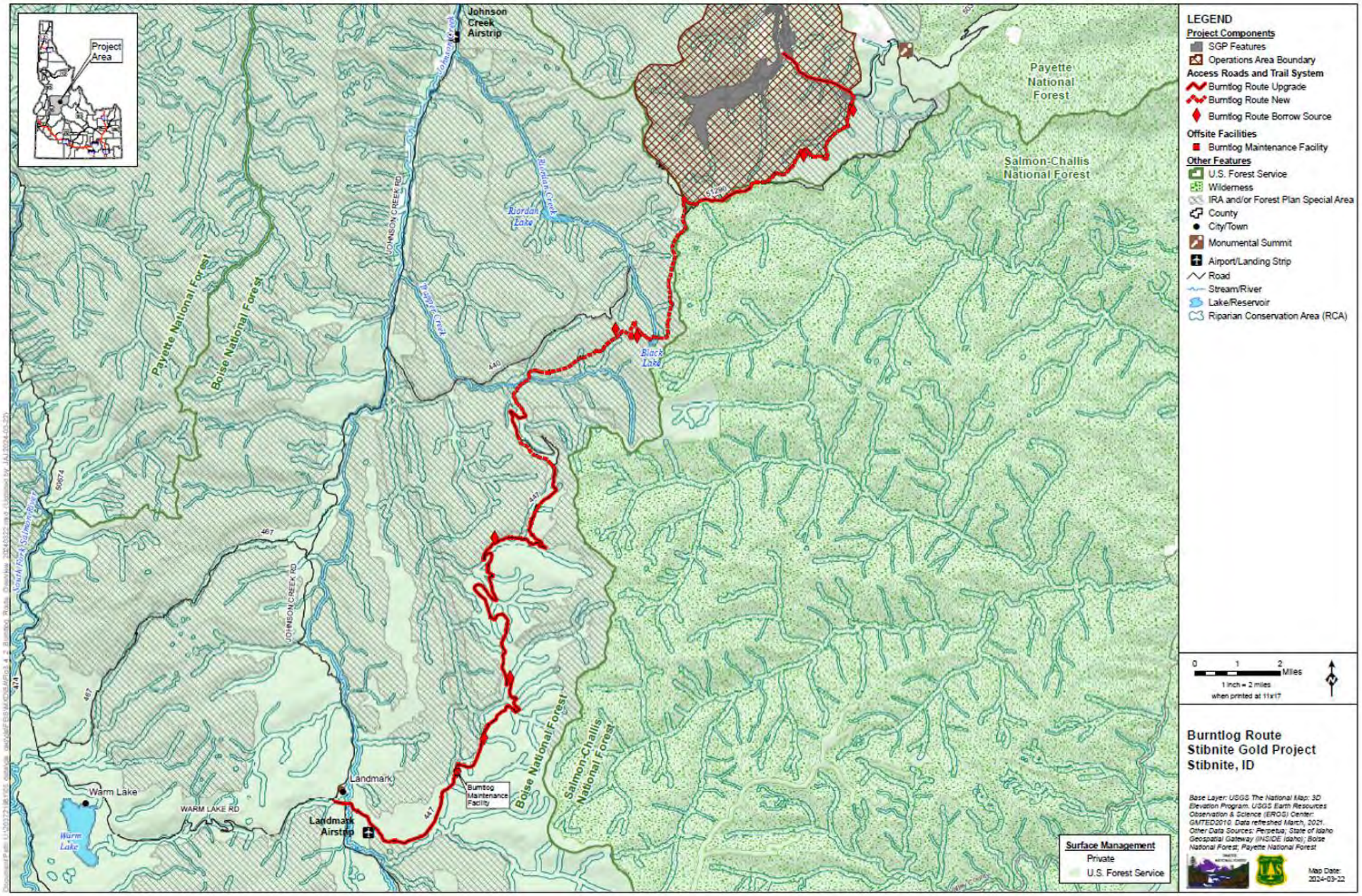


Figure 6. Burntlog Route, Stibnite Gold Project.

Perpetua wintertime maintenance and use of Warm Lake Road will result in two changes to current traffic conditions:

- Warm Lake Road east of Warm Lake Lodge will not be available as a recreational OSV route from the start of construction through reclamation of the SGP. To replace this recreational use, a dedicated alternative OSV route will be established from the Warm Lake area to Landmark via the Cabin Creek/Trout Creek drainages and adjacent to the Johnson Creek Road. Establishing this replacement OSV route will minimize the interactions between SGP traffic and recreational traffic in the winter. The proposed OSV route is illustrated in Figure 7.
- Expanded wintertime public vehicle access on Warm Lake Road east of Warm Lake Lodge will commingle SGP and public travel.

Warm Lake Road and its supporting infrastructure (i.e., for stormwater management) are not being expanded or modified.

The USFS is not a party to Perpetua's Road Maintenance Agreement with Valley County, the owner of the Warm Lake Road, Johnson Creek Road, and Stibnite Road. Therefore, the USFS will not be involved in the review, implementation, or enforcement of the agreement from a road maintenance perspective. However, as part of Project approval, the USFS will require the Project implementation of environmental requirements pertaining to road use and maintenance indicated in this document (Appendix A, Table A-5).

In the event that road maintenance requires more substantial efforts than typical maintenance (e.g., landslide or avalanche recovery), the USFS will engage with Valley County and Perpetua on efforts that will affect USFS lands outside the current road footprint and roadside support structures (e.g., ditches, culverts). Maintenance activities within the existing road footprint and support structures will not require additional USFS engagement. Activities involving USFS land not currently utilized by the road and support structures will require additional USFS engagement and potential permitting.

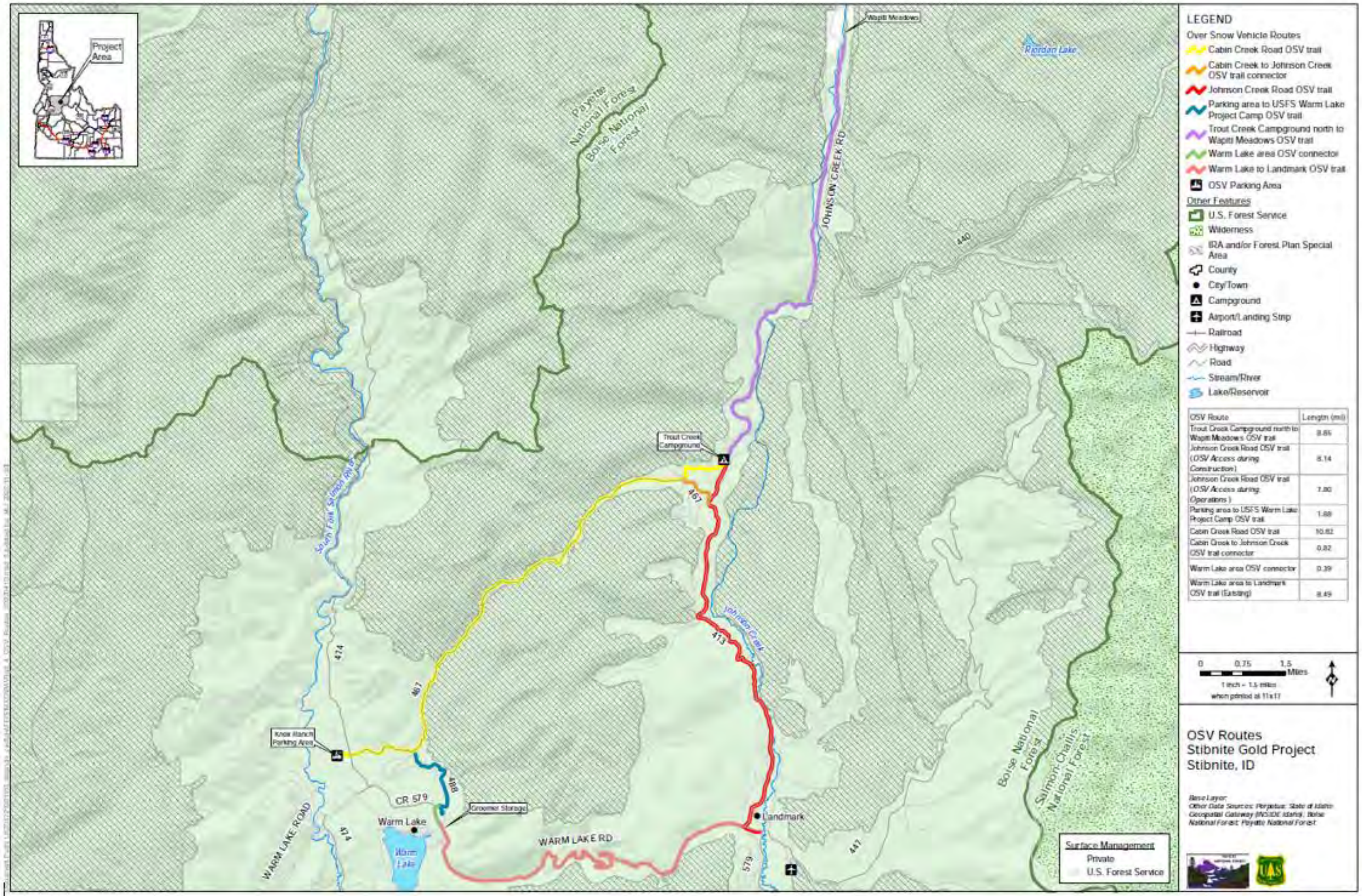


Figure 7. OSV Routes – Stibnite Gold Project.

1.6.3.2. **Johnson Creek Route**

During the initial construction period of the Burntlog Route (approximately 2 to 3 years), mine-related traffic will access the SGP from SH 55, north of the city of Cascade, via Warm Lake Road for approximately 34 miles. Then, north on Johnson Creek Road (CR 10-413) for approximately 25 miles to the village of Yellow Pine, and from Yellow Pine east approximately 14 miles to the SGP via the Stibnite Road (CR 50-412). The portion of the route that includes Johnson Creek Road and Stibnite Road is known as the Johnson Creek Route. This route is primarily situated topographically adjacent to the valley bottom, paralleling Johnson Creek and the East Fork South Fork Salmon River (EFSFSR).

Johnson Creek Road is a county-maintained, native-surface road that is open to vehicles with seasonal restrictions due to snow. During the winter, Valley County plows approximately 10 miles of Johnson Creek Road from Yellow Pine south to Wapiti Meadow Ranch and grooms the remaining 17 miles of Johnson Creek Road from Wapiti Meadow Ranch to Warm Lake Road at Landmark for OSV use.

The Stibnite Road portion of the route is also a county-maintained native surface road, open to all vehicles with seasonal restrictions due to snow. This road is plowed in the winter by Perpetua through an agreement with Valley County to allow site access for exploration activities. Seasonal restrictions and measures implemented under the Golden Meadows Exploration Project to restrict access will remain in place during the three-year construction period. Upon construction of the Burntlog Route, winter plowing of the Stibnite Road for SGP access will be discontinued. Stibnite Road connects to Thunder Mountain Road on the southeastern portion of the Stibnite site and currently provides seasonal (non-winter) public access through the site.

Minor surface improvements (such as ditch and culvert repair, winter snow removal, resurfacing [i.e., gravel addition] if required, and summer dust suppression) will occur on the Johnson Creek Route under the proposed action to reduce sediment runoff and dust generation. However, there will be no road alignment modification or widening of the road prism of these existing roads along the Johnson Creek Route, as the current road is able to accommodate the equipment and materials needed to be transported during the construction period. In practice, resurfacing, dust suppression, and repairs will be conducted on an as needed basis. Resurfacing and repair work will generally occur annually following the winter season. Dust suppression using water application will be frequent (i.e., every few weeks) during the summer season.

Use of chemical dust suppressants such as magnesium chloride ($MgCl_2$) will occur near the start of the summer season. Water application will utilize over-the-road water trucks (e.g., 2,000 gallon) that will fill from diversion points authorized by Idaho Department of Water Resources (IDWR) water rights approval (e.g., from the groundwater well at the Landmark Maintenance Facility).

Prior to construction of the Burntlog Route, the Johnson Creek Route will be used for fuel transport with precautionary measures being: (1) staged spill response kits; (2) pilot cars equipped with spill response kits; (3) radio contact with hauling trucks; (4) only day-time fuel deliveries; and (5) driver training on route. Once the Burntlog Route is completed, fuel transport using the Johnson Creek Route will be discontinued.

Portions of Johnson Creek Road (i.e., Landmark to Wapiti Meadows) are currently used as a groomed OSV trail during winter and use of the Johnson Creek Route by mine-related construction traffic will conflict with this existing groomed OSV trail. Thus, while the Burntlog Route (described below) is under construction, a temporary 16-foot-wide groomed OSV trail adjacent to Johnson Creek Road between the proposed Cabin Creek Groomed OSV Route and Landmark will be constructed (Figure 7). However, the OSV trail from Trout Creek Campground to Wapiti Meadows will be closed until construction of the Burntlog Route is complete; once mine traffic moves to that route, then the OSV route will return to Johnson Creek Road and will reconnect Landmark with Wapiti Meadows.

Perpetua has an existing agreement with Valley County for maintenance of Johnson Creek and Stibnite Roads, including performing maintenance measures to repair segments that have deteriorated. Appropriate revisions to the road maintenance agreement will be established for use of the Johnson Creek Route as a construction route and to ensure year-round access in accordance with Valley County's public road easement stipulations. Once construction of the Burntlog Route has been completed (2-3 years), the Johnson Creek Route will no longer be used by mine-related traffic.

1.6.3.3. **Burntlog Route**

The Burntlog Route will connect the eastern end of Warm Lake Road (at Landmark) to the SGP (to the northeast) by widening and improving approximately 23 miles of existing roads, including the full length of the existing Burntlog Road (FR 447) and segments of Meadow Creek Lookout Road (FR 51290) and Thunder Mountain Road (FR 50375). The three road segments will be connected with two new road segments totaling approximately 15 miles. Burntlog Road is currently a native surface road that is open year-round to all vehicles with seasonal restrictions due to snow. The last 0.25 to 0.5 mile of the existing road is closed and motorized traffic prohibited. Meadow Creek Lookout Road is a native surface road, open year-round to all vehicles. The Burntlog Route is primarily situated topographically on mid-slopes and ridgeline.

Improvements on the existing roads that comprise the Burntlog Route will include:

- Straightening tight corners to allow for improved safety and traffic visibility;
- Maintaining grades of less than 10 percent in all practicable locations;
- Placing sub-base material and surfacing with gravel;
- Application of a road binding agent in localized segments to suppress dust, increase stability, and reduce sediment runoff;
- Widening the existing road surface (currently approximately12 ft. wide) to a 21 ft. wide travel way (approximately 26 ft. including shoulders); and,
- Installing side-ditching, culverts, guardrails, and bridges, where necessary, with EDF to provide fish passage and limit potential sediment delivery to streams.

Figure 6 shows the proposed Burntlog Route, which includes the proposed new road construction. A segment of new road construction for the Burntlog Route will be located on the south side of the Riordan Creek drainage and cross Riordan Creek north of Black Lake. The approximately 5.3-mile road segment will have 12 stream crossings, three of which cross perennial streams. Along the Burntlog Route, culverts designed and installed to allow fish passage will be used for fish-bearing stream segments crossed by the route. Upon construction of the Burntlog Route, the route will be used for fuel transport with precautionary measures being: (1) staged spill response kits; (2) pilot cars equipped with spill response kits; (3) radio contact with hauling trucks; (4) only day-time fuel deliveries; and (5) driver training on route. After construction is complete, public use will be allowed on Burntlog Route when other public access roads are blocked by mine operations.

The connection segment between the end of Burntlog Road and Meadow Creek Lookout Road is approximately 11 miles and will cross Trapper Creek. The second connector between the Meadow Creek Lookout Road and Thunder Mountain Road will be approximately 4 miles and links up with Thunder Mountain Road approximately 2 miles south of the SGP. Minor surface improvements (e.g., blading) will occur on the portions of the existing Thunder Mountain Road and Meadow Creek Lookout Road that will not become part of the Burntlog Route to provide a safe road surface for transportation of construction equipment required to build the Burntlog Route. There will be no road alignment modification or widening of the portions of the existing roads that are not part of the Burntlog Route.

Construction of new segments of the Burntlog Route will utilize cut and fill techniques to create a level surface for installation of the roadway. Most cut and fill will be conducted by mechanical construction equipment (i.e., dozers, rollers, graders) to relocate and compact unconsolidated materials then place a gravel road surface. In instances where consolidated bedrock material is encountered in cut areas, blasting may be used to break up the bedrock to complete the cut. Areas requiring blasting will typically occur on steeper side slopes in upland areas where unconsolidated soil and cover materials overlying bedrock may have limited thickness.

Primary SGP access will shift from the Johnson Creek Route to the Burntlog Route near the end of the construction phase. The Burntlog Route will avoid environmental and human health and safety risks associated with the Johnson Creek Route which passes through identified areas for avalanches, landslides, and floods. This route will decrease the potential for spill risk adjacent to fish-bearing streams.

The Burntlog Route road design prioritizes safe transportation conditions (e.g., appropriate road grade, width, turning radii, etc.) that minimize the risk associated with traffic incidents as well as minimize impacts to environmental resources. The EDF, reclamation, and mitigation measures to minimize or offset impacts are described in the BA and compiled in Appendix A, Tables A-1 to A-9.

1.6.3.4. **Burntlog Route Borrow Sources, Staging Areas, and Construction Camps**

Up to eight borrow sites will be established along the Burntlog Route (Figure 6) to meet construction and ongoing maintenance throughout the life of the mine and to support decommissioning following mine closure while avoiding Riparian Conservation Areas (RCA). Additionally, those same eight borrow areas will be utilized for staging of equipment and supplies. Three construction camps will be located within the disturbance created by borrow sources or staging areas. The construction camps will be for trailer parking. Each trailer will be equipped with fresh water and sanitary waste storage.

1.6.3.5. **Culverts and Bridges**

Construction of the Burntlog Route (i.e., improvement of the existing FS 447 plus new road development) will require installation of bridges and culverts to cross stream segments and to manage stormwater diverted from the roadway. Design documents refer to culverts that cross-stream segments containing perennial flows as "Stream Crossing Culverts" while culverts that do not cross flowing streams but instead manage stormwater are referred to as "Relief Culverts".

EDF for bridges and culverts consider the criteria described in the Forest Service Structures Handbook (USFS 2014), the Valley County Roadway Design Guide (Valley County 2008), and NMFS guidelines (NMFS 2022a). These criteria are summarized in Table 3.

The number of bridges, stream crossing culverts, and relief culverts by drainage are summarized in Table 4. Bridges and culverts which have been installed within the last 20 years that are in good condition will be retained if possible.

Table 3. Bridge and Culvert Design Criteria.

Item	Bridges	Stream Crossing Culverts	Relief Culverts
Design Storm	100-year	100-year	25-year
Minimum Size	Span 120% of bankfull width for 1.5-year event	100-year peak discharge and span 120% of bankfull width for 1.5-year event	25-year peak discharge
Minimum Cover	N/A	Manufacture's specification	12 inches to finished grade
Minimum Width	Full roadway plus three feet	N/Ae	N/A
Freeboard	Three to five feet	Headwater to not exceed 0.8 diameter	Headwater to not exceed 0.8 diameter
Loading	AASHTO-93	AASHTO-93	AASHTO-93

Table 4. Burntlog Route Bridges and Culverts.

Hydrologic Assessment Segment	Bridges	Stream Crossing Culverts*	Relief Culverts	Relief Culvert Diameter**
A – Johnson Creek	1	4 (1 retained)	52	18" – 48"
B – Burntlog and East Fork Burntlog Creeks	3 (1 retained)	7 (1 retained)	80	18" – 48"
C – East Fork Burntlog and Trapper Creeks	1	7	57	18" – 60"
D – Riordan Creek	0	1	69	18" – 30"
E – EFSFSR	1	6	50	18" – 48"
Total	**6**	**25**	**308**	**18" – 60"**

*Stream culverts sized based on 100-year flows (see below for fish passage information).

**Relief culverts sized for 25-year events based on drainage area runoff analyses.

All of the bridges cross stream segments with fish passage while nine of the 25 stream crossing culverts cross segments with fish passage based on drain area analyses and environmental DNA (eDNA)[1] data. In addition to the Burntlog Route access road crossings, there will be one haul road crossing of the EFSFSR in the mining area along with an existing box culvert. Design information for the crossings with fish passage are summarized in Table 5. Final designs for bridges, culverts, and plate arches are pending geotechnical assessment of the crossing locations. Conceptual design drawings are shown in Figures 3.4-3 through 3.4-10 of the BA (Stantec 2024).

Project incorporation of site preparation, staging, and sequencing stream crossing work has been developed for instream work such as the Burntlog Route stream crossings as described in the FMP, Section 5.4.7 (Brown and Caldwell, Rio ASE, and BioAnalysts 2021). A planning team with representation from project management, engineering, and fish biology will be assembled to coordinate with construction personnel and equipment operators to plan the staging and sequence for work area isolation, fish capture and removal, and dewatering, i.e.:

- Scheduling within an appropriate instream work window (see Section 1.11.2.2);
- Establishing the length of channel to be isolated for each crossing;
- Conducting work area isolation and fish salvage in consideration of habitat requirements, flow and temperature conditions, and exposure to turbidity or other unfavorable conditions; and,
- Dewatering via a bypass flume or culvert with diversion by sandbags, sheet piling, or cofferdam.

When stream segments require dewatering for bridge or culvert installation, they will be isolated using a method appropriate for the location, including block nets, sandbags, diversion, pumps, sheetpiling, flashboards, cofferdams, and other structures. The specific method will depend on the stream segment location, diversion sequencing, operational requirements, segment length, segment slope, flow conditions, depth, and fish salvage (see below). All isolation barriers will be monitored during installation and operation. Partial dewatering will generally be conducted during low-flow periods to facilitate stream segment isolation and fish salvage. Whenever possible, dewatering will not begin until fish have been captured and removed for relocation. However, depending on the location and water depth, it may be necessary to partially draw down the water first to perform fish removal. Partial dewatering before fish salvage operations begin may also improve fish capture efficiency by reducing the total volume of stream habitat that needs to be salvaged. In those cases, dewatering pumps will be screened to meet NOAA Fisheries and IDFG standards to avoid entrainment of juvenile fish. Fish capture from work area isolation will consist of:

[1] Environmental DNA sampling is a technique that identifies DNA found in the environment (e.g., water, soil, air) from cellular material shed by organisms that has accumulated in the surrounding water, soil, air, etc. It allows for testing without having to sample the organism itself; and is a tool that allows for monitoring and detection of species which may be present in low numbers and therefore difficult to find.

- Slowly reducing flow in the work area to allow some fish to leave volitionally;
- Installation of block nets upstream and downstream of the isolation area with the nets secured to stream channel bed and banks until fish capture is complete and exclusion of fish from the work area is necessary;
- Hourly monitoring of block nets during instream disturbance in the work area;
- If block nets are in place for more than one day, they will be monitored daily to ensure they are secured to banks and are free of organic accumulation plus monitored every four hours for fish impingement if located in bull trout (*Salvelinus confluentus*) spawning and rearing habitat (unless a variance is granted by the USFS);
- Seining the isolated area to capture and relocate fish;
- If areas are isolated overnight, minnow traps will be placed overnight in conjunction with seining;
- Collecting any remaining fish by hand or dip nets as dewatering continues; and,
- If all other techniques have been exhausted, electrofishing may be used to capture remaining fish under electrofishing conservation measures.

Captured fish will be relocated as quickly as possible to pre-planned release areas using aerated and shaded transport buckets holding limited numbers of fish of comparable size to minimize predation. Dead fish will not be stored in transport buckets but will be left on the streambank to avoid mortality counting errors.

Upon completion of the instream work, flow diversions will be removed slowly to allow gradual rewatering of the isolated stream segment to minimize turbidity. Once the stream segment is rewatered, the upstream and downstream block nets will be removed.

Erosion and sediment control for in-water work for the Burntlog Route will be consistent with controls used for other aspects of the project (see below, Section 1.11, and Appendix A, Tables A-1, A-2, A-5). Turbidity monitoring and protocols will include:

- Turbidity monitoring will be required and shall be completed in accordance with designated protocols (for the type of planned work);
- Work will be performed in a manner that does not cause turbidity exceedances within the waterway;
- If turbidity exceedances do occur, the work will stop to address the turbidity issues; and,
- Construction discharge water will be collected to remove debris and sediment and will meet turbidity requirements for discharging back to receiving streams.

Table 5. Design Information for Fish Crossing Bridges and Culverts.

Stream	Description	Structure Type	Bankfull Width (feet)	Minimum Span (feet)	Drainage Area (sq. mi.)	Streambed Material (D_{50} mm)	Upstream Channel Slope (%)	Downstream Channel Slope (%)
Johnson Creek (Ck.)	Existing bridge to be upgraded	Bridge (80’)	61.4	75	46.9	Sand and gravel	0.15	0.37
Burntlog Ck.	Existing bridge to be upgraded	Bridge (24’)	-	-	3.1	-	-	-
East Fork (E. Fk.) Burntlog Ck.	Existing bridge to be upgraded	Bridge (20’)	12.9	16	2.1	-	-	-
Tributary to E. Fk. Burntlog Ck.	Retain existing bridge installed in 2021	Bridge (60’)	-	-	4.3	-	-	-
Trapper Ck.	New bridge installation	Bridge (30’)	17.3	21	6.4	32 – 45	-0.16	0.22
EFSFSR	New bridge installation	Bridge (20’)	10.2	12	4.3	22 – 32	3.49	2.30
Mudlake/Peanut Ck.	Existing corrugated metal pipe culvert to be upgraded	Corrugated metal pipe (96")	5.7	6.8	0.4	<2 over gravel	1.37	2.79
Peanut Ck.	Retain existing corrugated metal pipe culvert installed in 2008	Plate Arch (13’ x 5.1’)	5.2	6.3	1.3	25 – 40	5.06	1.53
Tributary to E. Fk. Burntlog Ck.	Existing corrugated metal pipe culvert to be replaced with box culvert	Aluminum Box (11’ x 4.3’)	6.9	8.3	0.6	20 – 35	5.21	10.81
Tributary to E. Fk. Burntlog Ck.	Existing corrugated metal pipe culvert to be replaced with box culvert	Aluminum Box (11’ x 4.3’)	7.8	9.4	0.6	30 – 45	4.83	4.40
Tributary to E. Fk. Burntlog Ck.	Existing bottomless box culvert to be retained	Concrete Box (20’)	11.6	3.9	1.4	80 – 120	11.35	9.66
Tributary to E. Fk. Burntlog Ck.	Existing corrugated metal pipe culvert to be upgraded	Corrugated metal pipe (60”)	1.7	2.1	0.1	10 – 20	2.80	12.81
Tributary to Trapper Ck.	Existing corrugated metal pipe culvert to be replaced with box culvert	Aluminum Box (12.3’ x 4.5’)	9.4	11.3	1.0	30 – 45	2.10	8.59
Riordan Ck.	New culvert installation	Corrugated metal pipe (72”)	3.9	4.7	0.3	65 – 90	11.15	16.00
Rabbit Ck.	Existing corrugated metal pipe culvert to be upgraded	Corrugated metal pipe (72”)	4.0	4.8	0.7	16 – 23	22.00	6.20
EFSFSR	Existing box culvert to be retained	Box	26.5	-	-	128 – 181	-0.58	3.70
EFSFSR	New bridge installation	Bridge	20.9	-	-	75 – 125	-	-

Sediment controls will include the implementation and use of the following as needed in appropriate locations:

- Instream work will conform with the work, turbidity, and dewatering procedures as specified in design conservation measures (RioASE 2023) and adhere to Bonneville Power Administration Habitat Improvement Program conservation measures;
- Placement of fine mesh silt fences and straw waddles;
- Minimization of equipment wet crossings with vehicles and machinery crossing at right angles to the main channel whenever possible;
- No construction equipment stream crossings will occur within 300 feet (ft.) upstream or 100 ft. downstream of an existing redd or spawning fish;
- After construction, temporary stream crossings will be removed and banks restored while adhering to turbidity requirements;
- Cofferdams and diversion structures will have 1-ft. of freeboard;
- Dewatering pump discharge will be released onto floodplain areas away from wetlands and construction activities where discharge will fully infiltrate prior to reaching wetlands and surface waters unless otherwise approved;
- Any return flows from dewatering discharge will meet turbidity requirements;
- Bag fill materials will be clean, washed, and rounded material meeting standard specifications for drain rock, streambed aggregate, streambed sediments, or streambed cobbles; and,
- Work activities within the ordinary high-water channel will conform with the water quality standards established for the project.

1.6.3.6. **Road Maintenance Measures**

Road maintenance will be conducted per the project design, USFS requirements, and requirements of the Road Maintenance Agreement with Valley County. Routine maintenance will involve resurfacing, fixing holes, best management practices (BMPs), grading, ditch cleaning and use of traffic signs. For non-routine road maintenance (e.g., activities outside the current road prism, new construction, or reconstruction), the USFS will engage with Valley County when activities involve repairs or new infrastructure that departs from the current roadway and infrastructure footprint. The USFS will focus on enforcement of its existing requirements when activities occur within the current footprint.

To assess road conditions and fulfillment of requirements, the USFS will meet annually with Perpetua to discuss road maintenance needs, road maintenance activities, and best practices that must be employed to minimize impacts to Federally-protected resources. The USFS will present an annual summary of the implemented and planned road maintenance activities to the Interested Agency Review Board (IARB) (see Section 1.11.1 for additional detail). These activities and reports will include the status of road maintenance requirements for the Project including:

- Use of gravel for road surfacing that meets American Association of State Highway and Transportation standards, design specifications for particle size (90 to 100 passing 1 inch, 85 to 95 percent passing 3/4 inch, 70 to 83 percent passing 3/8 inch, 47 to 62 percent passing No. 4 sieve, 27 to 40 percent passing No. 16 sieve, 18 to 27 percent passing No.

40 sieve, and 10 to 16 percent passing No. 200 sieve), percent fracture (75, one face), and plasticity index (4 to 10), and does not rapidly degrade into fine material.

- Avoids side-casting of snow where it has the potential to dam adjacent streams.
- Use of dust suppressants $MgCl_2$, calcium chloride ($CaCl_2$), or lignin-based chemicals such as lignin sulfonate with IARB approval required for use of any other dust suppressant.
- Application of dust abatement will be centered in the road so that all the chemical is absorbed before leaving the road surface when the road is within 25 feet of stream channels.
- Avoid installation of berms along the outside edge of roads unless an outside berm was specifically designed to be part of the road and low-energy drainage is provided for.
- Grade and shape roads in a manner that conserves existing surface material and designed drainage.
- Remove fines that cannot be bladed into the road surface by end-hauling to areas outside RCAs for disposal (i.e., no side-casting of materials); slides and rock failures of more than one half cubic yard will be hauled to disposal sites outside RCAs; scattered clean rocks (i.e., 1" plus) may be raked or bladed off the road except within 100 ft. of streams.
- Maintain blocked motorized access on all roads and road segments that are not open to the public, particularly service roads for the power transmission line, and gravel roads through RCAs when the roads will be used daily or used by heavy equipment.

1.6.4. Public Access

During construction of the SGP and completion of the Burntlog Route, to the degree practicable, the public will continue to have access on forest roads currently available to the public (Figure 3) and following construction road use with seasonal restrictions per current conditions will return. A new 4-mile long, 12-ft.-wide gravel road will be constructed to provide public access from Stibnite Road (FR 50412) to Thunder Mountain Road through the SGP (Figure 4). The road will be constructed on a widened bench on the west side within the YPP, then head south of the YPP, where this road will utilize an underpass to cross under an SGP haul road and continue southward, parallel to and on the east side of the mine haul road on a partially revegetated portion of a former haul road (Figure 4). Southwest of the ore processing area, the public access road will connect with Thunder Mountain Road and continue toward the worker housing facility, exiting the SGP to the southeast.

During operations, the public access road through the SGP will provide seasonal use, open to all vehicles; access will not be provided in winter when impassable (current county maintenance standards) and signs will inform the public of seasonal and temporary closures.

Public access will continue along Johnson Creek Road and Burntlog Road. Total closures of half-day to multiple days could occur during construction work on Stibnite Road between the village of Yellow Pine and the SGP, part of Thunder Mountain Road, and Burntlog Road. The long duration road closures will primarily occur in the mine site area associated with modification of the YPP wall to start construction of the fishway tunnel and construction of a light vehicle underpass below the mine equipment haul road. Public use of the Burntlog Route will provide motorized access to Meadow Creek Lookout Road (FR 51290) and Monumental Summit. Other routes available for public use are shown on Figure 3.

1.6.4.1. **Warm Lake to Landmark Groomed OSV Trail.**

Due to year-round access to the SGP along the Burntlog Route, an existing, approximately 8.5-mile-long groomed OSV trail from Warm Lake to Landmark will be closed for the life of the SGP. To replace this recreational use, a dedicated alternative OSV route will be established from Warm Lake area to Landmark via the Cabin Creek/Trout Creek drainages and Johnson Creek Road (Figure 7). The trail will be established largely along existing roads using a snowplow wing attachment requiring some vegetation and tree removal for safe snowplowing.

Near Warm Lake, an approximately 2-acre parking area will be established west of South Fork Road on FR 474B. A new 3.2-mile groomer access trail will be established from the parking area to the USFS Warm Lake Project Camp south of Paradise Valley Road (FR 488) where the groomer will be stored. An approximate 0.1-mile segment will be groomed from the intersection of Paradise Valley Road and FR 488A to Warm Lake Road. The Cabin Creek Road (FR 467) portion of the groomed OSV trail will extend approximately 13 miles to the Trout Creek Campground on Johnson Creek Road. Portions of Cabin Creek Road will require stream crossing improvements, localized road widening, and surface grading to support the OSV route grooming equipment.

1.6.4.2. **Johnson Creek Groomed OSV Trail.**

From Trout Creek Campground to Landmark, an approximately 8-mile temporary groomed OSV trail will be created and maintained on NFS lands adjacent to the west side of Johnson Creek Road (CR 10-413). Portions of the temporary groomed OSV trail (approximately 16 ft. wide) will be established using a snowplow wing attachment requiring some vegetation and tree removal to allow for safe snowplowing. In areas where topography and vegetation prevent using the wing attachment to establish the groomed OSV trail, sections will merge with Johnson Creek Road. During construction, the replacement OSV route will include an additional 0.34 of a mile segment east along the Warm Lake Road connecting Johnson Creek Road to Deadwood-Stanley Road (FR 579) (Figure 7).

1.6.4.3. **Warm Lake Area OSV Connection.**

A 16-foot-wide groomed OSV trail will be created and maintained north of Warm Lake Road to connect the southern end of the Cabin Creek Road OSV trail to the Warm Lake Road (FR 579). It will also provide access to North Shoreline Drive (FR 489) from the Cabin Creek Road OSV trail. This 0.3-mile route will be used throughout construction and operations and will require the removal of some vegetation and trees.

1.6.4.4. **Temporary OSV Closure Trout Creek Campground to Wapiti Meadows.**

OSV access will be temporarily halted between Trout Creek Campground and Wapiti Meadows (about 9 miles north of Trout Creek Campground on Johnson Creek Road; Figure 7) for approximately 2 to 3 years during construction of the Burntlog Route. Once construction of the Burntlog Route has been completed, the Johnson Creek Route will no longer be used by mine-related traffic and the OSV route will be returned to the unplowed Johnson Creek Road and extended northward to provide approximately 17 miles of groomed OSV access between

Landmark and Wapiti Meadows. Resumption of OSV access between Trout Creek Campground and Wapiti Meadows will occur following construction of the Burntlog Route.

1.6.5. Traffic

Traffic associated with SGP construction will occur year-round, depending upon road and weather conditions. Construction-related traffic and material hauling will be most concentrated from May through November, and personnel will be transported primarily using buses and vans. The total estimated annual average daily traffic (AADT) for construction activities driving from the SGLF and the SGP is listed in Table 6.

Table 6. Project Construction and Operations Stibnite Gold Project Traffic.

Phase	Route	Transport Type	AADT
Construction	SGLF to SGP	HV	45
		LV	20
Subtotal			**65**
Operations	SGLF to SGP	HV	33
		LV	17
Subtotal			**50**
Reclamation and Closure	SGLF to SGP	HV	15
		LV	12
Subtotal			**27**

AADT – annual average daily traffic; HV – heavy vehicle; LV – light vehicle.

Note: Table has been modified from Table 3.4-5 in the BA to include only traffic within watersheds occupied by ESA-listed Chinook salmon or steelhead.

SGLF to SGP - Stibnite Gold Logistics Facility to Stibnite Gold Project via the Johnson Creek Route during construction and via the Burntlog Route during operations.

1.6.6. Water Treatment During Construction

During construction, mine-impacted water will be generated and will require treatment before being discharged to receiving streams. Water treatment plants will be modular, vendor-supplied equipment package skids placed on improved pads with covers and freeze protection for sensitive piping and equipment located in the process plant and YPP work areas to treat for analytes including cadmium, copper, lead, mercury, silver, thallium, zinc, arsenic, and antimony. Peak capacity on-site for construction water treatment requirements is expected to be 300 gallons per minute (gpm) (or 0.67 cubic feet per second [cfs]) with average flows of 18 gpm (0.04 cfs) and 128 gpm (0.29 cfs) during the first and second years of mine site construction, respectively. Water treatment plant residuals will be sent to the TSF for disposal. See Section 1.7.10.1 for additional details.

1.6.7. Transmission Line Upgrades

In order to serve Perpetua's 60-megawatt (MW) load requirement for the SGP, Idaho Power Company (IPC) will rebuild or construct 72.8-miles of transmission line and associated facilities

(Figure 8). The existing Cascade to Warm Lake 69-kilovolt (kV) transmission line, and much of the Lake Fork to Cascade and the Warm Lake to Yellow Pine 69-kV transmission lines, will be rebuilt to 138-kV clearances and capacity (Perpetua 2021b)[2]. A new Johnson Creek Substation will be constructed and a new 9.1-mile, 138-kV transmission line will be built between the new Johnson Creek Substation and the new Stibnite Substation at the SGP. The existing single-phase distribution line between the proposed Johnson Creek Substation and the village of Yellow Pine will remain intact. A new single-phase underground distribution line, within the existing road right of way (ROW), will be built along Johnson Creek Road between the Johnson Creek Substation and Wapiti Meadows to the south.

Changes to the existing IPC system for SGP operations will include:

- Upgrade approximately 59.1 miles of the existing 12.5-kV and 69-kV transmission lines between the Lake Fork and Johnson Creek Substations to 138-kV service. The ROW will be 50 to 100 ft. (depending on slope aspect) and existing transmission line support structures will be replaced with taller structures.
- A new approximate 9.1-mile, 138-kV line will be constructed from the Johnson Creek substation to a new substation at the SGP, partially within a former transmission line ROW. The ROW for the new transmission line will be approximately 100 ft. wide. At the SGP, transformers will reduce the voltage from 138-kV to 34.9-kV for distribution to facilities through overhead distribution lines or underground conduits.
- A new substation (Johnson Creek Substation), approximately 0.7 mile south of the Johnson Creek Airstrip on NFS lands, will be built to provide low voltage distribution to Yellow Pine and electricity to the SGP (Figure 8). The substation is outside RCAs (see the Wetlands Specialist Report, Figure 5-5b for location details; USFS 2023c).
- Install approximately 3 miles of new underground power distribution along Johnson Creek Road from the Johnson Creek substation south to Wapiti Meadows. This underground power distribution line is within the existing Johnson Creek Road in a segment that does not cross Johnson Creek (Perpetua 2021b; Maps 59 through 62).

[2] The transmission line from Cascade Dam, including the Cascade switching station, and the Scott Valley substation, are located in the Payette River subbasin, and outside the range of anadromous fish. Because activities in the Payette River drainage do not have the potential to affect Chinook salmon, steelhead, or their designated critical habitat, they will not be further described. Please see the BA (Stantec 2024) for more details about these components of the SGP.

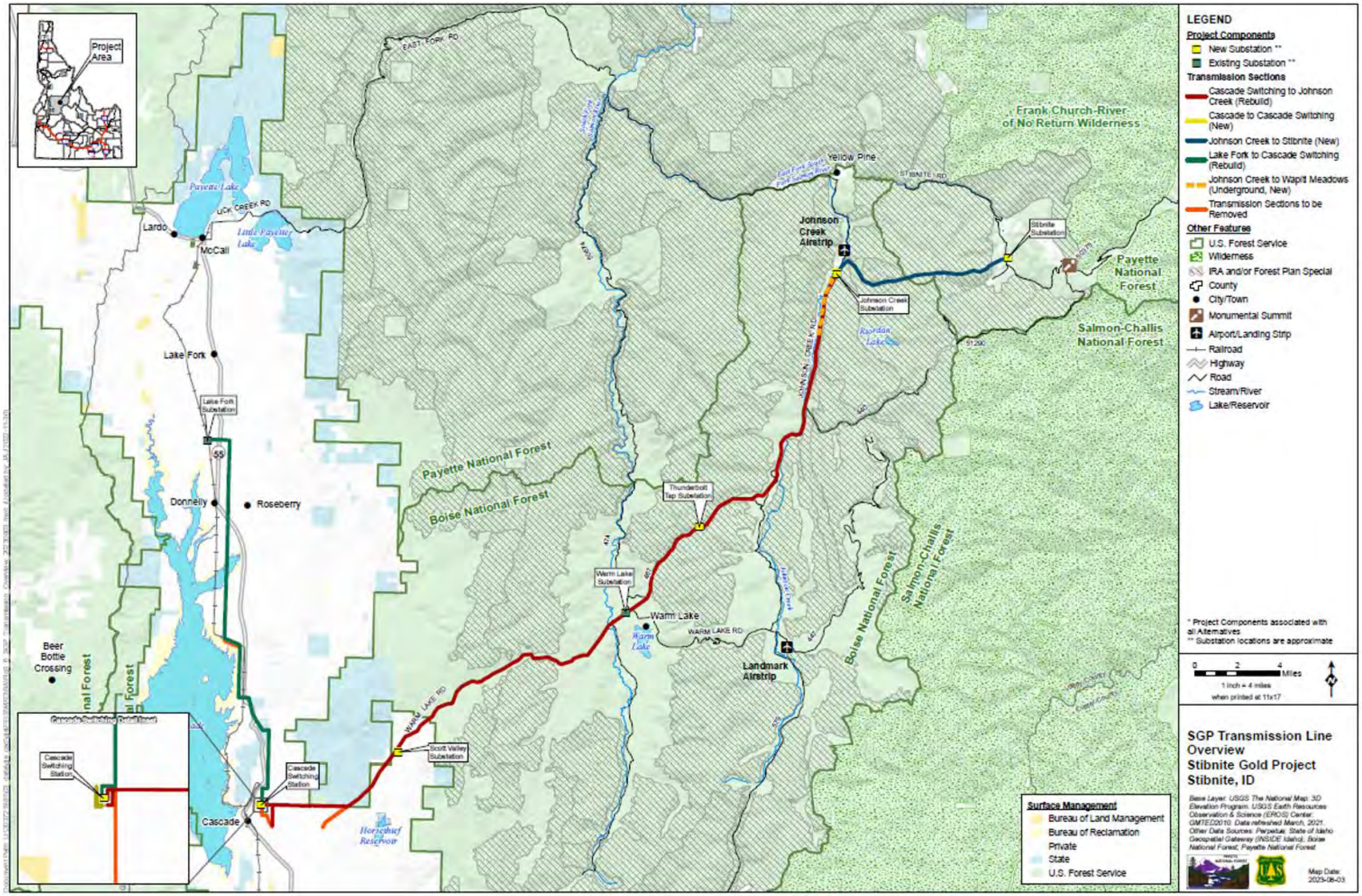


Figure 8. Transmission Line and Associated Infrastructure.

Utilities associated with the SGP (existing transmission line upgrades and structure work, ROW clearing, new transmission line, and transmission line access roads) will cross 37 different streams. Of the 37 streams that will be crossed, 26 will be related to the upgrade of existing IPC transmission lines. The existing transmission line currently crosses multiple streams, including Cabin Creek, Trout Creek, and Riordan Creek. The ROW overlaps with 132.4 acres of RCAs. However, the utility poles are not directly along the creeks or within the RCA, and the line is currently kept cleared for access when necessary. Upgrades of these lines, while requiring a wider clearing zone, the effects will be limited to trimming of trees that pose a fire risk to the power line.

The transmission line extends across lands managed by the BNF, PNF, BOR, IDL, and private lands (Figure 8). Table 7 summarizes the transmission line segments by land ownership crossed.

Table 7. Transmission Line Segment Summary by Land Ownership.

Line Segment	Total Miles	USFS		Private		State or Local	
		Miles	%	Miles	%	Miles	%
Cascade Switching Station to Johnson Creek (Ck.)	43.6	31.5	72.2%	6.6	15.1%	5.5	12.6%
Johnson Ck. to Stibnite	9.1	8.7	95.6%	0.4	4.4%	--	--
Johnson Ck. to Wapiti Meadows Distribution (underground)	3.1	2.6	83.9%	0.5	16.1%	--	--

Note: *Crossings on BOR land are located from Lake Fork to the Cascade Switching Station in the Payette River drainage, crossing streams outside the range of anadromous fish, and are therefore not included in the table.*
Source: *Land ownership derived from parcel data (Valley County 2019).*

Both temporary and permanent disturbances will be required for the construction of the transmission line and substations. While existing structure locations will be used when possible, the removal and installation of new structures will require temporary disturbance. Where possible, single-pole structures will be installed rather than H-frame structures to minimize the structure disturbance footprint. Table 8 lists areas permanently disturbed for each transmission line structure type.

Table 8. Land Permanently Disturbed for Transmission Line Structures.

Structure Type	Area Required Permanently
Single Pole Tangent Structure	16 square feet (sq. ft.), 4-ft. by 4-ft. base
Single Pole Guyed Structure	28 sq. ft., 4-ft. by 4-ft. base, 3 x multi-helix screw anchors
H-Frame Tangent Structure	64 sq. ft., 16- ft. by 4- ft. base
H-Frame Guyed Structure	156 sq. ft., 37- ft. by 4- ft. base Up to 500 sq. ft., for up to 10, 5- ft. by 10- ft. down guy wire plate anchors

Each transmission line structure site needs a construction space large enough to remove the existing structure, excavate structure foundation holes, and install new structure poles and any guys and anchors. Temporary disturbance is based on a 100-ft. by 60-ft. pad for each structure location. Some temporary disturbance areas will be 100-ft. by 100-ft. pads. Lands affected during construction by line segment and substations and the land status are listed in Table 9.

Table 9. Land Affected During Construction by Line Segment/Project Component and Land Status (acres).

Line Segment/Project Component	USFS	Private	State or Local	Total[1]
Cascade Switching Station to Johnson Creek[1]				
Access, Existing (Minor Improvements, 0-50%)	55.0	2.0	0.3	57.3
Access, Existing (Major Improvements, 50-100%)	65.7	4.4	7.5	77.5
Access, New (Bladed)	2.8	0.7	1.2	4.7
Access, New (Overland Travel)	0.9	7.7	1.4	10.0
Access, Temporary (Minor Improvements, 0-50%)	--	1.6	0.2	1.7
Access, Temporary (Overland Travel)	--	2.0	--	2.0
Pulling-Tensioning Sites	17.3	4.4	3.1	24.7
Staging Areas	17.3	9.9	--	27.1
Structures	31.7	12.3	6.4	50.4
Structures, (Remove Existing)	--	4.7	<0.1	4.8
Substation, Cascade Switching Station	--	2.6	--	2.6
Substation, Johnson Creek	1.1	--	--	1.1
Substation (Scott Valley), SGLF	---	0.9	--	0.9
Substation, Thunderbolt Drop Substation	0.1	--	--	0.1
Substation, Warm Lake	0.3	--	--	0.3
Cascade Switching Station to Johnson Creek – Total[1]	192.2	53.2	20.1	265.2
Johnson Creek to Stibnite				
Access, Existing (Minor Improvements, 0-50%)	10.9	1.1	--	12.0
Access, Existing (Major Improvements, 50-100%)	36.5	1.2	--	37.6
Access, New (Bladed)	15.3	0.6	--	15.9
Access, New (Overland Travel)	--	--	--	--
Pulling-Tensioning Sites	6.5	0.5	--	7.0
Staging Areas	9.7	9.2	--	18.9
Structures	8.7	0.9	--	9.7
Johnson Creek to Stibnite – Total[1]	87.6	13.5	--	101.1

Source: Land ownership derived from parcel data (Valley County 2019).
[1] Only portions of the transmission line in the South Fork Salmon River and Johnson Creek are occupied by Chinook salmon and steelhead in this transmission line segment.
Key: SGLF = Stibnite Gold Logistics Facility.

Lands required permanently for Project operations by route segment and land status are listed in Table 10.

Table 10. Land Permanently Disturbed During Operations by Line Segment/Project Component and Land Status (acres).

Line Segment/Project Component	USFS	Private	State or Local	Total[1]
Cascade Switching Station to Johnson Creek[1]				
Access, Existing (Minor Improvements, 0-50%)	32.1	1.2	0.2	33.4
Access, Existing (Major Improvements, 50-100%)	30.4	2.0	3.4	35.8
Access, New (Bladed)	1.0	0.2	0.5	1.7
Access, New (Overland Travel)	0.8	6.8	1.2	8.8
Structures	0.4	0.1	0.1	0.5
Substation, Cascade Switching Station	--	2.6	--	2.6
Substation, Johnson Creek	0.4	--	--	0.4
Substation (Scott Valley), SGLF	--	0.9	--	0.9
Substations, Thunderbolt Drop Substation	0.1	--	--	0.1
Substation, Warm Lake	0.3	--	--	0.3
Cascade to Johnson Creek – Total[1]	65.5	13.8	5.4	84.5
Johnson Creek to Stibnite				
Access, Existing (Minor Improvements, 0-50%)	6.4	0.6	--	7.0
Access, Existing (Major Improvements, 50-100%)	17.0	0.5	--	17.6
Access, New (Bladed)	6.0	0.2	--	6.3
Access, New (Overland Travel)	--	--	--	--
Structures	0.1	<0.1	--	<0.1
Johnson Creek to Stibnite – Total[1]	29.5	1.3	--	30.9

Source: Land ownership derived from parcel data (Valley County 2019).
[1] Only portions of the transmission line in the South Fork Salmon River and Johnson Creek are occupied by Chinook salmon and steelhead in this transmission line segment.
Key: SGLF = Stibnite Gold Logistic Facility

1.6.7.1. **Access Roads**

In addition to the transmission line work detailed above, the existing road network used to access these structures may require maintenance/improvements to allow construction equipment safe access into the power line corridor. While the existing road network proximate to the transmission line ROW will be used to the maximum extent possible, some new service roads (roads used solely by Perpetua or IPC to access Project facilities) could be needed to reach structure locations without existing access (Table 11).

Additionally, overland service routes will be required from the existing access road to reach structure locations without current access. These overland service routes will not require blade work (i.e., recontouring). A 14-foot-wide ROW is being requested for the existing/proposed roads outside of the power line corridor ROW to accommodate construction and maintenance equipment. For FR 467, a 16-foot-wide ROW is being requested to accommodate OSV.

During construction, the new section of transmission line between the Johnson Creek substation and the SGP will require major improvements to Horse Heaven Road (FR 416W) and NFS Trail 233 (no name), and approximately 4 miles of new spur roads will be constructed. Minor upgrades to Cabin Creek Road (FR 50467) will also be required.

Road maintenance requirements prior to construction will vary depending on the type of road, level of use, and condition of the road. However, maintenance generally will consist of clearing vegetation and rocks, as well as repairing cut and fill slope failures, as necessary, to allow for a 14-ft.-wide road surface. In most cases, the roads will be left as close to an undeveloped nature (i.e., two-track road) as possible without creating environmental degradation (e.g., erosion or rutting from poor water drainage). Equipment to perform the required road maintenance will include hand tools (e.g., chainsaws), track driven machines (bulldozers and graders) and crew-haul vehicles (such as 4-wheel-drive pickups and/or off-highway vehicles [OHV; includes all terrain vehicles, utility task vehicles, and side-by-sides]). Roads will be opened/cleared for use by trucks transporting materials, excavators, drill rigs, bucket trucks, pickup trucks, and crew-haul vehicles. Specific actions, such as installing water bars and dips to control erosion and stormwater, will be implemented to reduce construction impacts and will follow standard designs.

Access road construction and disturbance can typically be summarized into five types of access roads:

Existing (No Improvement) – These existing roads provide access to structures and will not require improvement. Minor maintenance activities such as pruning of vegetation for construction vehicle access and applying water to the road to reduce dust may be required.

Existing (Minor Improvement) – These existing roads provide access to structures and should not require significant improvement to utilize for construction. Existing road widths typically vary from 14-ft.-wide access roads to 24-ft.-wide gravel roads with 14 ft. being the minimum needed to accommodate construction traffic. Minor maintenance activities such as applying water to the road to reduce dust and improve workability of the soil for blading and compaction, and blading may be required during and after construction to support construction traffic and return the road to a preconstruction condition.

Existing (Major Improvement) – These existing roads provide access to the structures and may require major reconstruction work. These roads appear to be in questionable condition and will likely require major reconstruction to support construction traffic. Existing road widths may be as narrow as 8 ft. for primitive two-track roads that need reconstruction to widen the driving surface to 14 ft., with curve widening and turnouts added to accommodate construction traffic. Overall disturbance width is estimated to be an average of 20 ft., which includes cut/fill slopes and other impacts associated with reconstruction. Maintenance activities such as applying water to the road, to reduce dust and improve workability of the soil, and blading may be required during and after construction to support construction traffic. Aggregate/crushed rock placement may be required to maintain the existing road.

New (Overland Travel) –These roads traverse existing agricultural fields or open areas and are not expected to require grading work to support construction traffic. No permanent road construction is anticipated on these routes, and any earthwork or aggregate imported will be reclaimed after construction. Temporary driving surface is estimated to be 14 ft. to accommodate construction traffic. Sections of road that cross wet fields or wetlands may have temporary matting installed to provide a stable surface to support construction equipment without disturbing the ground. Minor work such as grade smoothing at ditches or large rock removal may be required to provide a drivable surface.

New (Bladed) – New bladed roads are typically required where the existing ground has a significant cross slope or traverse's terrain that needs to be bladed smooth. Construction of the road prism will require excavation and placement of fill material to provide a stable driving surface. The driving surface is constructed to a minimum width of 14 ft. and includes curve widening and turnouts to accommodate construction traffic. Overall disturbance width is estimated to be an average of 35 ft., which includes cut/fill slopes and other impacts associated with construction. Earthwork quantities are typically balanced for each road by adjusting the grade to balance material being cut versus filled. Surfacing rock is not typically placed on these roads unless required by stakeholders or needed to support construction traffic.

Table 11 provides a summary of miles of access roads by route segment and land status.

Table 11. Miles of Access Roads by Line Segment and Land Ownership.

Line Segment/ Access Type	BOR	USFS	Private	State or Local	Total[1]
Cascade Switching Station to Johnson Creek					
Access, Existing (No Improvements)	--	5.1	4.2	4.6	13.9
Access, Existing (Minor Improvements, 0-50%)	--	18.9	0.7	0.1	19.7
Access, Existing (Major Improvements, 50-100%)	--	17.8	1.1	2.0	20.9
Access, New (Bladed)	--	0.6	0.1	0.3	1.0
Access, New (Overland Travel)	--	0.4	4.0	0.7	5.1
Access, Temporary (Minor Improvements, 0-50%)	--	--	0.5	0.1	0.6
Access, Temporary (Overland Travel)	--	--	1.0	--	1.0
Cascade Switching Station to Johnson Creek – Total[1]	--	42.8	11.6	7.7	62.1
Johnson Creek to Stibnite					
Access, Existing (No Improvements)	--	<0.1	0.7	--	0.7
Access, Existing (Minor Improvements, 0-50%)	--	3.7	0.4	--	4.1
Access, Existing (Major Improvements, 50-100%)	--	10.1	0.3	--	10.3
Access, New (Bladed)	--	3.5	0.1	--	3.7

Line Segment/ Access Type	BOR	USFS	Private	State or Local	Total[1]
Cascade Switching Station to Johnson Creek					
Access, New (Overland Travel)	--	--	--	--	--
Johnson Creek to Stibnite – Total[1]	--	17.3	1.5	--	18.9

Source: Land ownership derived from parcel data (Valley County 2019).
[1] Totals may not sum correctly due to rounding.

1.6.7.2. **Substations**

Several substations along the transmission line from Cascade to Yellow Pine will need to be upgraded from 69-kV to 138-kV. A 138-kV metering substation will be placed in the Johnson Creek area to feed the village of Yellow Pine and serve as a metering point for the Stibnite 138-kV line. The substations will be operated and maintained by IPC. Table 10 provides the area that is needed, by land ownership, for each of the substations. Additional details regarding the upgrades needed to existing substations and the construction of new substations are available in the Electrical Transmission POD (Perpetua 2021b).

Routine operation and maintenance activities that may be conducted by IPS as necessary and without prior notification to the USFS include: routine inspections (air and ground), clearing of vegetation (including hazard tree removal) to prevent encroachment into the minimum vegetation clearance distance, access road inspection and routine maintenance, wood treatment to retard rotting, and application of fire retardant to base of poles. A more detailed description of these activities is provided in Section 3.4.7.9 of the BA (Stantec 2024).

Substation maintenance activities will include equipment testing, preventative repair, and procedures for providing continual service and maintaining electrical service. Typical substation maintenance does not require ground-disturbing activity, although ground disturbance could be required to replace damaged equipment, oil containment facilities, or other miscellaneous items.

1.6.8. Off-site Facilities

Perpetua will require off-site facilities to support mine-related activities, of which only the Burntlog Maintenance Facility is located within the SFSR subbasin. This facility will support. road maintenance and snow removal activities. This facility will be located on NFS land within a previously disturbed borrow source site 4.4 miles east of the junction of Johnson Creek Road and Warm Lake Road (Figure 3) and will be accessed via the Burntlog Route with two points of ingress/egress. The facility footprint will be approximately 3.5 acres and will include three main buildings: a 7,000-square-foot maintenance building; a 7,000-square-foot aggregates storage building; and a 4,050-square-foot equipment shelter (Figure 9).

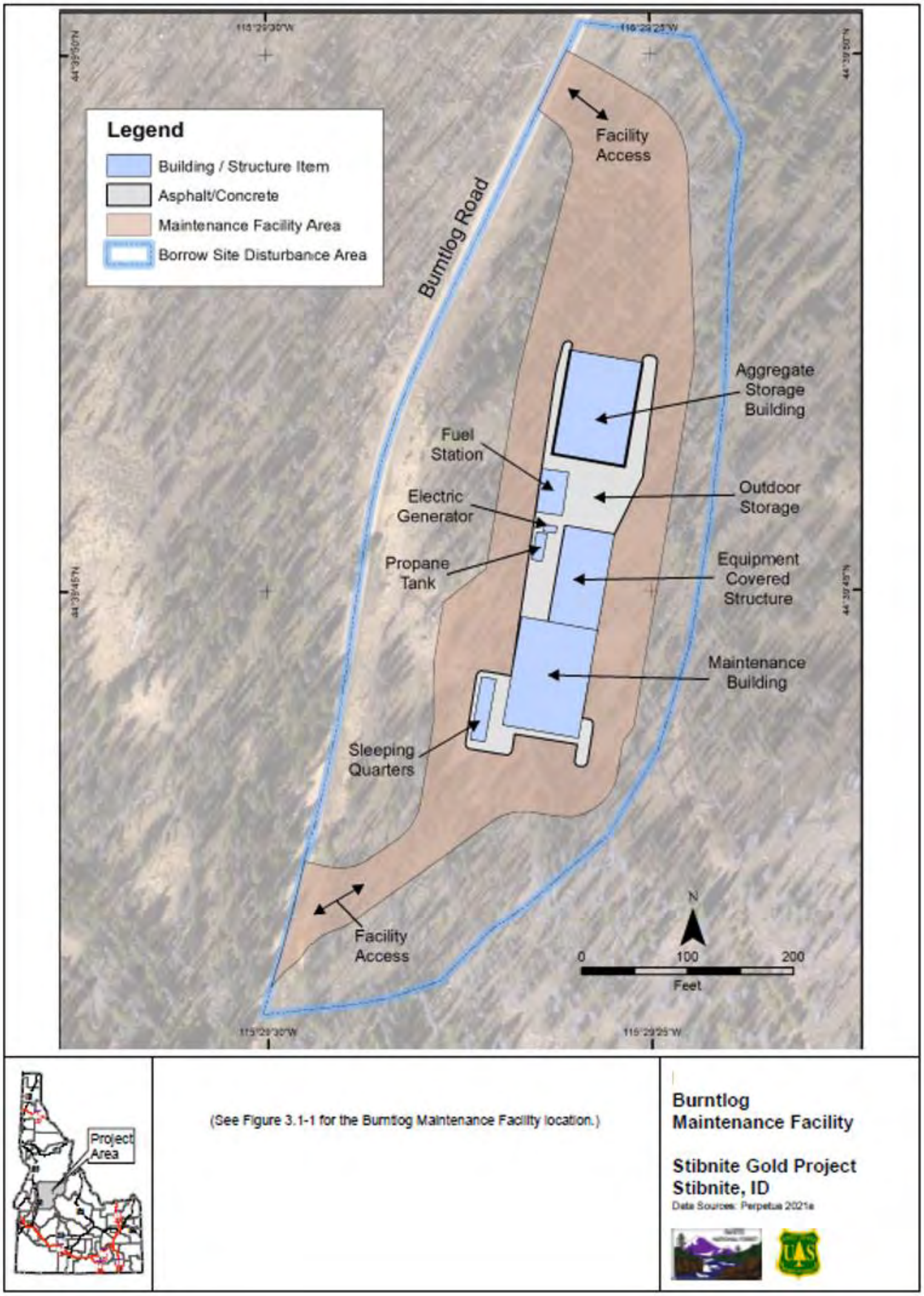


Figure 9. Burntlog Maintenance Facility.

The Burntlog Maintenance Facility will also contain a fuel station, electric generator, propane tank, outdoor storage area, and worker sleeping quarters. It will house sanding/snowplowing trucks, snow blowers, road graders, and support equipment in the equipment shelter or maintenance buildings. The Burntlog Maintenance Facility will require a domestic groundwater well to service the facility. This well and associated water right will require permitting through the IDWR.

This facility will include a double-contained fuel storage area housing three above-ground 2,500-gallon fuel tanks for on-road diesel, off-road diesel, and unleaded gasoline. Additionally, a 1,000-gallon used oil tank will be located inside the maintenance facility and a 1,000-gallon propane tank will be located at the facility for heating.

Additional features of this facility could include covered stockpiles of coarse sand and gravel for winter sanding activities; temporary or emergency on-site housing for road maintenance crews during periods of heavy snow removal needs and other winter maintenance activities; and communications equipment including a tower. This facility could also serve to support snowmobile trail grooming and grooming equipment storage as needed.

1.7. Mine Operations

The SGP will consist of mining three primary mineral deposits and the re-mining of historical tailings using conventional open pit shovel and truck mining methods. Ore from three open pits (Yellow Pine, Hangar Flats, and West End Pits) will be sent to either the crusher, located near the processing plant, or one of several ore stockpiles in various locations within the Operations Area Boundary (Figure 4) (M3 2021). Pre-stripping, or removing the overlying soil and rock (i.e., development rock) to access the mineral deposit, will commence during the construction phase in MY -2. Ore removal and processing will begin in MY 1 (operations phase) and continue year-round for approximately 15 years. Mine operations will occur in the area of two historical open pit mined areas (Yellow Pine and West End) and one new open pit (Hangar Flats) that includes former underground mining and mineral processing facilities.

In general, ore mined from the three open pits will be hauled directly to the primary crusher area; however, during extended periods when the ore tonnage or ore type from the pits exceed the availability of the ore processing plant, the ore will be stockpiled and processed at a future time. Development rock (also commonly referred to as waste rock) will be hauled to the TSF embankment or placed in one of four destinations: the TSF Buttress or the Yellow Pine, Hangar Flats, and West End open pits once they are mined out.

1.7.1. Open Pits

Figure 4 shows the location and extent of the three pits to be mined. A general sequence for mining, assuming 15 years of mine operations as shown on Figure 5, will be as follows:

- YPP – MYs 1 through 7
- HFP – MYs 4 through 7
- West End Pit (WEP)– MYs 7 through 12
- Stockpile mining – MYs 12 through 15

The YPP will be in the northern portion of the SGP, in the same general location as a historical open pit mining area. The pit will be expanded to include a shallower mining area to the northeast previously mined as the Homestake Pit. The EFSFSR currently flows through the legacy YPP, forming a small pit lake (YPP Lake) when the EFSFSR flowed into the pit after it was abandoned in the 1950s.

The WEP will be in the northeast portion of the SGP, east of and at a higher elevation than the YPP, generally situated between Sugar Creek to the north and Midnight Creek to the south. The WEP will be in the same general location as historical open pit mining where multiple open pits, mine benches, waste rock dumps, and areas of deep backfill exist. The existing Stibnite Pit is within the southern portion of the WEP, and once expanded will be known as the Midnight Pit.

The HFP will be in the central portion of the SGP, generally encompassing steep south and southeast facing slopes and the adjacent Meadow Creek valley floor at the toe of these slopes. Historical mining activity in this area was primarily underground but the proposed pit also will encompass the site of the former Bradley mill and smelter, the Hecla heap leach, and Stibnite Mine Inc. leach pads. Table 3.5-1 in the BA (Stantec 2024) provides a summary of characteristics for each pit.

Partial dewatering of the open pits will occur prior to and concurrent to renewed SGP mining. Shallow alluvial and deeper bedrock wells will be drilled adjacent to the pits to intercept and pump groundwater before it flows into the pits. During mine operations, groundwater seepage and in-pit surface water runoff will be collected for reuse in the ore processing plant or treated and discharged, according to whether there was a water deficit or surplus at a given time. Additional details on pit water management can be found in Section 1.7.10.

1.7.2. Drilling and Blasting

Drilling and blasting will be used to break ore and development rock in the mine pits (see M3 2021 for additional details as well as Section 3.9 in the BA for information on controls). Following drilling, explosives will be used to break rock into fragments that are suitable for loading into equipment. An Explosives and Blasting Management Plan will be prepared as part of the final mine plan. This plan will include blasting measures techniques, charge sizes, and setbacks to minimize effects on fish and wildlife as summarized below and described in the FMP. Explosives storage, transport, handling, and use will comply with applicable Department of Homeland Security, Bureau of Alcohol, Tobacco, Firearms and Explosives, Department of Transportation, and Mine Safety and Health Administration (MSHA) regulations.

- Perpetua will employ blasting setback distances and other controlled blasting techniques following industry BMPs (modifying blasting variables including charge size, and vibration and overpressure monitoring) to minimize impacts to fish from blasting. Perpetua will follow up with monitoring in early stages of operation to evaluate effectiveness and refine blasting protocols in coordination with federal, state, and tribal agencies, if needed. Blasting setbacks are described in the FMP. Blasting for the YPP will be in proximity to the EFSFSR while blasting for the HFP will be in proximity to the Meadow Creek diversion, above its confluence with the EFSFSR.

- Blasting peak particle velocity will be < 7.3 pounds per square inch (psi) (50 kilopascals [kPa]) where fish are present.
- Blasting airblast overpressure will be < 2.0 inches per second (in/s) (51 mm/s) during sensitive stage (embryo incubation before epiboly is complete).
- Required setbacks for blasting are set to meet maximum overpressure and maximum peak particle velocity, including a 239-ft. blasting setback on 20-ft. benches, and 419 ft. setback on 40-ft. benches (as measured from the closest point the blast field to stream and lake habitats).
- Perpetua will develop an Explosives and Blasting Plan that will ensure compliance with the blasting requirements of the MSHA, 30 CFR Part 56, Subpart E – Explosives and Part 57, Subpart E – Explosives. The blasting plan will include the setback distances and options for other mitigative measures and BMPs.
- Observe setback distances for each blasting activity, wherever possible. In the event a blasting activity will not meet the required setback distance, Perpetua will attempt to adjust the bench height or blast intensity to minimize potential adverse effects to fish communities in the nearby stream. Where the setback distance cannot be met and alterations to the blasting protocol will not adequately mitigate potential harm to fish communities, Perpetua will implement measures to isolate, capture, and relocate ESA-listed fish species from the stream segment where potential for impact exists.

Perpetua developed a spreadsheet tool to compute the required setback distances from fish-bearing streams and lakes. The spreadsheet tool was developed using the following steps:

1. The equations used in the spreadsheet were taken from Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998), including equating the peak particle velocity to charge weight and distance.
2. The standards used came from the Alaska Blasting Standard for the Proper Protection of Fish (TR 13-03) (ADFG 1991) described above—the blast overpressure threshold limit was set at 7.3 psi and peak particle velocity threshold was set at 2.0 in/s.

The spreadsheet tool was then populated with the anticipated drill and blast assumptions (bench height, drill hole diameter, stemming length, powder column height, powder volume and charge per hole [weight]).

Perpetua used these required setback distances to do a high-level review of streams and lakes in closest proximity to areas where blasting may be required. This review identified areas where the blasting may be within the 239-ft. and 419-ft. setbacks. These include some stream segments adjacent to the EFSFSR diversion tunnel, YPP, WEP, the TSF and HFP where Meadow Creek is closest to the pit. This analysis does not definitively identify areas where impacts will occur but points to areas where adjustments to blasting methods may be needed to reduce the required blasting buffer (bench heights, charge size, and detonation pattern, etc.). According to the proposed implementation, such areas will be the locations at which initial calculation and testing of blast effects (instantaneous pressure and peak particle velocity) will be conducted. It is also noteworthy that blasting in some of the areas identified may not occur until non-consolidated materials are removed without blasting, such that the distance between blast sites and streams will have increased. The predicted setback distances will be verified via blast monitoring instrumentation (blast seismographs and pressure transducers) utilized for test blasts at three sites with different physical conditions.

1.7.3. Rock Hauling and Storage

Rock loading and haulage will use a development fleet and a production mining fleet. Mine development excavation required to establish haul truck access roads, access limestone, and pre-strip pits prior to production mining will use a fleet of medium sized excavators, wheel loaders, and 45-ton articulated trucks. This development fleet will also be used to salvage GM and support reclamation activities. Production mining will use a conventional diesel truck and shovel fleet consisting of two 28-cubic yard hydraulic shovels, approximately sixteen 150-ton haul trucks, and one 28-cubic yard wheel loader. The wheel loader will be used primarily to load haul trucks during shovel maintenance and to load stockpiled ore as needed. The ore will be hauled directly to the primary crusher or the run-of-mine ore stockpile at the ore processing facilities.

1.7.4. Ore Management

Ore from the open pits will be hauled to and placed directly into the ore processing plant, except during periods when the amount or type exceeds the availability of the ore processing plant, the excess ore will be stockpiled in unlined facilities on top or within other mine disturbance areas. Seven long-term ore stockpiles and one short-term stockpile will be used to manage the excess ore (Figure 4). The long-term ore stockpiles will be located on and near the TSF Buttress and HFP and the short-term stockpile will be located near the crusher. The short-term stockpile will hold ore that will be processed within weeks while the long-term stockpiles will hold ore for a period of months to years until the process has the capacity to receive the stored ore.

Highest-grade ore will be sent directly to the crusher, or to the short-term stockpile area near the crusher where it will likely be processed within a few days. Lower-grade ore will be sent to the long-term ore stockpiles where it will remain for months or longer. Some of the ore sent to the low-grade ore stockpiles will be re-handled during active mine operations, and some will be re-handled and processed once open pit mining has ceased. If metal prices do not support processing of some of the long-term stockpiles, the stockpiled material will be covered as part of TSF Buttress closure activities (Section 1.9).

Three long-term ore stockpiles will be on the TSF Buttress on the north side of the valley. Two stockpiles will be adjacent to the HFP and extended onto the pit footprint after it is backfilled. A stockpile within the WEP footprint will temporarily store ore mined during West End Road development and pre-stripping. Ore storage in long-term stockpiles peaks in Year 11 with approximately 19 million tons.

1.7.5. Development Rock Production and Storage

Development rock from the three open pits will be sent to five different permanent destinations over the mine life including the TSF embankment and rind fills; the TSF Buttress; the mined-out YPP; the mined-out HFP; and the Midnight area within the mined-out WEP. In addition to these five areas, other destinations will receive development rock from the three open pits including a temporary ore stockpile base within the WEP, a foundation for stockpiling growth medium and recovered seed bank material, a reclamation materials stockpile located on the TSF Buttress, and miscellaneous projects such as road fills and ore stockpile foundations. Approximately 280 million tons of development rock from active mining areas will be used to construct the TSF embankment and buttress, and placed in the mined-out pits, as described in BA Table 3.5-2 (Stantec 2024).

After the main portion of the YPP Pit has been mined and mining commences in the northern portion of the pit, development rock will be end-dumped into the YPP as backfill. The dumped development rock will not be mechanically compacted, except as it nears the final reclaimed surface elevation of the backfilled area.

The upper lifts of the backfill will be placed by direct dumping and compaction. The final backfill will be covered with a geosynthetic liner and soil/rock cover, and the EFSFSR and Stibnite Lake will be established across the backfill in a geosynthetic-lined stream/floodplain corridor. The inclusion of the lined Stibnite Lake on the YPP backfill will help buffer temperature extremes in the EFSFSR and replace the fish habitat of the existing YPP Lake. The 16-million-gallon lake feature was designed based on results of lake temperature modeling to reduce diurnal temperature fluctuations, in particular, to lower the maximum temperature. Development rock to backfill the YPP will be sourced predominantly from the WEP, with minor quantities originating from the YPP and HFP.

Upon construction of the Stibnite Lake, the lake feature will be filled with 16 million gallons of water diverted from the EFSFSR upstream from the tunnel location. This diversion will flow through the restored portion of the EFSFSR located on top of the YPP backfill until entering Stibnite Lake. Once Stibnite Lake is filled, it will outflow to another segment of restored stream channel on top of the YPP backfill which subsequently enters the EFSFSR channel north of the YPP. The diverted flow rate will be a portion of the total EFSFSR flow for a period of several weeks to minimize sediment generation from the restored stream channel and to maintain flows in the EFSFSR and tunnel to support fish habitat and passage. The diverted portion will be based on the available flow in the EFSFSR while maintaining habitat and passage and will fill Stibnite Lake feature slowly (i.e., a 1 cfs diversion will require approximately 24 days to fill the feature).

Once mining ceases at the HFP, development rock to backfill the HFP will be sourced predominantly from the WEP. The Midnight Pit, a portion of the WEP in the southeast corner of the pit near Midnight Creek, will be backfilled concurrent to mining the WEP, with development rock from the WEP once mining in the area to be backfilled is completed.

In addition to the permanent development rock storage described above, a temporary development rock storage facility (DRSF) will be constructed within the WEP during road construction and pre-stripping activities. This temporary DRSF will contain approximately 2.5 million tons and serve as the base for the West End In-Pit stockpile. Since this is a temporary DRSF entirely within the footprint of the WEP, material will be rehandled during regular mine operations at the WEP and relocated to other facilities for permanent development rock storage.

Perpetua has conducted geotechnical investigations supporting the design of the development rock backfills. Because backfills will be below grade, they will not be susceptible to mass failure events in the post-closure period. Development rock in the above grade TSF embankment will be placed per a design with a 5.85 Factor of Safety that will not be susceptible to mass failure events in the post-closure period (Tierra Group 2021).

Surface water and groundwater management for facilities that permanently store development rock are discussed in Section 1.7.10, Surface Water and Groundwater Management. The Development Rock Management Plan describes procedures and methods for mining, haulage, and placement of development rock that is produced and stored across the SGP during operations (Brown and Caldwell 2022).

1.7.6. Spent Ore and Legacy Tailings Removal in Meadow Creek Valley

The Meadow Creek Valley contains legacy materials created from historical mining activities. Legacy materials include development rock, spent ore in the unlined spent ore disposal area (SODA), the Bradley Mill Tailings, and run-of-mine and crushed ore in the historical lined heap leach pads. An Environmental Legacy Management Plan (Perpetua 2021c) describes procedures and methods for active management of legacy materials encountered during construction and mining operations. While the TSF is being built and expanded, Perpetua will remove and reuse as construction material the 7.5 million tons of spent ore within the unlined SODA and other areas (Hecla and Stibnite Mine Inc. leach pads). Physical and chemical testing of the legacy material will determine if the material is suitable for construction uses (e.g., TSF starter dam material) and determine the final placement of the material. Legacy tailings removal will be a component of early-Project ore processing using water to mobilize legacy tailings and collecting excess water in the SODA contact water pond. The water will be initially sourced at approximately 800 gpm (1.7 cfs) from dewatering wells, industrial supply wells, and the EFSFSR freshwater intake, then recirculated with an expected reclaim efficiency of 80 percent. Water not reclaimed will be entrained in the tailings within the TSF or lost to evaporation. The temporary water addition and pumping facility to make up for entrainment and evaporation will be an enclosed, heated structure located within the limits of the SODA.

The legacy tailings will be pumped to the ore processing facility. During the first four years or so of ore processing operations, Perpetua will remove and reprocess the three million tons of Bradley tailings underlying the SODA using approximately 1.5 million gallons of water recirculated daily per the water usage forecasts for the overall Project. If other legacy materials are encountered during construction they will be removed and hauled off site to an appropriate disposal facility, placed in the TSF, used as pit backfill or construction material, or left in place, depending on testing to determine physical and chemical suitability. Physical suitability will be based on the material's geotechnical characteristics (e.g., grain size, shear strength) compared to the geotechnical specifications of the facility at their location. Chemical suitability will be based on the potential for leaching of the materials to affect water quality (i.e., acid-base accounting and kinetic geochemical testing) as described in the Environmental Legacy Management Plan (Perpetua 2021c). Legacy development rock not used for TSF construction purposes or reprocessed will be placed in pit backfills or used for the TSF Buttress.

1.7.7. Ore Processing

During operations, approximately 115 million tons of ore will be mined from the three proposed pits and processed at the mill facilities during the approximately 15-year process facility operation. At full operation, targeted ore production will range from 20,000 to 25,000 tons per day, which will be transported to the processing facility to separate the gold, silver, and antimony from the ore. The ore processing is summarized in the following sections. Additional details on ore processing can be found in section 17 of SGP's updated feasibility study (M3 2021).

Ore feed for processing will be sourced from either the open pits, Bradley tailings, the SODA, the short-term stockpiles, or long-term stockpiles. The ore processing flow sheet is shown on BA Figure 3.5-1 (Stantec 2024). The ore processing facility and associated support infrastructure are shown on Figure 4.

The ore processing area will be designed to provide for containment of ore processing materials, chemicals, wastes, and surface runoff. Potentially hazardous chemicals and wastes will be stored within buildings or areas with both primary and secondary containment. Surface runoff within the ore processing area will be directed to a contact water pond for collection. Any leaks or spills escaping both primary and secondary containment will flow to the contact water pond for collection and will not discharge off site.

The processing will result in production of an antimony mineral concentrate, gold- and silver-rich doré, tailings, and other waste products (e.g., small quantities of other non-saleable metals recycled back into the process). Tailings disposal is discussed in Section 1.7.8, Tailings Storage Facility.

1.7.7.1. **Crushing and Grinding**

Ore will be hauled to the crusher where it will be crushed and ground to reduce the size of the rock to separate the gold, silver, and antimony-bearing minerals from the host rock. Mined ore will typically be direct-dumped into the jaw crusher or stockpiled at the uncovered run-of-mine stockpile area near the crusher. Stockpiled ore will be loaded into the crusher dump pocket, based on crusher availability, using a loader. The residence time for material in the stockpile will be short (i.e., days); therefore, there will not be sufficient time for infiltration through the stockpile material to the subsurface. Surface water runoff from the run-of-mine ore stockpile area will be captured and directed to a pond and be used in the ore processing facility (Section 1.7.10).

Following crushing, the crushed ore will be transported via conveyor to a dome-shaped, covered stockpile. Dust emission controls, such as water sprays and/or bag house dust collectors, will reduce dust from crushing, conveying, and stockpiling. Apron feeders below the crushed ore stockpile will convey the ore to a semi-autogenous grinding mill followed by a ball mill for additional size reduction of the ore. Grinding will occur within an enclosed building to reduce noise levels. Grinding with process water will reduce the ore to the size of fine sand in a water slurry for further processing.

1.7.7.2. **On-site Lime Generation**

Ground limestone and lime are needed for pH adjustment in the SGP ore processing plant. Rather than trucking these materials to site from an off-site source, a limestone bed in the WEP is of suitable quality and quantity to satisfy the life-of-mine SGP requirements for lime. Over the life of the mine, approximately 130,000 to 318,000 tons of limestone will be mined annually, averaging approximately 240,000 tons per year. Approximately 25 to 30 percent of the limestone mined annually will be crushed and run through an on-site lime kiln to produce metallurgical lime powder, with the remainder (70 to 75 percent) will be crushed and stockpiled for direct use as limestone. Both ore and limestone will be temporarily stored at the run-of-mine stockpile area.

The on-site lime generation will require additional equipment, which will be placed within the ore processing area. This equipment will include: limestone crusher and conveyor, propane-fired kiln (200 tons per day output capacity), kiln combustion air system including preheat heat exchanger, propane storage tank plus vaporizer, air compressor, receivers, and dryers for plant air and instrument air at kiln area, roll crusher for kiln product discharge, conveyors for moving feed and product materials, off-gas fume filter for kiln discharge, dust collector kiln feed bin, storage bin for kiln feed material; and storage bin for lime products. The limestone crusher, screens, conveyors, and feed bins will not be enclosed. Dust will be controlled in a similar manner to the ore crushing and conveying process through the use of water sprays and/or bag house dust collectors.

1.7.7.3. **Antimony Flotation**

Two flotation circuits will be utilized; one circuit produces an antimony concentrate, and the other produces a gold-rich sulfide concentrate. Ore high in antimony will be processed by the antimony circuit to produce an antimony concentrate (M3 2021). Following grinding, the ground ore slurry will be mixed with lime and small amounts of sodium cyanide or equivalent to inhibit flotation of the gold-bearing minerals (pyrite and arsenopyrite). Lead nitrate or equivalent will be added and then a sulfur- and phosphate-bearing organic chemical. These chemicals make the stibnite mineral particles hydrophobic where the particles then attach to air bubbles and float to the surface in the stibnite flotation tanks. The gold-bearing mineral particles which do not adhere to the bubbles in the stibnite flotation tanks will drop to the bottom of the flotation tanks and be routed to the subsequent gold flotation circuit for further processing. The antimony flotation facility will have interior curbing high enough to contain 110 percent of the volume of the largest tank.

The stibnite-laden bubbles form a froth and will be collected from the top of the stibnite flotation tanks. The stibnite concentrate froth will be subjected to one or two additional flotation steps to further clean the concentrate. The resultant antimony-rich concentrate will be finally thickened and filtered. The final antimony concentrate will be placed in 2-ton supersack containers ready for shipment off site for further refining.

1.7.7.4. **Antimony Concentrate Transport**

The antimony concentrate will contain approximately 55 to 60 percent antimony by weight. The remaining balance, 40 to 45 percent by weight, of the concentrate includes sulfur and common minerals with trace amounts of gold, silver, and mercury. As described in the Transportation Management Plan (TMP) (Perpetua 2022) for transportation of antimony concentrate, Perpetua will load the sealed 2-ton super sacks containing the concentrate into a shipping container at the processing facility. Perpetua will load the concentrate by forklift and hooked lifting racks to safely move the super sacks, which are equipped with lifting straps, into fully enclosed shipping containers for the full course of their transport from the SGP site to their final destination. The supersacks and shipping container will provide primary and secondary containment for the antimony concentrate (Perpetua 2022). The concentrate will be trucked via SH 55 to a commercial truck, train, barge, ship loading facility depending on the refinery location. An estimated one to two truckloads of antimony concentrate will be hauled off site each day. It is assumed that the concentrate, when sold, will be shipped to facilities outside of the U.S. for smelting and refining because there are currently no smelters in the U.S. with capacity for refining the antimony concentrate.

1.7.7.5. **Gold and Silver Flotation**

Low-antimony mill feed will be processed in the gold flotation circuit only, bypassing the antimony circuit (M3 2021). Gold and silver flotation are a process similar to that described for stibnite flotation, and will be housed in the same building, but using different chemicals to float pyrite and arsenopyrite, the minerals that contain the gold and silver. The flotation building will have interior curbing high enough to contain 110 percent of the volume of the largest tank. The flotation froth, with particles containing gold and silver, will be collected and pumped to the gold concentrate thickener to further separate the gold/silver mineral particles from the process water which will be recycled. The particles from gold flotation that do not float will become the tailings slurry. The gold and silver concentrations of the tailings will be regularly monitored and, if the concentrations are high enough to warrant further processing, they will be sent to the leaching circuit; otherwise, the tailings will be thickened to recycle additional process water and then routed to the TSF as described below.

1.7.7.6. **Oxidation and Neutralization**

An autoclave pressure-oxidation system will be used to oxidize the gold- and silver-bearing sulfide minerals comprising the gold and silver concentrate to liberate the gold and silver for subsequent leaching. Before the gold concentrate is pumped into the autoclave, it will be mixed with appropriate amounts of ground limestone to maintain a constant free acid level of approximately 10 grams per liter in the autoclave. This value was established through bench and pilot-scale metallurgical testing to promote the formation of stable, crystalline arsenic compounds in the autoclave. Oxygen will be injected into the autoclave to promote the oxidation reaction, and the temperature in the autoclave will be maintained at approximately 220°C. Water will be injected into the autoclave as needed to control the temperature. After pressure oxidation, the acidic slurry containing gold and silver will be neutralized using slurried lime and other chemicals and cooled in two forced draft cooling towers. The neutralized slurry will then be sent to the leach circuit for recovery of gold and silver from the slurry.

When increasing arsenic levels are observed, the oxidized slurry will be treated with hot arsenic cure (HAC) prior to neutralization. Metallurgical tests showed that this process promotes formation of the stable crystalline form of the arsenic precipitate enhancing environmental stability of arsenic.

The autoclave system will be housed in a steel frame building set on concrete foundations, with interior curbing to provide secondary containment. Air emissions from the pressure oxidation facility will be captured in a series of air pollution controls, and the material collected will be disposed of as a solid waste or a hazardous waste depending on the waste characterization.

1.7.7.7. **Gold and Silver Leaching and Carbon Adsorption**

The gold and silver leaching component of the recovery process will be regulated by the Idaho Department of Environmental Quality (IDEQ) under the Cyanidation Rule (Idaho Administrative Procedures Act [IDAPA] 58.01.13) and will be designed and operated consistent with the International Cyanide Management Code for the Manufacture, Transport, and Use of Cyanide in the Production of Gold (Perpetua 2021a). Gold and silver leaching and carbon adsorption will occur in a steel frame building set on concrete foundations, with secondary containment of 110 percent of the volume of the largest tank and could include audible alarms, interlock systems, and/or sumps, as spill control measures (Initiative for Responsible Mining Assurance [IRMA] 2018).

The leaching to recover gold and silver from the oxidized gold and silver concentrate slurry will occur in large carbon-in-pulp tanks which will be fully contained to capture, retain, and recycle process solutions. Sodium cyanide will be added to the tanks containing the neutralized solution to form a gold-silver-cyanide complex and activated carbon will then be added to the tanks to promote the adsorption of the gold-silver-cyanide complex onto the carbon (BA Figure 3.5-1) (Stantec 2024). The pH of the slurry in the leach circuit will be closely managed at an elevated level to maintain the cyanide in a stable soluble form.

The loaded carbon with gold-silver-cyanide complex attached will then be collected on screens and sent to the carbon stripping circuit. Inside sealed tanks, the carbon with the gold-silver-cyanide complex will be washed with an acid solution to remove impurities, rinsed with fresh water, and stripped of the gold using a hot alkaline elution solution. The resulting gold and silver-bearing elution solution will be piped to the electrowinning and refinery area.

The acid solution used during carbon stripping will be reused until it loses its effectiveness. The solution will be neutralized and sent to the tailings thickener for pumping to the TSF. Air emissions from the leaching facility will be captured in a series of air pollution controls, and the material collected will be disposed of as a solid waste or a hazardous waste depending on characterization of the waste.

1.7.7.8. **Gold and Silver Electrowinning and Refining**

The gold and silver electrowinning and refinery facility will be a closed-circuit system with 110 percent containment of the largest vessel. The elution solution pumped into electrowinning cells which will electrolytically precipitate the precious metals into a solid sludge that will be removed from the elution solution with a filter. The solid precipitate will then be heated in a retort system to drive off and collect any contained mercury. The gold and silver precipitate from the retort will then be mixed with flux and then placed into an induction furnace and heated. The molten material from the induction furnace, consisting of gold and silver metal and slag, will be poured into molds to cool. The slag will be recycled within the mill circuit and the doré gold/silver bars will be shipped off site to refineries for further processing and refining.

Air emissions from the induction furnace and retort will be treated in a series of emission controls. Mercury metal will be securely stored prior to shipment to a certified hazardous waste disposal facility.

1.7.7.9. **Tailings Neutralization Circuit**

Cyanide-bearing process slurry from the carbon-in-leach circuit will be neutralized within the ore processing plant to less than approximately 10 milligrams per liter weak acid dissociable cyanide before being pumped to the TSF. Residual cyanide in the slurry will be treated using a sodium metabisulfite and air system to oxidize cyanide to form cyanate. After neutralization, tailings will be routed to one or more tailings thickeners, to partially dewater the tailings before they are pumped to the TSF. The process water separated from the thickened tailings slurry will be recycled within the ore processing facility. The neutralized and thickened tailings slurry will be pumped to the TSF.

1.7.7.10. **Tailings Pipeline Maintenance Pond**

Lined tailings pipeline maintenance ponds will be located at the truck shop and at the ore processing facility, to which tailings slurry from the tailings pipeline between the mill and the TSF and process water from the tailings reclaim pipeline could drain by gravity during maintenance shutdowns or if there were a leak in either pipeline. The ponds will typically be empty except during maintenance or unforeseen problems with the tailings or reclaim water pipelines, pumping system, or TSF. The ponds are designed to contain the contents of the pipelines and the runoff from the pond and open-trench portions of the lined pipeline corridor from a 100-year, 24-hour storm event plus snowmelt.

1.7.8. Tailings Storage Facility

The TSF will be located on NFS lands within the Meadow Creek valley (Figure 4). The TSF, its embankment, and associated water diversions will occupy approximately 423 acres at final buildout with approximately 405 acres of new disturbance. Perpetua has conducted geotechnical and geophysical investigations to support the design of the TSF and associated buttresses. The TSF at the end of operations will be capable of holding approximately 120 million tons of tailings, the operational water pool, and precipitation falling within the TSF and contributing watershed up to the 24-hour Probable Maximum Precipitation event of 11.74 inches of rainfall. Additional details on ore processing can be found in section 18 of SGP's updated feasibility study (M3 2021).

The TSF will consist of a rockfill embankment, a fully lined impoundment, and appurtenant water management features. The TSF Buttress located immediately downstream of, and abutting against, the TSF embankment will substantially enhance embankment stability.

EDFs were established based on the facility size and risk using applicable dam safety and water quality regulations and industry best practice for the TSF embankment on a stand-alone basis; the addition of the buttress substantially increases the safety factor for the design to about double the minimum requirements. The upstream face of the TSF embankment and the Meadow Creek valley, where the TSF impoundment will be located, will be fully lined to minimize leakage. The TSF will be surrounded by an 8-ft. high, chain-link fence designed to keep wildlife, such as deer and elk, from entering the impoundment area.

The TSF includes an engineered, rockfill starter embankment. Historical development rock (i.e., waste rock), spent ore from the historical SODA and heap leach areas, and development rock from mine pits will be used for the TSF embankment construction. The TSF Buttress will be built by first constructing a ramp along the north side of the valley to access the crest of the TSF embankment and upper portions of the buttress (BA Figure 3.5-2) (Stantec 2024). Historical spent ores from the SODA and Hecla heap leach will be placed as bedding on the upstream face of the embankment or impoundment fill prior to placement of the liner to minimize interaction with infiltrating surface water. The starter embankment will be constructed to an elevation of 6,850 feet (or 245 feet above the existing ground surface). The TSF Buttress will then be constructed upwards to further access TSF embankment lifts while the base expands down the valley (eastward) as historical spent ore and legacy tailings are removed from the valley bottom. Engineered fill will be placed against steep slopes within the impoundment to flatten and smooth slopes to facilitate liner placement. This method of construction will allow for controlled material placement across the valley from the ramp north of the valley to the south side. The TSF Buttress will provide additional short- and long-term geotechnical stability. The final embankment height will be 475 ft. at a crest elevation of 7,080 ft. (BA Figure 3.5-3) (Stantec 2024).

1.7.8.1. **TSF Underdrain System**

The TSF will have an underdrain groundwater collection and conveyance system located beneath the liner. Prior to construction, the area will be evaluated for springs and seeps. Evaluations will consist of visually identifying intermittent wet areas (seeps), areas with flowing water (springs), or areas supporting increased plant growth when compared to surrounding areas (see section 18 of M3 2021 for additional detail).

Groundwater underdrains will be a series of parallel drains with branching laterals, instead of a single valley bottom drain, due to the broad u-shaped nature of the Meadow Creek valley. Pipes will transition from perforated (able to collect groundwater) to solid-wall (for conveyance only) as they exit their respective collection areas (impoundment and embankment) and flow underneath the buttress to the outlet. Underdrain flows will be collected in a sump downstream of the toe of the buttress, monitored for water quality, then either discharged to Meadow Creek surface water through a permitted Idaho Pollution Discharge Elimination System (IPDES) discharge, or pumped to the ore processing facility or a contact water pond for either treatment and discharge or use as makeup water for the mill process. The TSF liner system will then be installed in the TSF impoundment area over the underdrain system.

Underdrains will be installed beneath the TSF Buttress to ensure that groundwater does not saturate the base of that fill and potentially lead to water quality impacts or geotechnical instability; however, little if any flow is expected in the buttress underdrains owing to lower observed groundwater levels beneath the buttress. Underdrain collection sumps and downgradient monitoring wells will be used for TSF leak detection.

1.7.8.1.1. TSF Liner System

Due to water quality regulations and the presence of dissolved metals (chiefly arsenic and antimony, with trace mercury) and residual cyanide in the tailings pore water and supernatant pool, the TSF impoundment (including the upstream embankment face) will be composite lined with geosynthetic materials to prevent seepage of process water or transport of tailings out of the facility. A network of geosynthetic drains will be placed above portions of the geomembrane liner to reduce hydraulic head on the liner and excess pore pressure in the overlying tailings. The drains will report to a sump near the upstream embankment toe, and the water will be pumped out to the pool or reclaim system for reuse (M3 2021).

A composite liner consisting of a 60-mil, single-sided, textured, linear low-density polyethylene liner over a geosynthetic clay liner (GCL) will be employed to contain the tailings. Before placement of the liner within the TSF, the subgrade will be re-worked and compacted, or a minimum of 12 inches of buffer/liner bedding fill will be placed if re-working and compaction of native materials is not expected to meet subgrade design specifications as defined under IDAPA 50.01.13 (Rules for Ore Processing by Cyanidation). Geosynthetic overliner drains will be placed above portions of the liner to reduce hydraulic head on the liner and pore pressure in the overlying tailings solids during operations. The drains will direct water that migrates through the tailings to a sump near the upstream toe of the embankment, and the water will then be pumped out to the tailings pool within the impoundment or the reclaim system for reuse in the mill.

Facilities that use cyanide in their mineral extraction process are required to obtain a permit from the IDEQ and follow the Rules for Ore Processing by Cyanidation (IDAPA 50.01.13). The liner system proposed for the SGP meets the requirements of the rule under which the Project's Cyanidation permit is expected to be issued.

1.7.8.1.2. TSF Management Support Facilities

Light vehicle roads and haul roads will provide access between the ore processing facility and the TSF, and the tailings delivery and reclaim water return pipelines will parallel the haul road. Secondary containment in the event of a pipeline break will consist of a geosynthetic wrap or an open geosynthetic lined trench. Further, the pipeline corridor will drain to one of two pipeline maintenance ponds – one at the truck shop and one at the ore processing facility. Electrically powered pumps will be located at the ore processing facility to pump tailings to the TSF and reclaim pumps will be located at the TSF to return water to the ore processing facility for reuse.

1.7.8.1.3. TSF Water Management

Thickened tailings slurry will be pumped to the TSF (see section 18 of M3 [2021] for additional details). The TSF will be designed and operated as a closed-circuit, zero-discharge facility meaning no tailings water will be discharged during the mining operations phase to surface water or groundwater except in compliance with applicable permits and regulations. As the tailings consolidate, water collected in or falling on the surface of the TSF will form the supernatant pool on top of the tailings and be reclaimed for use in ore processing. Cyanide levels in the TSF reclaim water will be monitored throughout operations to ensure they remain in compliance with issued approvals and permits.

1.7.9. Mine Support Infrastructure

SGP infrastructure to support surface mining and ore processing operations will include the following:

- A one-story mine administration building that will be sided or painted and roofed in neutral colors.
- A maintenance workshop which will store materials and supplies as discussed in Section 1.7.14, Materials, Supplies, Chemical Reagents, and Wastes.
- A truck wash facility which will include an oil/water separation system and water treatment facilities to enable recycling of the wash water.
- A worker housing facility (Figure 10), which will be constructed on NFS lands adjacent to Thunder Mountain Road (FR 50375) and will accommodate up to 500 people. This facility will include dormitories, food service, and recreation facilities, along with the supporting infrastructure of power, water supply, and wastewater treatment plant. The SGP main gate and security building will be collocated with the worker housing facility.
- Haul roads to transport ore, development rock, and reclamation materials from mining or storage areas, and to transport vehicles to the maintenance workshop. A typical haul road travelway will be approximately 87 ft. wide (81.1 ft. of running surface and 5 ft. of safety berm width). The haul roads will be built and maintained for year-round access and will be surfaced with gravel materials. Road maintenance activities will be conducted to manage fugitive dust emissions and maintain stormwater management features. The total disturbance associated with haul roads and other Project access roads based on the Reclamation Closure Plan is estimated to be 127.5 acres.
- Culverts will be installed where haul roads cross drainages or to direct stormwater to collection and retention structures. Culvert inlets and outlets will be lined with rock riprap, or equivalent, as needed to prevent erosion and protect water quality. Crossings of known fish-bearing streams will be constructed to support fish passage, with appropriately designed and constructed culverts or bridges.
- Service roads and paths that will provide an internal access system for employees and visitors to the site. The service roads will typically be 12 to 15 ft. wide; some will be graveled or covered with rock aggregate, while others will be two-track roads. There will be no planned public use of the SGP service roads or trails. The path system will enable SGP pedestrian traffic to move safely throughout the SGP operating area. Service roads and paths will be located within the overall disturbance area defined for the SGP and existing roads will be used to the extent possible.

- Employee and visitor parking that will be maintained during construction and operations. During construction, the gravel parking areas will be located at the new worker housing facility, near the contractor/construction laydown areas, and at the Scout Portal. As operations are initiated, gravel parking areas will be maintained for buses, vans, and other miscellaneous vehicles for employees, contractors, vendors, and visitors at the new worker housing facility, at the shop area, and near the mine administration office.

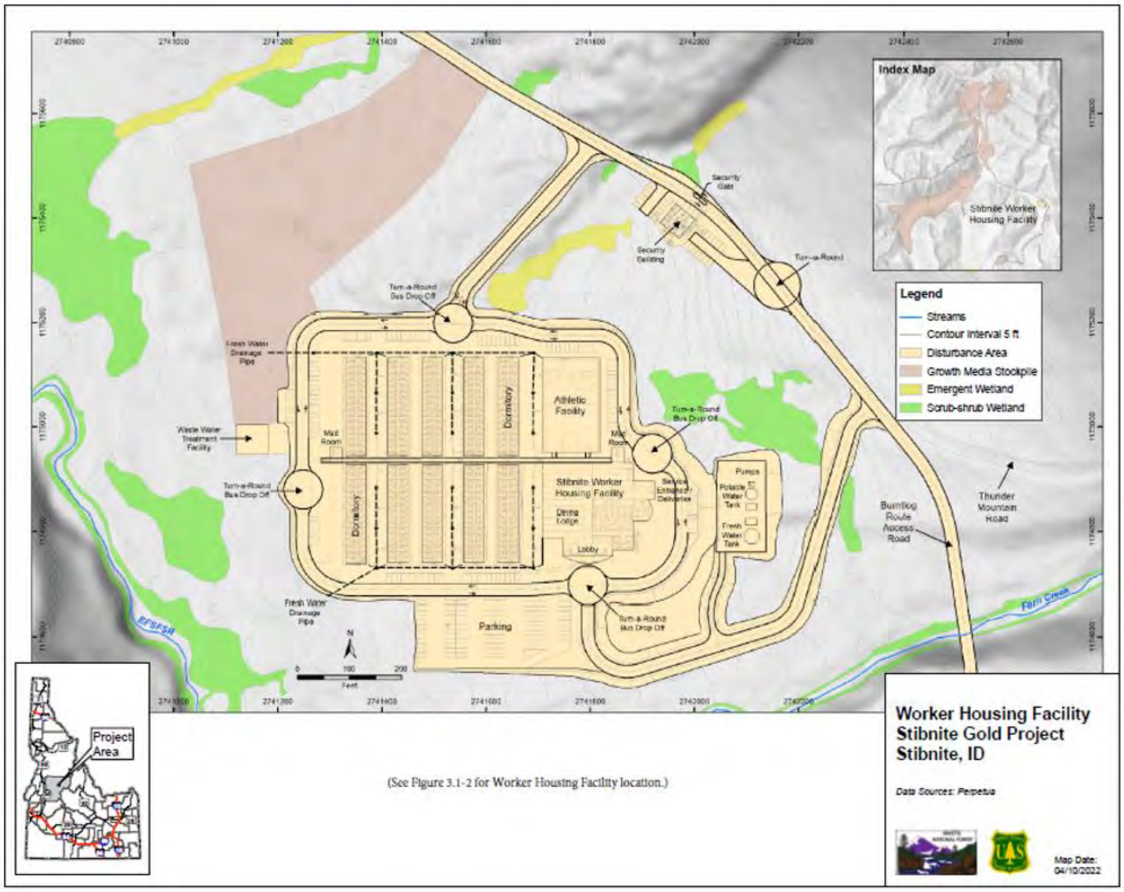


Figure 10. Worker Housing Facility, Stibnite Gold Project.

1.7.10. Surface and Groundwater Management

1.7.10.1. **Water Use and Water Balance.**

The water balance is an accounting of inflows, outflows, and storage for various components of the mining and ore processing system. Actual volumes for water balance inputs and outputs could vary seasonally and annually from the volumes estimated. In particular, the seasonal basis for dust control is related to the time of year where the ground is not snow-covered or does not have enough ambient moisture present to control dust. This period is generally from June to October but can start earlier or extend later depending on precipitation conditions experienced each year. Precipitation events between June and October will also result in temporary periods during and immediately following the precipitation where dust control is not required due to the presence of ambient moisture. A water balance flow diagram for the mining and ore processing operations phase is provided in BA Figure 3.5-5 (Stantec 2024) with components of the water balance described below.

1.7.10.1.1. Water Use and Supply

Sources of water are required for ore processing, surface and underground exploration, dust control, and potable use. Water for industrial and mining uses will be supplied from water pumped from the dewatering wells located around the Hangar Flats, Yellow Pine, and West End Pits; industrial water supply wells; contact water storage ponds; a surface water supply intake on the EFSFSR; and process water recycled within the ore processing and tailings circuit. Dewatering production varies over the mine life from 100 gpm (0.22 cfs) to 2,200 gpm (4.9 cfs); industrial supply varies between zero and 1,300 gpm (2.9 cfs); contact water varies between zero and 1,600 gpm (3.6 cfs), and EFSFSR surface diversion varies between zero to 2,020 gpm (4.5 cfs). The surface water supply intake will be located immediately downstream of the debris screen before diverted flow enters the south portal of the EFSFSR tunnel. The intake will be equipped with a fish screen designed in accordance with the NMFS 2011 Anadromous Salmonid Facility Design guidance. Dedicated wells will provide potable water for worker consumption and sanitary use. Projected water use for the SGP is described in Table 12.

Table 12. Estimated Gross Fresh and Recycled Water Usage.

Component	Construction and Start-Up (gpm)	Operations (gpm)	Closure and Reclamation (gpm)
Underground and surface exploration	50	50	0
Surface dust control (seasonal basis)	33	66	16.5
Ore processing including tailings storage	0	3,900	0
Potable or domestic use	26	12	4
Sub-Total Use	109	4,028	20.5
Contingency (10%)	11	403	2
Total Estimated Use	120	4,431	22.5

Source: Perpetua 2021a
gpm = gallons per minute

As shown in Table 12, ore processing facility operations will represent approximately 97 percent of water use associated with the SGP. A separate wellfield of up to four wells will be developed in the EFSFSR drainage adjacent to the worker housing facility to provide potable water for the housing facility. The use of water from pit dewatering, contact water from precipitation runoff, surface water, and development of separate wellfields for supplemental industrial water and potable water at the worker housing facility will require permitting through the IDWR as new water rights or transfer of the place of use for one of Perpetua's existing water rights. Perpetua has submitted an application to IDWR for a total diversion of up to 9.84 cfs (4,416 gpm) for use by the SGP[3]. A description of water rights authorizing diversion of water for use at the SGP main facility, and at the Landmark Maintenance facility, is in Section 1.7.10.1.9.

[3] As of July 5, 2024, IDWR had approved water rights with a total maximum diversion rate of 9.8 cfs for use at the SGP mine site, and an additional 0.04 cfs for use at the Landmark maintenance facility.

1.7.10.1.2. Water for Ore Processing.

Ore processing is the primary driver for water use. Process water will require a continuous supply with approximately 80 percent of process use reclaimed from the TSF (i.e., approximately 3,000 gpm [6.7 cfs]). Water sources for ore processing include water from pit dewatering and water supply wells, contact water, EFSFSR surface water intake, and water recycled from the TSF. Outflows from ore processing include tailings slurry conveyed to the TSF and evaporative losses from various process components.

The majority of the water needed for ore processing will be recycled (reclaimed) from the TSF. Reclaim water will be pumped from the supernatant water pool at the TSF to the reclaim water tank at the ore processing facility. Makeup water will be supplied from pit dewatering in wells located around the Hangar Flats, Yellow Pine, and West End Pits; water supply wells; contact water; and surface water intake in the EFSFSR. Water will be pumped from the pit dewatering wells to freshwater tanks near the ore processing facility site. These tank facilities also could supply water for exploration drilling, development drilling, in-pit road dust control, and emergency fire suppression. The freshwater tanks could store approximately 360,000 gallons of water; 240,000 will be available for process uses, and the remaining 120,000 gallons will be maintained for fire suppression. Additional water needed for ore processing, domestic uses, etc. will be diverted from the EFSFSR and from groundwater wells, in accordance with State of Idaho water rights (see Section 1.7.10.1.9).

1.7.10.1.3. Water at the TSF

Inflows to the TSF include tailings slurry and precipitation. The TSF will store tailings solids, water entrained with the tailings, and free water atop the tailings (supernatant pool). Stormwater and snow falling directly on the TSF and water from the supernatant pool, that forms as the tailings consolidate, will be stored in the TSF and will be reclaimed for ore processing. Water infiltrating to the base of the TSF will be captured by the liner overdrains, enter a sump, and be pumped back to the supernatant pond. The volume of available reclaim water will be influenced by the ore processing volumes, precipitation, and evaporation. The reclaim water will be pumped from the TSF to the reclaim water tank located at the ore processing facility. During periods of site-wide water excess, reclaim can be curtailed and contact water could be used directly in ore processing to facilitate emptying the contact water ponds, while retaining water in the TSF for use in an upcoming dry season. Periods of site-wide excess water coincide with the periods of greatest mine dewatering in MYs 4, 5, and 6. There is a potential for excess water in other years (MYs -1 through 12) if there is greater than average precipitation events contributing to more contact water collection. Local stormwater and snowmelt runoff from outside the TSF footprint and the existing Meadow Creek will be routed around the TSF.

1.7.10.1.4. Water for Potable Use

Potable water will be needed for worker consumption and sanitary use. Groundwater will be the primary source of water for potable use at the SGP. An existing well located near the exploration camp in the EFSFSR drainage will be used to supply an independent water circuit, along with a separate wellfield in the EFSFSR drainage adjacent to the worker housing facility. Wells also will be drilled for potable and industrial or commercial water uses at the Burntlog Maintenance Facility and the SGLF. See Section 1.7.10.1.9 for information on water rights associated with the proposed action.

1.7.10.1.5. Water Treatment

The Project's water treatment requirements, objectives, and methods are described in detail in the Stibnite Gold Project Water Management Plan (Brown and Caldwell 2021b) and summarized here. Three water types will require treatment over the life of the SGP: (1) contact water from mine facilities, which includes dewatering water (construction through closure); (2) process water from the TSF (closure); and (3) sanitary wastewater (construction through early closure). During operations, treating and releasing contact water will generally be limited to periods when a significant amount of dewatering water is being produced, or seasonally in wet years (i.e., Spring runoffs). Outside of that time, much of the collected contact water could be put to beneficial use in the mill. During construction and at closure, absent a water demand for ore processing, less contact water will be consumed and proportionally more will be disposed of through evaporation or treatment and discharge. From construction through early closure, the camp and offices will produce sanitary wastewater needing treatment. Additional water treatment that could be required during post-closure is discussed in Section 1.9.13, Post-Closure Water Treatment. Permit discharge limits will be developed according to IDEQ and CWA requirements and the limits will be established by the IPDES permit issued by the IDEQ.

The sources proposed for operational water treatment by Perpetua include:

- Contact water from dewatering of the Yellow Pine, Hangar Flats, and West End Pits;
- Stormwater runoff (including snowmelt) from the pits, TSF Buttress, Bradley tailings, SODA, Hecla heap leach, run-of-mine ore stockpile area, truck shop, and ore processing facility;
- Toe seepage from the TSF Buttress and long-term ore stockpiles;
- Groundwater produced by the dewatering system; and,
- Sanitary wastewater from the worker housing facility, truck shop, ore processing facility, and administrative buildings.

The conceptual water treatment system during operations will need to adhere to surface water quality standards for regulated constituents, most notably arsenic and antimony. The discharge quality will meet IDEQ standards for all regulated constituents. The discharge rate will be between zero and 2,000 gpm (4.5 cfs) at a primary location at the process plant (near the confluence of Meadow Creek and EFSFSR) and a secondary location on Meadow Creek east of the HFP area. This water will be used to supplement flows in Meadow Creek if needed. The outfalls will be installed to minimize sedimentation and maintain total suspended solid (TSS) within IDEQ accepted limits. Water treatment discharge is predicted to be 2.5°C higher than ambient flow in Meadow Creek. This effect will be offset through the use of diversion pipes around the TSF which maintain cooler water from upstream, resulting in stream flow 2.3°C cooler in the EFSFSR below the treatment plant outfalls. Thus, coupled with the timing of water treatment needs with respect to the mining sequence and dewatering excess, treatment methods and capacity will be phased. During construction and early in operations, a modular, mobile, two-stage iron coprecipitation system will be utilized. Early in operations, this system will be replaced by a two-stage iron coprecipitation system located near the ore processing facility. Residuals (sludge) from the water treatment during construction will be stored in a small impoundment in the TSF footprint. During operations and closure, the residuals will be stored in the TSF. Due to contact water runoff seasonality, reuse, and equalization storage (i.e., ponds), average treatment rates are often significantly less than nominal treatment capacity, except during the HFP dewatering when a substantial proportion of treated water will be from relatively constant dewatering flows.

Dewatering flows will be met with a staged water treatment strategy. The construction time period is paired with 300 gpm (0.7 cfs) of peak capacity from package iron coprecipitation systems. The first three years of operations will require 1,000 gpm (2.2 cfs) of total treatment capacity, using an iron coprecipitation system that will remain until closure. During peak simultaneous dewatering of the YPP and the HFP, an additional 1,000 gpm (2.2 cfs) of modular water treatment capacity will be brought online for approximately three years, then treatment capacity will be scaled back to 1,000 gpm (2.2 cfs) for the remainder of operations and early closure.

Prior to closure, a new closure water treatment plant will be constructed to accommodate treatment of water from the TSF, which will include iron coprecipitation and the application of reverse osmosis membrane treatment. After mine closure and final reclamation of the TSF Buttress and pit backfill surfaces, contact water treatment will no longer be required because installation of a geosynthetic liner, growth material cover, and revegetation will preclude contact of surface runoff with mined materials; but process water treatment for the TSF (Section 1.9.13) will continue longer, through approximately year 40. The closure treatment plant will be located on private land at the TSF Buttress as the TSF will ultimately be the only remaining water source requiring treatment.

Enhanced evaporation, using snowmaker style misters located over the lined TSF, collection ponds, and/or pits, will supplement the treatment system, in particular to prevent surplus process water accumulation in the TSF and eliminate contact water inventory, if necessary, when environmental conditions are conducive to evaporation. Predicted dewatering rates were combined with estimated volumes of mine-impacted waters from the Site-Wide Water Balance (Perpetua 2021d) to forecast the volume requirements for water treatment during operations and closure. Water treatment is required whenever the volume of produced groundwater plus mine-impacted waters exceed the consumptive use demands for the Project. Hence, the water treatment volume estimate represents the sum of predicted mine-impacted water values (e.g., dewatering production, contact water) less the consumptive use by the Project (i.e., process water). These volumes ranged from 2,000 gpm (4.5 cfs) during the years of highest dewatering production down to zero flow from the collection of mine-impacted waters post-closure. Estimates also included potential variability associated with meteoric conditions on the generation of contact water to develop potential contact water volumes associated with the range between the 5^{th} and 95^{th} percentiles of predicted volumes. Contact water storage ponds will be used to provide temporary storage of contact water flows. The location of these storage ponds is constrained by topography, other proposed mine facilities, legacy materials, and near-surface groundwater levels. The ponds are also located to manage runoff in proximity to the water-generating areas (Table 13). The Project water management system is designed with storage capacity for meteoric water events so that water destined for treatment can be contained until it can be transferred to the water treatment plant (WTP) for constituent removal at the plant's 2,000 gpm (4.5 cfs) design rate (Table 14). Contact water ponds will be geomembrane-lined earthen facilities, equipped with emergency spillways and designed to contain runoff volumes associated with design storm runoff events (Table 15).

Table 13. SGP Contact Water Pond Locations.

Pond Name	Location	Duration in Mine Years	Facilities Served	Pumped Inflow Source
Hangar Flats Pond	In footprint of Hangar Flats Pit (HFP)	-2 to 4	TSF Embankment and Buttress, HFP, SODA	Gravity inflow
Soda Pond	East of TSF Buttress in footprint of SODA/Bradley tailings	3 to 17	TSF Buttress, SODA	Gravity inflow
West End Pond	Downstream and north of West End Pit (WEP) in the West End Creek drainage	-1 to 9	WEP	WEP sumps
Midnight Pond	Upstream and south of the Yellow Pine Pit (YPP) near the confluence of Midnight Creek and the EFSFSR	-2 to 15	WEP, YPP	WEP sumps, YPP sumps
North Truck Shop Pond	In Meadow Creek valley in the footprint of the truck shop area	-2 to 17	Truck Shop	Gravity inflow
South Truck Shop Pond	In Meadow Creek valley in the footprint of the truck shop area	-2 to 17	Truck Shop, HFP	HFP sumps
North Plant Pond	North of Garnet Creek on the northern side of the process plant site	-2 to 17	Process Plant site, ore stockpile	Gravity inflow
Central Plant Pond	North of Garnet Creek in the central portion of the process plant site	-2 to 17	Process Plant site	Midnight Pond, South Truck Shop Pond, North Truck Shop Pond, Hangar Flats Pond
Scout Pond	North of Garnet Creek on the eastern side of the process plant site	2 to 15	Scout stockpile	Gravity inflow

Table 14. SGP Contact Water Ponds Design Summaries.

Pond	Pond Capacity (excluding freeboard; acre-feet)	Design Storm Runoff (acre-feet)	Freeboard (feet)	Embankment Height (feet)
Hangar Flats Pond	201.8	33.9	3	35.0
Soda Pond	147.7	24.6	3	29.4
West End Pond	28.7	39.3[1]	3	60.5
Midnight Pond	83.9	16.8	3	72.7
North Truck Shop Pond	3.2	3.2	2	N/A
South Truck Shop Pond	18.3	17.9	2	N/A
North Plant Pond	7.5	7.3	2	N/A
Central Plant Pond	4.3	4.3	2	N/A
Scout Pond	9.0	9.0	2	N/A

Source: Brown and Caldwell 2021b, Table 6-2.
[1]West End Pond can contain the 100-year, 24-hour storm volume (25.8 acre-feet). Additional potential volume from snowmelt will be managed using in-pit sumps or pumping stored water from West End Pond to Midnight Pond or YPP.
n/a = not applicable – ponds excavated into the sub-grade

The installation of geosynthetic liner systems on the top surface of the TSF, TSF Buttress, YPP backfill, and Hangar Flats backfill inhibits the generation of contact water in the post-closure period plus drainage of the water entrained in the TSF results in the abatement of contact water flows after approximately 40 years.

1.7.10.1.6. Contact Water Pond Chemistry

During operations, contact water from SGP facilities, and occasionally pit dewatering water, will be directed to site contact water collection ponds and subsequently directed to the WTP. Inflow sources to each collection pond, and predicted analytes of concern for each contact water pond, are provided in Table 3.5-6 of the BA (Stantec 2024). Open pit dewatering water that is not directed to site contact water collection ponds will be pumped directly to the WTP. The predicted quality of the treatment plant inflow is summarized in Table 3.5-7 of the BA.

1.7.10.1.7. TSF Embankment and Buttress

During the construction and early operations phases, Hangar Flats Pond will be located near the northeast toe of the TSF Buttress to provide contact water storage. Runoff and toe seepage from the TSF Buttress and remaining legacy materials in SODA will be conveyed to the Hangar Flats Pond using a series of runoff collection channels or berms, internal collections sumps, pumps, and pipelines as needed. The SODA Pond will be constructed south of the TSF Buttress to provide contact water storage for the remaining years of operations and closure, as the Hangar Flats Pond will be deconstructed as the HFP is mined below the valley bottom. Details regarding the TSF Buttress design can be found in Perpetua 2021a. A summary of the information follows.

At final buildout, the TSF Buttress and adjacent TSF Embankment will contain 142 million tons of material, comprising 85.5 million tons (60 percent) of non-potentially acid generating (PAG) development rock from the YPP, 22 million tons (16 percent) of non-PAG development rock from the WEP, 14.3 million tons (10 percent) of non-PAG development rock from the HFP, 6.4 million tons (4 percent) of PAG development rock, 11.7 million tons (8 percent) of borrow material, 1.25 million tons (0.9 percent) of spent ore from the Hecla Heap, 0.85 million tons (0.6 percent) of spent ore from the SODA, and 0.2 million tons (0.1 percent) mine waste placed on the former Stibnite Mine, Inc. on/off leach pads during the Stibnite Administrative Settlement and Order on Consent (ASAOC) action. Active 'blending' of the development rock during operations is not proposed. During operations, ore stockpiles 1, 2, 3 and 4 will be located on top of the TSF Buttress and are assumed to contribute to solute loading from the facility during the operational period only. These stockpiles are assumed to have been completely removed and processed prior to closure.

At closure, the TSF Embankment and Buttress will be regraded to promote positive drainage and a low permeability geosynthetic cover will be placed over the entire facility, which will be designed to limit infiltration through the underlying development rock (Perpetua 2021a). The geosynthetic cover will be overlain by an inert soil/rock layer and GM and revegetated. Both the runoff and the toe seepage from the TSF Embankment and Buttress report to a contact water pond and then to the WTP.

The mine-affected waters that report to the ground surface will be subject to consumptive use in ore processing with any water production above consumptive use subject to water treatment and discharge. To summarize, these mine-affected waters that will be subject to water treatment include: dewatering production, waters collected in contact water ponds, stockpile runoff and toe seepage, TSF Buttress runoff and toe seepage, and post-closure TSF facility solutions.

Waters infiltrating into the subsurface under the mine facilities will mix with alluvial groundwater and are not subject to water treatment except in instances where alluvial groundwater is subsequently pumped for mine dewatering.

The Site-wide Water Balance model (Perpetua 2021d) provides a forecast for the volumes of water that will require water treatment for the operating and post closure time-periods. A principal driver for predicting water treatment rates will be uncertainty in future precipitation rates and their effect on contact water. A 120-year precipitation record was utilized to develop percentile estimates for meteoric inputs to the water balance. Initially, the volumes of water destined for water treatment will be less than 500 gpm (1.1 cfs) because dewatering and seepage rates from newly constructed facilities will be ramping up at the same time that consumptive use demand for processing needs will be at its largest and consuming contact water as a supply. Over time, water treatment volumes will increase through about MY 6 to approximately 2,000 gpm (4.5 cfs) as dewatering production and seepage rates will constitute a higher percentage of diversion for process water in those years, displacing contact water as a source. Differences in actual versus predicted dewatering rates will have limited effect on water treatment needs because diversion from industrial supply wells or surface waters will be reduced to offset any increase dewatering production (USFS 2023a). Following MY 6, predicted dewatering rates will decline removing most of the need for water treatment as water recycling will be needed to meet consumptive use demands, except during seasonal runoff periods when contact water volumes will increase. Any short-term volumes in excess of the water treatment capacity (i.e., following a large storm event) will result in water storage within the TSF and/or contact water ponds.

In the closure and post-closure periods, beginning in MY 15, volume of mine-affected waters requiring water treatment will range seasonally up to approximately 1,000 gpm (2.2 cfs) until geosynthetic cover installations (planned to commence in MY 19) could be completed in MY 23 to prevent mixing of surface water runoff and contact waters with consolidation water. Once the cover installations are in effect, volumes consisting of residual seepage and TSF consolidation water will continue to be treated but will decrease from approximately 200 gpm (0.4 cfs) down to very minor, unmeasurable flow as the tailings solids consolidate and stop emitting water. To meet applicable discharge standards, the target post-treatment concentrations for analytes were identified for the water treatment plant design (Table 15).

Table 15. Target Post-Water Treatment Plant Effluent Analyte Concentrations.

Parameter	Units	Treatment Objective[1]
pH (range)	s.u.	6.9 – 9.0
Silver	mg/L	0.0007
Arsenic	mg/L	0.01
Cadmium	mg/L	0.00033
Chromium (III)	mg/L	0.035
Chromium (IV)	mg/L	0.0106
Copper	mg/L	0.0025
Mercury	mg/L	0.000012
Nickel	mg/L	0.024
Lead	mg/L	0.0009
Antimony	mg/L	0.0052
Sulfate	mg/L	250
Thallium	mg/L	0.005
Zinc	mg/L	0.054
Nitrate/Nitrite	mg/L as N	10
Ammonia	mg/L as N	2.1
Cyanide, Total	mg/L	0.0052
Cyanide, WAD	mg/L	0.0039
Total Dissolved Solids (TDS)	mg/L	500

Source: Brown and Caldwell 2021b
[1]Treatment objectives are equivalent to the strictest potentially applied water quality standard.

Brown and Caldwell (2021b) performed an assessment of the viability of potentially applicable water treatment technologies to the predicted maximum influent water chemistry and identified the following technologies, described below, to incorporate into the Project design for the construction, operational, and post-closure periods.

Temporary treatment systems will be employed during the construction period until the Project's WTP is constructed and commissioned. These temporary systems will utilize trailer-mounted or skid-mounted equipment packages containing membrane treatment and/or iron coprecipitation systems that can be set up with limited lead time. Figure 3.5-9 in the BA (Stantec 2024) illustrates the construction period water treatment flowsheet.

Figure 3.5-10 in the BA (Stantec 2024) illustrates the operational period water treatment plan flowsheet with a design capacity of 2,000 gpm (4.5 cfs). For the operational period water chemistry, a treatment process consisting of sodium hypochlorite oxidation, two-stage iron coprecipitation with ferric sulfate, and solids separation with contingent mercury precipitation via organic sulfide precipitant addition between iron precipitation stages was selected. Influent waters will be stored in lined storage ponds for flow equalization and pumped into the WTP. This operational water treatment generally targets dissolved nitrate, metals, and oxyanions in influent solution, primarily arsenic and antimony. Addition of the mercury-sequestering precipitant is included as a contingency for the design to account for uncertainties regarding the effectiveness of iron coprecipitation in reducing dissolved mercury and methylmercury concentrations to levels below applicable receiving stream standards. Residual solids from the treatment plant will be placed in the TSF.

Under an IPDES permit, the water treatment plant effluent will be directed to Meadow Creek at a location upstream of the HFP when flow augmentation is required (i.e., when Hangar Flats groundwater pumping results in decreased Meadow Creek baseflow) and otherwise to the EFSFSR for the remainder of operations.

For the post-closure period, the water treatment process will need to be augmented to treat cyanide, sulfate, and total dissolved solids (TDS) concentrations that will be derived from the remaining inventory of TSF process water and tailings consolidation seepage (BA Figure 3.5-11, Stantec 2024). The treatment process begins with chemical oxidation followed by iron coprecipitation to remove a significant fraction of dissolved metals. Organic sulfide precipitation of mercury will be provided. Softening will be performed via lime and soda ash to remove calcium and magnesium. Adjustment of pH will be provided in advance of ultrafiltration to remove carryover solids from the solids contact clarifier and prevent particulate fouling of the reverse osmosis (RO) membranes. The RO membrane treatment will separate the dissolved solids into a concentrated brine while the permeate water will be pH adjusted and re-mineralized prior to discharge to Meadow Creek via an IPDES-permitted outfall. Treatment plant residual solids will be placed in the TSF until its cover was completed, and thereafter dewatered and disposed of in a location constructed in the TSF above the cover.

The operations phase water treatment plant will treat mine-impacted water and discharge to the EFSFSR (or Meadow Creek if flow augmentation is necessary) through reclamation of operational components through MY 18. Prior to MY 15, the reclamation and closure phase WTP will be constructed on top of the TSF Buttress where it will treat mine-impacted water to Meadow Creek through the completion of water treatment requirements estimated to be in MY 40.

1.7.10.1.8. Sanitary Wastewater Treatment

The worker housing, administration building, warehouse, maintenance shops, and underground exploration surface facilities will produce sanitary wastewater. Wastewater from the administration building, warehouse, maintenance shops, and underground facility will be collected in tanks for transport to a sanitary wastewater treatment plant equipped with a septage receiving system located near the worker housing facility. The sanitary wastewater treatment plant will consist of a package plant containing a membrane bioreactor or equivalent system to treat wastewater to applicable discharge permit requirements. The volume of wastewater influent will depend on the number of personnel working on site and is expected to be approximately 50,000 gallons per day (gpd) (0.15 acre-feet/day [afd]) during the construction period and 25,000 gpd (0.08 afd) during operations (Brown and Caldwell 2021b).

Sanitary wastewater treatment plant effluent will be discharged to the EFSFSR at an IPDES permitted location near the worker housing facility. Treatment residuals will be dewatered and transported to a permitted, off-site landfill for disposal.

1.7.10.1.9. State of Idaho Permits and Cyanidation Permit

The State of Idaho has regulatory authority over its IPDES process. The SGP will need permits issued by the IDEQ to discharge treated water from the WTP and the sanitary wastewater treatment plant. Under the IPDES program, IDEQ will establish specific discharge limits for constituents of interest plus monitoring and reporting requirements for the system based on its regulatory criteria.

The SGP will also need a Cyanidation Permit issued by IDEQ to allow the use of cyanide in its ore processing. Under this permit, IDEQ will institute permit obligations regarding the handling and containment of process solutions as well as responses to upset conditions. In addition, the permit will also contain requirements for the ultimate treatment and disposal of process water. The descriptions of handling TSF water in this report are consistent with the requirements of the Cyanidation Permit regulations.

The IDWR regulates mine tailings impoundments with dams higher than 30 ft. and administers regulations that may have to be considered when a tailings impoundment affects surface water hydrology. The IDWR also is responsible for administration of water rights, well construction standards, dam safety, and stream channel alteration. All water rights to implement the SGP will need to be granted to the applicant by the State of Idaho through IDWR.

In addition to the reclaimed water, described in Section 1.7.10.1.2, water will also be diverted from the EFSFSR and from groundwater wells. The single surface water diversion will be used to divert up to 4.5 cfs to serve three water rights (Water Right Nos. 77-7122, 77-7293, 77-14378) and will meet NMFS guidelines for screening and for upstream and downstream fish passage. All diversion of water within the EFSFSR drainage will be done in accordance with the water rights in Table 16. Although some of these water rights are in the permitting process, that process has been ongoing for several years and NMFS does not expect additional changes prior to project implementation.

Table 16. Water Rights Authorizing Water Diversion Needed to Support Mining Activities, Ore Processing, Domestic Uses Associated with the Proposed Action, etc.

Water Right Number	Maximum Diversion Rate		Beneficial Use	Points of Diversion (PODs)
	cfs	AF/year		
77-7122	9.6[1]	7.10	Mining, mining storage, mining from storage, diversion to storage, industrial, industrial storage, industrial from storage, water quality improvement storage, diversion to storage,	A single surface water POD on the EFSFSR between Meadow Creek and the YPP. Twenty-two groundwater PODs in the EFSFSR drainage between Meadow Creek and Sugar Creek. Thirty-three groundwater PODs in the Meadow Creek drainage.
77-7293		20.0		
77-14378		600.0		
77-7285		30.2		
77-7141	0.20	28.0	Domestic	Groundwater, four PODs adjacent to the EFSFSR upstream from Meadow Creek
77-14377				
77-14379	0.06	NA	Domestic	Groundwater, one POD near the EFSFSR/Meadow Creek confluence
77-14381[2]	0.04	NA	Industrial, domestic	Groundwater, one POD in the Burntlog Creek drainage

1. Surface water diversion from the EFSFSR is limited to 4.5 cfs; diversions are conditional on flows in the EFSFSR, at the POD, of at least 5.0 cfs from October 1 – June 29 and 7.25 cfs from June 20 – September 30; diversions are conditional on flows of at least 3.0 cfs in lower Meadow Creek; and diversions cannot reduce flows in the EFSFSR by more than 20% when flows are less than 25 cfs downstream from Sugar Creek.
2. This water right is for the Landmark maintenance facility in the Johnson Creek drainage, which is outside of the flow analysis area.
Source: Information was obtained from the IDWR water rights search engine (https://research.idwr.idaho.gov/apps/waterrights/wrajsearch/wradjsearch.aspx)
Key: cfs = cubic feet per second; AF = Acre Feet

In addition to the conditions described in the footnotes for Table 16, water diverted for use at the SGP must comply with additional conditions that are designed to protect instream flows for the Wild and Scenic River (WSR) reaches of the Salmon River, described in water rights 75-13316 and 77-11941. These conditions include mitigations that were designed by Perpetua Resources and proposed during development of the proposed action. Details of the water rights described in Table 16 are available at: https://research.idwr.idaho.gov/apps/waterrights/wrajsearch/wradjsearch.aspx.

The two USFS WSR water rights on the Salmon River are measured at the Shoup gage, which is upstream of the MFSR confluence. These are instream, non-consumptive water rights that maintain flows for the WSR designated segment of the Salmon River. When flows measured at the Shoup gage are less than 13,600 cfs, the minimum instream flow rates provided by the water rights range from 1,200 cfs for the period of September 1 to September 15 to 9,450 cfs for the period of June 1 to June 15. The SFSR joins this WSR segment of the mainstem Salmon River approximately 64.6 miles downstream from the SGP area. The BA explains that these water rights are subordinated to all water rights claims filed in the Snake River Basin Adjudication as of the effective date (September 1, 2003) of the Stipulation among the U.S., the State of Idaho, and other objectors. They also are subordinated to specified quantities of future beneficial use rights. Additional detailed information regarding these two water rights can be found in water right reports (referenced by water right number) available on the IDWR website (https://idwr.idaho.gov/water-rights/).

The surface water diversion, screen, and bypass facility will be constructed prior to operation of the SGP. Groundwater pumping will be via existing wells and via new wells that may be drilled before or during operation of the SGP. This includes a new well at the Landmark Maintenance Facility in the Burntlog Creek drainage.

The BA explains that no water right with a junior priority date can deplete the water needed to maintain the Idaho Water Resource Board (IWRB) maintained minimum streamflow water right on the EFSFSR (Water Right 77-14190), unless allowed as a condition of approval of the proposed junior water right. All the existing water rights at the SGP predate the priority date of April 1, 2005, associated with water right 77-14190. Any new water rights permits will have a junior priority date, but the minimum stream right (77-14190) on the EFSFSR is subordinate to all future domestic, commercial, municipal, and industrial uses, and up to 8.2 cfs of new non-domestic, commercial, municipal, and industrial uses. This will allow authorization of up to 8.2 cfs of new non-domestic, commercial, municipal and industrial water rights to which water right 77-14190 will be subordinate.

1.7.10.1.10. Drainage Area Alteration

The WEP Lake will be excavated in the Sugar Creek drainage, the catchment area of the Lake will be 185 acres, and the fill volume will be 7,027 acre-feet. In a median flow year, approximately 0.39 cfs runs off of the 185 acres that will become the WEP Lake catchment area via Sugar Creek. After MY 1, that water instead flow into the WEP, until the lake fills.

1.7.10.2. **Surface Water Management**

To manage surface water at the SGP, existing streams that run through areas proposed for mining related disturbance will be diverted. Temporary diversions will be used within the SGP to keep non-contact water separated from contact water. Contact water is water that flows into or through disturbed areas and mining facilities and could have the potential to pick up increased levels of sediment, metals, and other possible contaminants which cannot be discharged into surface water and groundwater without proper treatment. Non-contact water is meteoric water that does not contact disturbed areas or mining facilities.

1.7.10.2.1. Stream Diversions Around Mining Features

Existing streams will be temporarily diverted around SGP facilities, within constructed surface water channels. Diversion channel segments constructed in erodible materials will be lined with riprap to prevent erosion. Rock-cut channels will be constructed on steep slopes and in areas with shallow or at-surface bedrock, will have low erosion potential, and not require riprap lining. Certain channel segments constructed over fill or excavated in permeable materials will be lined with a geosynthetic liner to prevent seepage. A geotextile and/or transition layer of sand/gravel followed by riprap will be placed over the liner for erosion protection. Certain diversion sections will be piped as dictated by terrain or the need to limit warming of water. Diversions will be sized for high flows in diverted creeks, i.e., approximately 7.4 cfs for Hennesey Creek, 1.4 cfs for West End Creek, and 700 cfs for the EFSFSR tunnel. The underground diversion for Hennesey Creek will be 18- to 24-in. in diameter while the underground diversion for West End Creek will be 8 to 12-in. in diameter. The dimensions of the EFSFSR tunnel will be 15 ft. high by 15 ft. wide. These diversions will be in place through the mine operations period until replaced by the restored stream channels during the reclamation and closure period.

During mine operations, summer low flows in perennial diversion channels around the TSF impoundment and buttress (Meadow Creek), YPP (Hennessy Creek), and WEP (West End Creek) will be piped underground as an EDF to maintain cold stream temperatures. Eight- to 12-in. diameter pipes, sized to convey August baseflow, will be installed under the diversion channels in the riprap channel lining or under the adjacent access road to carry low flows. Stream flow will enter pipes through inlets at the same locations stream and tributary inflows will be diverted into the constructed channel. These combination diversions (combination of underground piping below diversion ditches) will be operated such that the pipe will contain flow year-round and surface flow will be intermittent. That is, surface flow will occur when the diverted flow is greater than the capacity of the pipeline (Richard Rymerson, personal communication, May 14, 2024). Some diversions, such as portions of Hennessy and West End Creeks, and the EFSFSR tunnel, will be entirely underground, in which case conduits will be larger and sized for high flows.

Streams will be routed into the diversion channels by constructing a temporary flow barrier, such as a diversion berm or cofferdam, to redirect flows from the existing streams into the diversion channels. Additional protection, such as riprap or energy dissipation structures, may be needed at the channel entrances and exits to ensure velocities do not scour the existing streambed or bank. Where needed, trash racks or similar debris removal structures will be installed at the channel entrances to prevent large wood and other debris from entering the diversions.

To help ensure the stream diversions are completed in a manner protective of fish inhabiting the streams, Perpetua has developed a plan for isolating channel segments, dewatering, and salvaging and relocating fish during dewatering or maintenance of natural stream channels and diversion channels, as described in the FMP (Brown and Caldwell, Rio ASE, and BioAnalysts 2021). Stream segments to be dewatered may be isolated using a variety of methods as appropriate for the site conditions. Fish salvage methods are described in Appendix A, Table A-1. Sediment controls will be installed, where needed, to reduce stream turbidity and prevent sedimentation of the downstream receiving streams.

Fish handling and salvage operations will be required for the following SGP activities:

- Construction of the TSF/DRSF;
- HFP mining;
- Stream restoration and enhancement activities;
- EFSRSR Tunnel construction and dewatering of the YPP;

- EFSFSR Tunnel maintenance; and,
- Culvert or bridge construction or replacement.

All temporary dewatering and diversion efforts for activities, such as stream repair, culvert maintenance, or temporary stream impacts from other mining activities, will have the proper fish exclusion screening, or other method, to minimize the risk of fish becoming entrained in the pump and/or diversion. Stream diversions around the TSF, TSF Buttress, YPP, Process Plant site, and Fiddle GMS will be assessed on a case-by-case basis for whether fish exclusion is necessary based on the diversion structure, channel dimensions, and likely fish presence. Further details on these potential exclusions are provided in the FMP and are incorporated here by reference (Brown and Caldwell, Rio ASE, and BioAnalysts 2021).

1.7.10.2.2. EFSFSR Temporary Diversion Tunnel

Currently, the EFSFSR flows into and through the YPP Lake. The cascade at the inflow to the pit lake currently blocks upstream fish passage. A tunnel will be built in MY -1 to direct the EFSFSR around the west side of YPP to allow mining in the pit and fish passage during construction and operations (Figure 11). The tunnel will be approximately 0.9-mile-long and 15 ft. high by 15 ft. wide. The tunnel will include a fishway stream channel designed to provide for upstream and downstream passage of migratory and anadromous salmonid fish.

The tunnel has been designed so that fish could swim through its entire length in both directions (Brown and Caldwell, McMillen Jacobs and BioAnalysts 2021). To encourage fish passage, low-energy lighting will be installed in the tunnel and set on timers to simulate daylight. A trash rack will be constructed near the upstream entrance to the tunnel to prevent large wood, boulders, and other debris from entering the tunnel, and will be periodically cleaned. The spaces between the trash rack bars will be sized to allow adult Chinook salmon passage. A surface water supply intake with fish screens will be installed upstream of the trash rack at a control weir to divert water from the EFSFSR for ore processing makeup when necessary.

A parallel roadway will be constructed in the tunnel to allow equipment and personnel access for monitoring, inspection, and maintenance. The accessway will function as a floodway for high flows, greater than the normal flow range within the fishway.

The tunnel fishway will incorporate concrete weirs, designed to produce hydraulic conditions that could be successfully navigated by fish (McMillen Jacobs 2018). The south portal (upstream end) of the tunnel will include a sediment collection and drop out area, a resting pool, trash rack, flow control weir, and picket panels. The north portal, located at the downstream end of the tunnel, will include an orientation pool for downstream migrating juvenile fish with an adult exclusion barrier to reduce potential predation, a separate adult fish holding/resting pool, rock weirs and a transition zone. A barrier to prevent upstream movement by fish would be established in the EFSFSR upstream of the north portal, using a picket type weir with a fish trap.

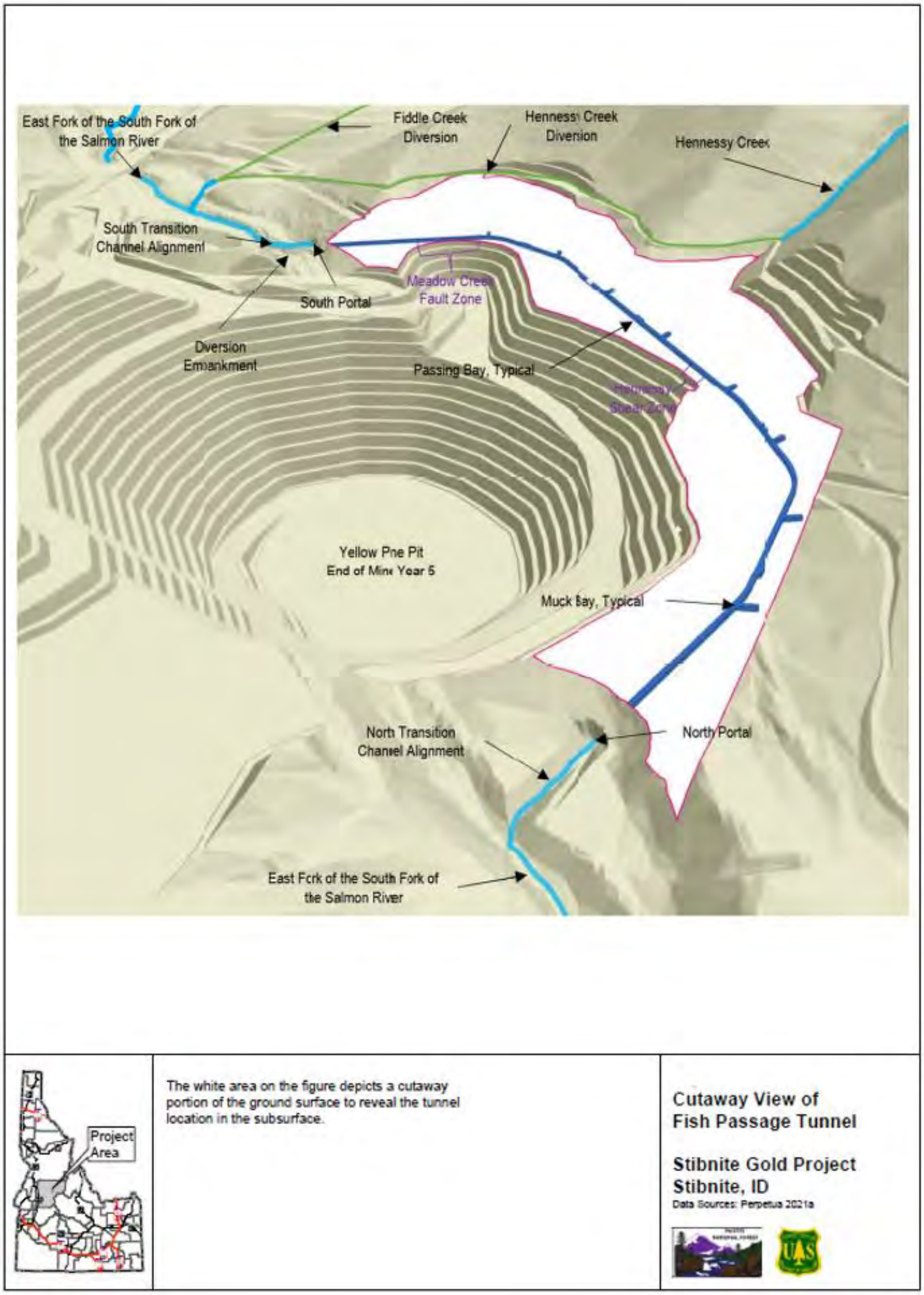


Figure 11. Cutaway View of Fish Passage Tunnel.

Activation of the EFSFSR tunnel is described in detail in the FOMP (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021), and summarized here. Activation would occur during an approved in-water work window and would follow the following sequence:

1. Pre-wash the fishway and accessway of the EFSFSR tunnel before watering up the tunnel. Water would be diverted from the stream into the fishway and accessway using a screened pump or seined opening in the cofferdam. Typical 6-inch trash pumps operate at a maximum pumping capacity of approximately 2 cfs, but pre-wash flow should be regulated to less than ¼ of the total flow upstream of the water switch location. This would fill the fishway until water reaches the downstream end. Turbid wash water would be detained and pumped to a predetermined upland location rather than discharged directly to fish bearing waters. Water would be detained and pumped from the adult holding pool.

2. Prepare EFSFSR tunnel for water by installing seine (or other appropriate fish barrier) at downstream and upstream ends to prevent fish from moving into the EFSFSR tunnel until 2/3 of the total streamflow is available in the EFSFSR tunnel (after step #4). Starting early in the morning, introduce 1/3 of the flow into the EFSFSR tunnel fishway over a period of 2–4 hours. There is approximately 3,134 feet of existing EFSFSR channel (not including the YPP) lying between the EFSFSR tunnel entrance and exit, with water flowing at an estimated velocity of 2 feet per second (fps); it would take a minimum of approximately 30 minutes for the reduction in flow (as flow introduced into the EFSFSR tunnel) to be noticed at the downstream end of the existing EFSFSR channel. Two to four hours would provide sufficient time for the existing channel to slowly reduce flows and allow some natural outmigration of fish from the reach into the YPP.

3. Monitor turbidity in north portal adult holding pool in accordance with state and federal regulations. For example, Idaho water quality standards state that the activity needs to be modified to reduce turbidity if instantaneous turbidity exceeds 50 nephelometric turbidity units [NTU]) above background or exceeds more than 25 NTU (above background) for more than 10 consecutive days (IDEQ 2017a). Continue monitoring until turbidity is within acceptable levels.

4. Prepare to introduce the second 1/3 of the flow (up to a total of 2/3) to the fishway by installing a seine (or other appropriate fish barrier) at the upstream end of the existing channel to prevent fish from moving downstream into a low-flow segment of existing channel. Introduce this additional 1/3 (2/3 total flow) flow into the fishway over 2–4 hours.

5. Repeat step #3 above.

6. Salvage fish from the existing natural stream channel before dropping below 1/3 of the incoming flow. Fish salvage within the YPP should begin shortly after incoming flow is cut off from entering the YPP. Depending on salvage techniques, a seine (or other appropriate fish exclusion device) may be installed at the downstream end of the existing channel being salvaged.

7. Remove seine nets blocking the EFSFSR tunnel entrance and exit and allow fish to move both downstream and upstream through the fishway.

8. Introduce the final 1/3 of the flow over a period of 2–4 hours. Once 100% of the flow is in the fishway, complete construction of diversion berm in the existing channel and remove seines from existing channel.

Specific details on the north and south portals, plus the overall design, function, operation, and maintenance of the diversion tunnel are thoroughly described in the FOMP (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021).

1.7.10.2.3. Midnight Creek

Midnight Creek is a first order, perennial, non-fish-bearing stream. The Midnight Creek stream diversion will reroute approximately 0.3 mile of the lower portion of Midnight Creek to the south, away from where it currently enters the YPP lake. The rerouted creek will be piped under haul roads so that it will enter the EFSFSR upstream of the proposed tunnel portal (Figure 12). The Midnight Creek diversion will manage flows in Midnight Creek during YPP operations and backfill activities. The creek will be restored when the newly developed EFSFSR alignment over the backfilled pit is complete and stabilized as described in Section 1.9.4.

1.7.10.2.4. Hennessy Creek

Hennessy Creek is a first order, perennial, non-fish-bearing stream. Hennessy Creek will be diverted south of YPP in a pipe along the public access road at the western edge of the pit (Figure 12). The diversion will include an impounding structure, overflow weir, and diversion cleanout basin. Diverted flows will be routed to Fiddle Creek downstream of the existing Stibnite Road culvert crossing, ultimately placing Hennessy Creek flows into the EFSFSR upstream of the south tunnel portal and disconnecting flow from the current unlined ditch passing alongside the Northwest Bradley dumps. Overflow, if any, will follow the existing stream channel into the YPP.

1.7.10.2.5. Fiddle Creek

Fiddle Creek is a second order, perennial, fish-bearing stream. Fiddle Creek will not be diverted. Rather, small stormwater diversions will route hillslope runoff around the Fiddle GMS and a culvert will route Fiddle Creek under the GMS, GMS access road, and public access road.

1.7.10.2.6. West End Creek

West End Creek is a first order, non-perennial, non-fish-bearing stream. The approximately 1.5-mile-long West End Creek stream diversion will reroute West End Creek around the north side of the legacy West End DRSF and cross the upper benches of the WEP (Figure 12). The diversion will consist of a lined channel along the upper legacy DRSF, and a pipe in the segments along a steep hillside above the WEP, within the pit, and along the steep hillside alongside the lower legacy DRSF down to the outlet at the existing stream channel. The lined channel portion will be designed to convey flows from a minimum 25-year storm event plus 2 ft. of freeboard.

1.7.10.2.7. Garnet Creek

Garnet Creek is a perennial, first order, non-fish-bearing stream. During construction, Garnet Creek will be re-routed downstream of the ore processing facility to a relocated confluence with the EFSFSR (Figure 12). The diverted length of Garnet Creek will be approximately 600 linear ft.

Details of the Garnet Creek re-route are depicted on Drawing GSK-002 in Appendix B of the Water Management Plan (Brown and Caldwell 2021b). Above the early restoration reach which passes through the processing plant site area, Garnet Creek will be routed along the upper processing plant site access road in a riprap channel, then cross under the ore processing facility roads in culverts, with EDF to reduce sediment loading to the stream, and to protect water quality. At closure, this segment of Garnet Creek will be restored, along with created wetlands at the plant site.

1.7.10.2.8. Meadow Creek

Meadow Creek is a perennial, third order, fish-bearing stream. Approximately 2 miles of Meadow Creek will be diverted around the south side of the TSF and TSF Buttress. The diversion will direct flows back into the existing SODA diversion upstream of the HFP (Figure 13). The new diversion will consist of a rock-cut channel in segments along the steep hillsides above the TSF and buttress, and an excavated channel in alluvium across tributary valley segments. Channel segments excavated in erodible or permeable materials will be lined with rock riprap and/or geosynthetic liner to prevent erosion and to minimize seepage. The Meadow Creek diversion channel around the TSF and TSF Buttress will be designed to convey flows from a minimum 100-year storm event with 1-ft. of freeboard.

The stream will also be diverted around the HFP. The Meadow Creek channel will be moved away from the pit to the south/southeast and reconstructed as a permanent, sinuous channel and floodplain to allow potential for spawning habitat and establishment of riparian habitat within the floodplain. A liner will be installed under the stream/floodplain corridor to minimize water seepage into the HFP or the pit dewatering well system, and to avoid potential pit wall instability or loss of stream habitat as a result of stream dewatering. The Meadow Creek diversion channel/floodplain corridor around the HFP will be designed to convey flows from a minimum 100-year storm event with 3 ft. of freeboard; as a natural channel design, the stream channel itself will be designed for bankfull flows (i.e., 1.5-year recurrence). This diversion will be permanent and incorporates design aspects to resemble natural channels not applied to temporary diversions of the other creeks. This permanent design accounts for channel migration, flooding, riparian development, and biological habitat. Details of the Meadow Creek diversion appear in the Water Management Plan, Appendix B (Brown and Caldwell 2021b), while details of its restoration appear in the CMP, Attachment D and are incorporated here by reference (Tetra Tech 2023).

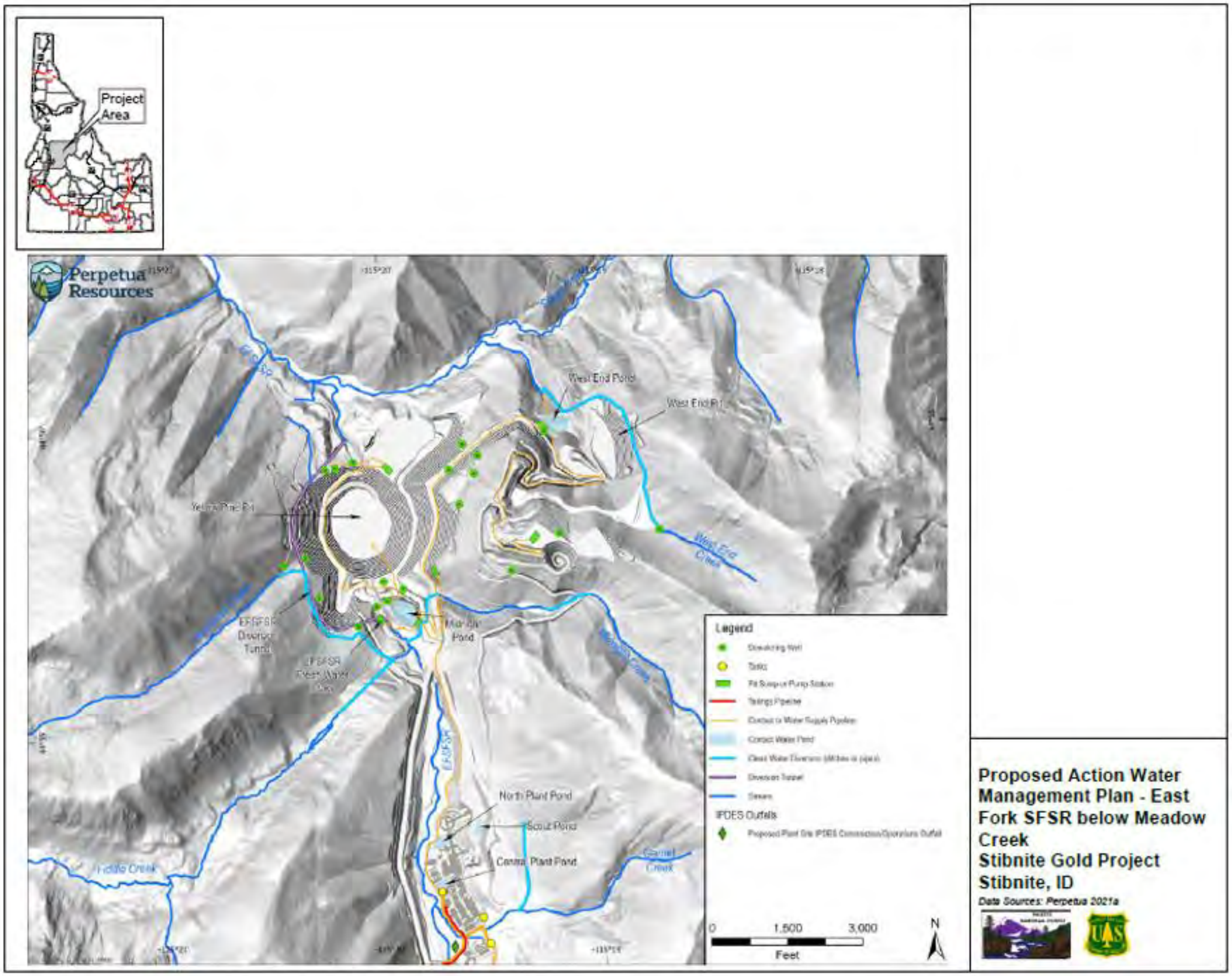


Figure 12. Proposed Action Water Management Plan – EFSFSR below Meadow Creek.

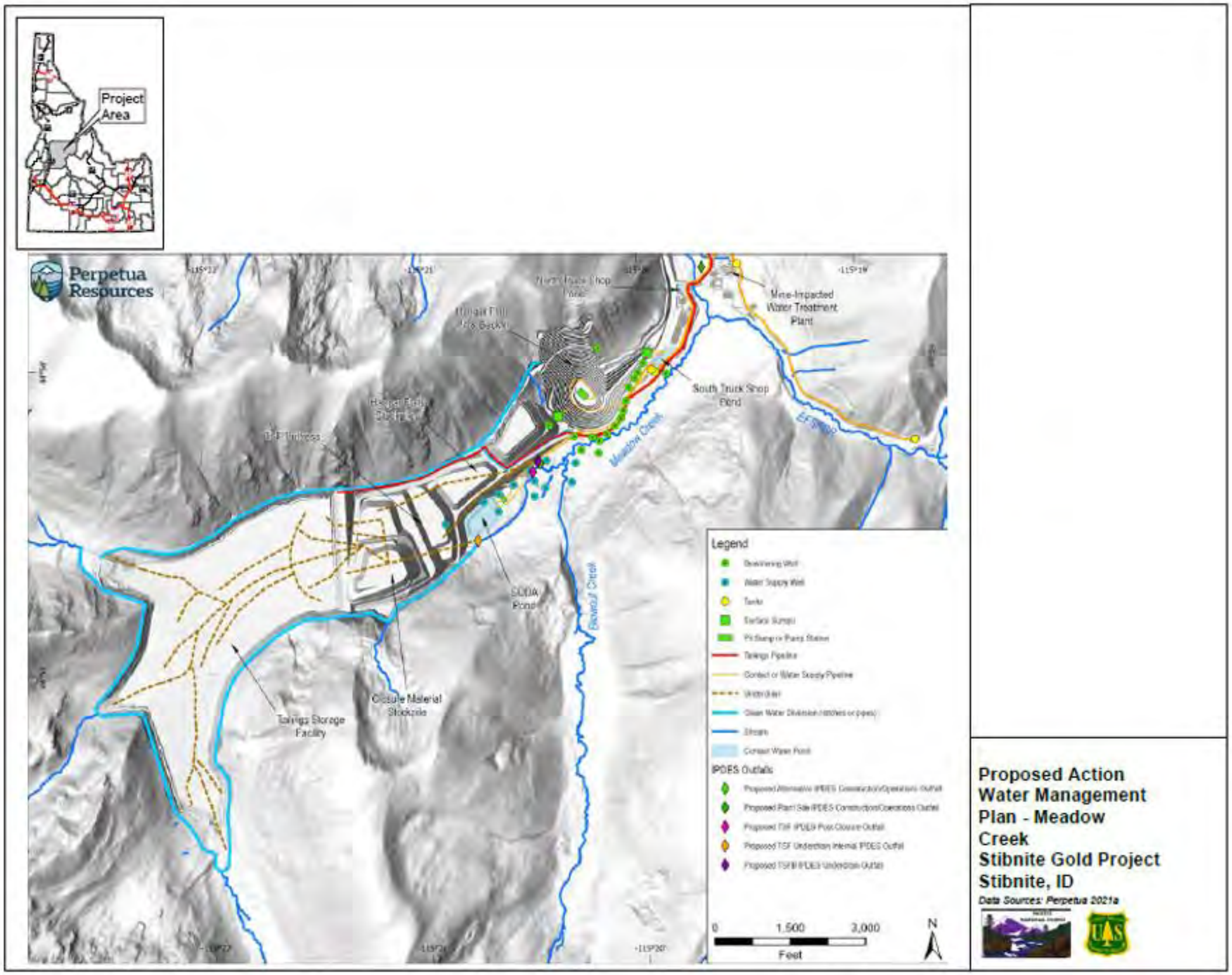


Figure 13. Proposed Action Water Management Plan – Meadow Creek.

1.7.10.2.9. East Fork Meadow Creek

East Fork Meadow Creek (EFMC, aka Blowout Creek [BC]) is a first order, perennial, fish-bearing stream outside the Project operational footprint. EFMC was impacted by the failure of a water storage dam in 1965 creating a steep actively eroding channel that conveys EFMC. In its current condition, EFMC is a downcutting creek with conditions not suitable for fish occupancy. There are fish in the wetlands area upstream of EFMC that will be excluded from the EFMC restoration area by proper fish exclusion screening.

The design for the EFMC repairs appears in the Water Management Plan; Section 6.1.4 which references the 2021 Rio ASE Stream Design Report. The design entails three reaches: (1) the segment downstream from the wetlands and upstream from the downcutting creek area (design reach BC1); (2) the downcutting creek area (BC2); and (3) the approximately 400-ft. segment between the downcutting area and the confluence with Meadow Creek (BC3). Perpetua proposes to stabilize and repair the failed area of EFMC in the actively eroding chute and raise groundwater levels in the meadow upstream of the former dam site to restore wetland hydrology. A structure to control the grade of the creek will raise groundwater levels in the meadow and a coarse rock drain will address ongoing erosion of the channel side slopes that currently deliver sediment directly to the creek, while facilitating construction of a permanent surface channel. This will be an SGP EDF and restoration effort, as the EFMC chute and upper meadow are unrelated to and unaffected by the proposed mine features.

The restored stream channels in EFMC (Tetra Tech 2023, CMP, Attachment D, Sheets 66 through 71) utilize placed streambed materials to maintain flows as surface water. These reaches have gradients greater than 14 percent which will promote runoff as surface water. The EFMC restoration will affect 2,668 linear ft. of stream below a 2,000 cubic yard structure placed as a rock grade control at the outlet of the wetlands area to the eroded channel. The rock grade control will be placed during the construction phase of the Project. For details on this construction, see the CMP Attachment D, Sheets 64 and 65 (Tetra Tech 2023). Upon exiting the rock drain (i.e., design reach BC2), flow will be conveyed by a restored stream channel to the confluence with Meadow Creek (i.e., design reach BC3, Tetra Tech 2023, Attachment D, Sheets 69 through 71). The lower portion of the EFMC alluvial fan will be an important borrow area for this and other restoration projects and is included in Project disturbance. Therefore, the restored stream channel will be constructed approximately 100 feet north of the existing channel which overlies sediments from the downcutting segment which will act as borrow materials for the restoration projects.

During construction and early mining, Perpetua will construct grade control and water retention features near the old reservoir water retention dam location to elevate the groundwater level and stream water surface sufficiently to restore wetland hydrology in the surrounding meadow. The retention structure will impound portions of the meadow channel, which will fill with sediment over time.

A coarse rock drain will be constructed within the chute downstream of the failed dam site to isolate the flow of EFMC from the actively eroding chute side slopes and to prevent further erosion of the gully bottom, facilitating subsequent restoration of a surface channel on top of the drain. The rock drain will also provide area for the collection and retention of side-slope erosion material rather than allowing that material to potentially contribute sediment to EFMC. As the rock drain fills with sediment, it will become closed off from the stream channel and flow will revert to the designed surface channel.

The existing alluvial fan in lower EFMC, located adjacent to Meadow Creek, will be partially removed, mostly during mine operations for borrow materials, and the area reclaimed. A surface diversion will be constructed at the margin of the lower alluvial fan to facilitate borrow excavation, and this stream reach subsequently restored.

1.7.10.2.10. East Fork South Fork Salmon River

Enhancement in the EFSFSR will begin in MY -1, and efforts will be focused on increasing hydraulic and geomorphic diversity while removing potential fish passage barriers. Enhancement in these stream reaches is intended to provide habitat for spawning and rearing Chinook salmon and steelhead. LWD and rock clusters will be used to enhance instream conditions, increase instream friction, sort sediment, and create localized velocity gradients. Grade control structures such as engineered riffles and/or channel-spanning rock or wood may be used to facilitate the development of relatively large pools intended to accommodate adult salmonids migrating upstream through these relatively steep reaches. The newly constructed EFSFSR, constructed across the surface of the YPP backfill, will be designed to interact with its floodplain, and will include side-channels, LWD, boulders, wetlands, and the lowest reaches of Hennessy, Garnet, and Midnight Creeks. See Appendix D of the Stream Design Report (Rio ASE 2021) for more detail and reach-specific designs.

1.7.10.2.11. Non-Contact Stormwater Diversions

Non-contact stormwater is meteoric water (i.e., precipitation) that does not contact tailings, open pits, the TSF, TSF Buttress, spent heap leached ore, and tailings from past mine operations, or any other mining related surfaces. IDAPA 20.03.02 and 37,03.05 set stormwater design criteria (e.g., storm events for design sizing and freeboard requirements). Stormwater runoff from undisturbed areas upslope of mine features in the major drainages will be captured in stream diversion channels described above or in other channels that will direct runoff away from mine disturbed areas (Figures 12 and 13). Smaller-scale diversion channels or earthen berms will be used, where necessary, to divert stormwater around other mine infrastructure. Non-contact water will be managed with features to reduce erosion and sediment delivery to streams. Where sedimentation is a concern, non-contact water stormwater diversions will be routed to sediment catch basins where the water can evaporate, infiltrate, or discharge into the stream system after settling. Energy dissipation structures will be installed at the non-contact surface outfalls as needed.

1.7.10.2.12. Contact Water

Water that contacts mining disturbances and has the potential to impact water quality is termed contact water. Contact water includes, but is not limited to, runoff from mine facilities such as the TSF, TSF Buttress, stockpiles, mine pits, haul roads constructed of development rock, toe seepage of precipitation infiltrating through the stockpiles, and underground exploration water. The TSF Buttress and stockpiles are unlined facilities. Therefore, water incident on the TSF Buttress and stockpiles that does not runoff will infiltrate into the buttress and then emerge as toe seepage or infiltrate into the subsurface and groundwater. The volume of runoff, toe seepage, and infiltration are accounted for in the site wide water balance (Perpetua 2021d) with runoff and toe seepage collected as contact water, and the effects of the infiltration are accounted for in the assessment of groundwater chemistry. Collection of contact water will begin during the first year of on-site construction and will continue throughout operations and the closure and reclamation phases. Contact water will be captured in channels and sumps and routed to the ore processing facility, contact water storage ponds, water treatment plant, or enhanced evaporation systems. In unusually high runoff periods collected water may be allowed to remain in the pits or the TSF temporarily, excess contact water from outside of the pits may be routed to mine pits for temporary storage. Contact water storage ponds will be lined to minimize leakage. Water in the contact water storage ponds could be pumped to the mill for use, treated and discharged in accordance with applicable requirements, or evaporated. Contact water in the mine pits will be directed to in-pit sumps in the lowest part of the pit and piped to the mill for use, to other contact water storage ponds, to water treatment or evaporation, or into trucks for spraying for dust control within open pits and on stockpiles or TSF Buttress. Any contact water beneficially used in the ore processing or for dust control or stored for more than 24 hours then treated and discharged will require water rights permitting, including mitigation as outlined in the water right permit, through the IDWR prior to use.

Contact water which exceeds regulatory discharge standards set by IDEQ and that cannot be used during operations will be disposed of through a variety of methods including forced evaporation using sprayers located within the TSF or other managed areas or treated and discharged. Water will be treated to meet IPDES permit limits and treated water will then be discharged through IPDES permitted outfalls to the EFSFSR or Meadow Creek.

Runoff from haul roads and access roads outside of pits, ore stockpiles, or development rock storage areas may be of sufficiently good quality to be eligible for coverage under the Multi-Sector General Permit (MSGP) for Stormwater Associated with Industrial Activities. Eligibility will depend upon the materials used for road construction and will be determined through coordination with IDEQ with oversight by EPA. Construction materials will be required to meet the 500 mg/kg arsenic concentration criteria associated with the protection of surface water from effects of metal leaching from the construction materials. The establishment of this criteria is detailed in the Development Rock Management Plan (Brown and Caldwell 2022). Runoff covered under the MSGP will be managed with a variety of EDF and conventional stormwater control measures to ensure the protection of surface water quality.

1.7.10.2.13. Surface Water Outfalls

The specific number and exact locations of outfalls will be determined via IPDES permitting through IDEQ. Approximate locations of the anticipated outfalls described below are shown on Figures 12 and 13. All outfalls will be required to meet water quality limits for specific constituents, and some outfalls may have discharge volume limits where the permit specifies a loading limit. Not all outfalls will necessarily be active or be permitted in the same permit cycle (e.g., post closure outfall will not be active during operations).

Two IPDES surface water outfalls will be used to discharge treated contact water from active mine pits, the TSF Buttress, pit dewatering, legacy mine materials disturbed by new mining activities, and the plant site and truck shop. One outfall located near the plant site will discharge to the EFSFSR. A second outfall will discharge to Meadow Creek upstream from EFMC to augment streamflow during pit dewatering.

Water from the TSF and TSF Buttress underdrains may be discharged from two outfalls shown on Figure 13, depending on whether IPDES discharge limits are met without treatment of the underdrain water (otherwise, underdrain water will be routed to the plant site for use in processing, to the water treatment plant, or back to the TSF). Discharges from these two outfalls are expected to have a strong seasonal component, with some parts of the year seeing reduced flows, or even no discharge, as contact water is used for ore processing or other mine uses. The expected water treatment and discharge rates range between zero and 2,000 gpm with the largest rates expected in MYs 5 and 6 when dewatering production is greatest and larger than the volume needed for use in the processing plant. Aside from those years, water treatment and discharge rates are zero during the summer months when water use is greatest then range between 200 and 1,000 gpm in the winter months.

An outfall will be permitted on upper EFSFSR for the sanitary wastewater treatment facility at the worker housing facility. That outfall will be active through the operations period and during mine closure until the facility is decommissioned. An additional outfall is expected to be permitted in a future IPDES permit renewal for closure and post-closure discharge of treated TSF process water. That outfall will be on Meadow Creek upstream of EFMC near the TSF Buttress.

Additional permitted outfalls may be necessary during a portion of the operations period for contact water storage pond spillways that could discharge to surface water – although discharge will be very rare or non-existent, only occurring in the event of excessive precipitation or snowmelt. The need for additional outfalls associated with pond spillways and their location will be determined with IDEQ. Each outfall will be permitted through IDEQ and will be required to be monitored, meet discharge limits, and regulate the rate of discharge.

1.7.10.2.14. Draining the Yellow Pine Pit Lake

Draining of the existing YPP lake will be initiated during construction. When the EFSFSR tunnel diversion is ready, stream flows will start being diverted into the tunnel during a period of low flow, most likely in the warmer months, and concurrent with salvaging fish from the pit lake and diverted sections of the EFSFSR. As the EFSFSR water is diverted into the tunnel, the decreased EFSFSR flow into the pit lake will be expected to cause some fish to out-migrate, thereby lessening the number of fishes requiring salvage and creating better conditions for salvaging fish. The period of fish salvage between the start of water diversion to full diversion into the EFSFSR tunnel is expected to be approximately one week. The methods applied for fish salvage are described in Appendix A, Table A-1.

Once fish salvage has occurred in the EFSFSR from the tunnel diversion downstream to the YPP Lake and most of the EFSFSR flow is being diverted into the tunnel, fish salvage in the lake will commence and take approximately one week to complete. The YPP Lake will drain naturally down to the elevation of the outlet of the lake, where the existing rock sill will control the water level, though some leakage and slow lowering via groundwater outflows may occur beyond that level. No erosion or downcutting of the outlet rock sill will be expected because it has endured the full range of EFSFSR flows over decades and both inflow and outflow rates will be minimal during draining due to the river flow being diverted into the tunnel. The drain-down process will naturally convey lake water downstream to the EFSFSR.

After the natural drain down, water remaining in the YPP Lake or entering the pit from groundwater seepage or local stormwater runoff from pre-stripping operations on the highwalls above the pit lake will be managed as mine-impacted water. The water pumped from the pit lake will be used for construction purposes, transferred to the TSF (after it is lined and available) for future use in ore processing, or treated to meet permit limits before being discharged downstream in the EFSFSR via an IPDES permitted outfall.

Sediment remaining in the pit lake bottom will be removed beginning near the end of the final year of construction. Approximately 80 vertical feet of sediment lies on the pit bottom, and the pit walls are too steep to operate equipment without a ramp. Therefore, removal may be staged to coincide with successively lower benches as the pit is mined, and therefore may extend into the first year of operations. During this time, the pit will be used seasonally to capture and store contact water from the adjacent pit walls, and this water will be used or managed as stated above.

The sediment will be removed using an excavator or similar equipment and loaded into trucks and delivered to the TSF. Slurry/dredging methods are not anticipated but will be considered as part of adaptive management if the sediments are too wet to load and/or blend. The truck beds will have flashboards to minimize water leakage from the low-strength, saturated sediments. The loading area will drain back into the former pit lake, preventing off-site discharge of bleed water during loading. If necessary, wet material will be blended with loose dry material (e.g., development rock) from elsewhere on site to enable better loading, transport, and ultimate stability at the destination.

1.7.10.2.15. Surface Water Chemistry

To minimize the volumes of contact water encountering Project disturbance and requiring treatment, the Project will divert upstream non-contact water to prevent it from interacting with SGP facilities during operations. Table 17 provides a summary of the non-contact diversion channels that are considered in the site-wide water chemistry (SWWC) model (SRK 2021a). At closure, the diversion channels will be decommissioned, and non-contact water will follow its natural drainage pathways.

Table 17. Summary of Diversion Channels included in the Surface Water Chemistry Model.

Diversion Channel	Description
North Diversion	Diverts non-contact runoff from the north of the TSF and TSF Buttress to Meadow Creek
South Diversion	Diverts Meadow Creek and its tributaries from the south and west of the TSF around the TSF
Hennessy Diversion	Diverts water from Hennessy Creek away from the YPP to Fiddle Creek
Midnight Diversion	Diverts Midnight Creek away from the YPP to the EFSFSR
West End Diversion	Diverts upper West End Creek around the West End Pit
EFSFSR Tunnel	Diverts the EFSFSR around the YPP downstream of YP-SR-6 to upstream of YP-SR-4

Source: SRK 2021a

1.7.10.3. **Groundwater Management**

Groundwater will require management to allow mining in the pits and to direct seeps and springs from beneath mine facilities. Groundwater also will provide a portion of the water supply for the SGP. Water supply aspects of the mine operations are described in the Water Use and Water Balance subsection below. Any groundwater used within the SGP will require permitting through IDWR prior to use. Depending on final use or disposal of groundwater, wells drilled on the site could be permitted as domestic use, industrial use, or dewatering wells.

1.7.10.3.1. Pit Dewatering

Lowering the water table in and surrounding the Yellow Pine, Hangar Flats, and West End Pits during operations will increase pit wall stability and provide dry working conditions in the pit bottoms. Development of the Yellow Pine and HFPs will require partial dewatering of the alluvium of portions of the EFSFSR and Meadow Creek valleys, respectively, to limit groundwater inflow to the pits and maintain stability of the pit slopes. Once the WEP is mined below the level of West End Creek, the WEP also will require dewatering.

Dewatering will be accomplished by drilling a series of alluvial and deeper bedrock wells near the pit perimeters to intercept and pump groundwater before the water reaches each pit. Alluvial groundwater at the Yellow Pine and HFPs will be managed using a series of vertical wells (Figures 12 and 13). The WEP is primarily in bedrock with only a thin layer of alluvium in the vicinity of the pit and no alluvial dewatering is planned for that pit. Pumps will be installed in each well and will run as necessary to draw down the groundwater and facilitate mining and backfilling operations. Horizontal drain holes in pit walls may also be considered for depressurizing remnant high pore pressure areas.

Groundwater pumped from pit dewatering will be considered to be contact water and will be managed through forced evaporation or active water treatment when the volume of pumped water exceeds the ore processing facility demand. Treated water will be discharged to either of two IPDES-permitted outfalls, either Meadow Creek or the outfall on the EFSFSR near the water treatment plant, depending on the need for streamflow support in Meadow Creek. The pit dewatering wells will be permitted as industrial wells in conjunction with a water right application through IDWR.

Groundwater not captured by the pit dewatering, and entering the pits as highwall seepage, will be directed to an in-pit sump in the lowest part of the pit where it will combine with stormwater and snowmelt runoff (i.e., contact water) from precipitation falling within the pit. The water will be used for dust control within the pits, and as needed, pumped to the ore processing facility for use as makeup water. In-pit water that cannot be used will be disposed of through forced evaporation or routed to the water treatment plant then discharged to the EFSFSR or Meadow Creek via IPDES permitted surface outfalls.

1.7.10.4. **Climate Change**

Per the definitions utilized by the NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change (NMFS 2023), the Project is a long-term project with a lifespan of more than 10 years with three ESA-listed fish species present (spring/summer Chinook salmon, steelhead, and bull trout). The Project includes potential risk pathways for fish passage including water diversion for consumptive use in accordance with water rights, construction of a fishway, installation of culverts and bridges for stream crossings, and the potential use of trap and haul as a secondary approach for fish passage in the event that primary approaches are not meeting targets. In addition, mine closure and site restoration activities include stream restoration through the mine area with fish passage in a designed channel.

The Project water balances and temperature forecasts utilized by Perpetua and the USFS for the development of the mine and closure designs employed sensitivity analyses to examine the potential range of future site conditions. These forecasts developed ranges for water diversion for consumptive use, contact water management, water treatment, restored stream channel flows, and riparian shading of restored stream segments. These ranges were incorporated into the component designs to allow for variability in stream flows (both high and low flows) and air temperature conditions. Idaho requirements for sizing channels and ponds were also applied so that the facilities will be engineered and constructed to contain high flow storm events with sufficient capacity and freeboard.

Because the operating lifetime of the Project will be approximately 15 years following a three-year construction period, effects of climate change during the operating lifetime will be limited by that duration. Therefore, there is less potential for climate change to affect Project operational components than components associated with mine closure and restoration. As such, the climate change risks associated with the post-closure components of the Project were prioritized. These post-closure risks were incorporated into the designs of the restored stream channels and their associated riparian shading so that the stream channels will respond to variable climatic conditions in a manner similar to natural drainages. Unlike the restored stream channels, water diversion for consumptive use and trap and haul practices will not continue past the operational period. Furthermore, access roads and stream crossing constructed for the Project will be removed during mine reclamation and closure.

The Project is located with the Columbia River watershed. As such, application of the NMFS guidance (NMFS 2023) calls for use of the Bureau of Reclamation’s West-Wide Climate and

Hydrology Assessment (BOR 2021) for forecasting future trends in stream flow and temperature as affected by climate change. Within the Columbia River watershed, the assessment makes the following forecasts from the present through 2021:

- Warming air temperatures by 5°F with a range of +/- 5 degrees based on the 10^{th} and 90^{th} percentiles of forecasts used;
- Consistent total annual precipitation within a range of +/-30 percent;
- Decreasing April 1^{st} snow water equivalents by 25 percent within a range of +/-45 percent;
- Consistent total annual runoff within a range of +/-45 percent;
- Increasing December-March runoff by 10 percent within a range of +/-65 percent;
- Decreasing April-July runoff by 10 percent within a range of +/- 75 percent;
- A six month increase in mean drought durations; and,
- An increase in the mean Palmer Drought Severity Index from 1.4 to 1.7.

Based on this assessment (BOR 2021), the effects of climate change will primarily manifest as the following risk pathways identified in the NMFS guidance:

- Drier dry extremes;
- Decreased minimum flows;
- Runoff starting earlier in the year;
- Increased water temperature; and,
- Increased wildfire effects.

These forecasts are qualitatively consistent with Department of Agriculture climate change assessments for the area (Halofsky et al. 2018). Project area flow data collected from U.S. Geological Survey (USGS) gauge 13313000 on Johnson Creek between 1929 and 2017 is also consistent with runoff earlier in the year when comparing recent periods (1988-2017 and 2012-2017) to earlier periods (1959-1988) and the overall record (1929-2017) (Figure 14).

Instantaneous peak flow events observed by USGS gauge 13313000 indicated lower low flow events and potentially slightly increased high flow events (Rio ASE 2019). This range of potential runoff conditions was utilized in the design of the restored stream channels.

To help inform Project design, Table 18 as a crosswalk to summarize the potential risks and mitigation measures identified by applying the risk pathways from the NMFS guidance (NMFS 2023) to the Project under the BOR assessment (BOR 2021) results.

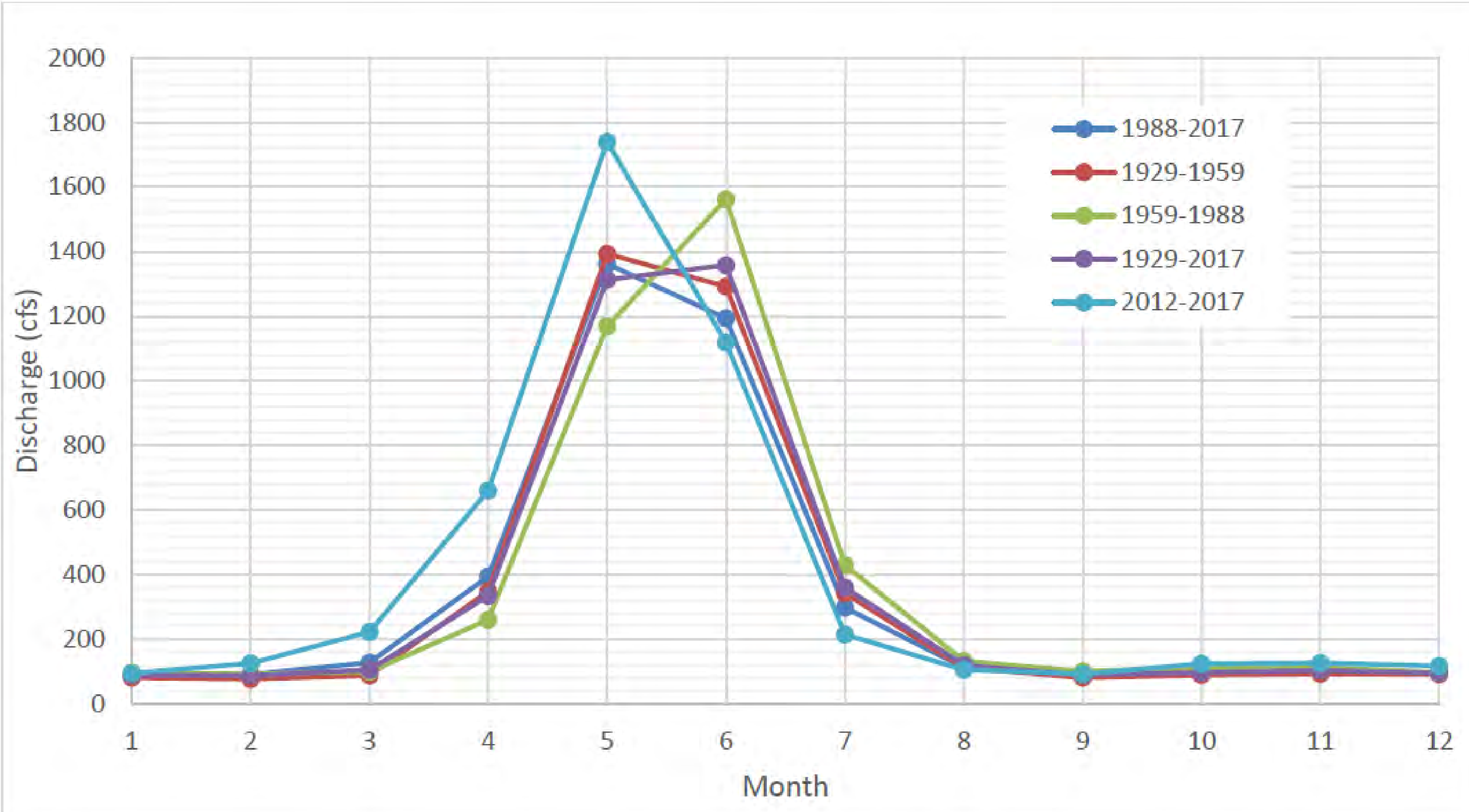


Figure 14. **Average Monthly Discharge at USGS 13313000 for Various Historic Time Periods, Stibnite Gold Project.**

Note: Month 1 is January.

Table 18. Summary of Risks Associated with Climate Change.

Element	Aspects	Risk Pathways[1]	Mitigation (if/as needed)
Water Diversion for Consumptive Use	Water Rights	Dry extremes – not able to divert at the desired rate Decreased minimum flows – not able to divert at the desired rate Wildfire effects – debris removal and maintenance	Alternative water supplies (i.e., recycled process water, contact water, mine dewatering water, and groundwater pumping) will be employed prior to diversion from stream flow (per the Water Management Plan [WMP]). Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Channel Stability	Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Predation	Dry extremes – more exposure to predators Decreased minimum flows – more exposure to predators Water temperature increase – more exposure to predators	Trap and haul will be employed to relocate fish to lower risk conditions (per the Fishway Operations Management Plan [FOMP]).
	Hyporheic Flow	Water temperature increase – reduced hyporheic flow	Water temperatures will be controlled via design features and mitigation measures including use of pipelines, riparian shading, and mechanical shading (per the WMP, Stream Design, and mitigation measures).
	Screen Design	Water temperature increase – biofouling potential Wildfire effects – debris removal and maintenance	Screen design includes brushing system to remove fouling. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Screen Cleaning	Runoff Timing Shift – shorter season for maintenance. Water temperature increase – weaker species reduced swimming performance Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP). Fish swimming will be monitored and addressed as necessary via trap and haul (per the FOMP).
	Structural	Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).

Element	Aspects	Risk Pathways[1]	Mitigation (if/as needed)
	Withdrawal for Use	Dry extremes – not able to divert at the desired rate Decreased minimum flows – not able to divert at the desired rate Water temperature increase – increased evaporation potential Wildfire effects – debris removal and maintenance	Alternative water supplies (i.e., recycled process water, contact water, mine dewatering water, and groundwater pumping) will be employed prior to diversion from stream flow (per the WMP). Diverted water will be conveyed in pipelines and will not be susceptible to evaporation (per the WMP). Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
Fishways		Dry extremes – water loss to permeable streambed Decreased minimum flows – water loss to permeable streambed Wildfire effects – debris removal and maintenance	Fishway entrance and exit channels armored to inhibit stream loss to infiltration and subsurface flow. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
Culverts	Flood Capacity	Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Embedded Pipe and Stream Simulation Designs	Dry extremes – water loss to permeable streambed Decreased minimum flows – water loss to permeable streambed Wildfire effects – debris removal and maintenance	Culvert entrance and exit channels armored to inhibit stream loss to infiltration and subsurface flow. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Hydraulic Design and Retrofit	Dry extremes – blocked passage due to low flow Decreased minimum flows – blocked passage due to low flow Wildfire effects – debris removal and maintenance	Culvert designs include basal channels to maintain flow to the extent supported by inflow from upstream. Monitoring fish passage will trigger mitigative measures per the FOMP. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Trash Racks and Livestock Fences	Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).

Element	Aspects	Risk Pathways[1]	Mitigation (if/as needed)
Trap and Haul	Attraction and Holding	Water temperature increase – limitation on safe holding time Runoff Timing Shift – shorter season for maintenance Wildfire effects – debris removal and maintenance	More frequent trap emptying and mechanical shading measures per the FOMP. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Debris Management	Runoff Timing Shift – shorter season for maintenance Wildfire effects – debris removal and maintenance	Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Fish Handling and Anesthesia	Water temperature increase – limitation on safe holding time Runoff Timing Shift – shorter season for maintenance	Cease handling during periods of excessive temperatures. Inspections and maintenance programs will be used to remove debris from facilities (per the WMP).
	Transport, Unloading, and Release location	Water temperature increase – limitation on safe holding time and suitable release locations	Control transport water temperature. Check conditions at release location prior to release.

[1] NMFS 2023.

1.7.11. Sanitary Waste Handling Facilities

Sanitary waste handling facilities will be present at SGP facilities and will be constructed and operated in accordance with Valley County, IDEQ, and Idaho Department of Health and Human Services standards. Sanitary wastewater will be treated using membrane bioreactor (MBR) or similar technology. Early in construction, the currently permitted MBR plant at the existing exploration camp will be used, and treated effluent reused for flushing toilets and urinals (as allowed by Perpetua's existing Reuse Permit M-228-02) or discharged to the existing drain field located in the process plant area, while the worker housing facility and its associated treatment plant is under construction. During operations and closure, sanitary wastewater from the worker housing facility, ore processing facility, and administration buildings will be treated at a new MBR or similar plant and discharged to the EFSFSR via a permitted IDPES outfall. Vaults or portable toilets will be used at off-site facilities and remote locations on site (e.g., TSF, pits, maintenance facility, etc.), and serviced as needed using vacuum trucks. Treatment residuals will be hauled off site to a permitted sanitary landfill. Vault/portable toilet wastewater will be hauled to the on-site sanitary wastewater treatment plant for treatment.

1.7.12. On-site Composting Facilities and Solid Waste Collection and Disposal

On-site composting facilities will be permitted by IDEQ with oversight by the local Health District. Small scale composting associated with organic materials generated at the worker housing facility may be incorporated within the centralized GMS in the Fiddle Valley. These composting facilities will be fenced. Any larger composting facilities deemed necessary to support GM quality or quantity improvements will be located off site.

All construction and demolition waste generated at the SGP will be hauled off site for disposal at a permitted landfill; a landfill will not be constructed or maintained at the SGP. Solid waste from the worker housing facility, shops, and other work areas that cannot be composted or recycled will be collected in wildlife-resistant receptacles and hauled off site for disposal in a municipal waste landfill. Material that meets the classification of a “hazardous waste” will be collected and stored, per the SGP Waste Management Plan at specially designed and operated secured satellite collection sites and a main storage site prior to shipment off-site to a Resource Conservation and Recovery Act certified hazardous waste disposal facility.

1.7.13. Mine Site Borrow Sources

Various types of earth and rock material will be used from borrow sources for construction, maintenance, closure, and reclamation activities. Most of these materials can be sourced at the SGP from existing development rock dumps, legacy spent heap leach ore, and from development rock removed as part of proposed surface mining and underground exploration activities. These materials will be subject to physical and chemical testing to determine suitability for use.

Native earth materials will be required for some applications. Specific areas within the SGP that have large quantities of high quality native alluvial and glacial granular borrow materials for use include:

- The alluvial and glacial soils in the Meadow Creek valley floor within the footprint of the TSF, TSF Buttress, HFP, and YPP;
- Sand, gravel, and cobbles in the lower EFMC alluvial fan; and,
- Glacial soils in the Fiddle Creek valley walls within the footprint of the Fiddle GMS.

1.7.14. Materials, Supplies, Chemical Reagents, and Wastes

Numerous materials, supplies, and chemical reagents will be used, including fuel, explosives, and ore processing reagents for the SGP. A Spill Prevention, Control and Countermeasure (SPCC) Plan will be developed prior to construction to establish procedures for responding to accidental spills and releases of petroleum products. In addition, a Hazardous Materials Handling and Emergency Response Plan will be developed prior to construction to address procedures for responding to accidental spills or releases of hazardous materials to minimize health risks and environmental effects (see Appendix A, Table A-7 for more details of these measures per the Project's TMP [Perpetua 2022]).

1.7.14.1. Diesel Fuel, Gasoline, and Propane

Aboveground storage tanks at the SGP will be used for fuels and other fluids, including gasoline, diesel fuel, lubricants, coolants, hydraulic fluids, and propane. Approximately 200,000 gallons of diesel fuel, 10,000 gallons of gasoline, and 30,000 gallons of propane will be stored at the SGP in addition to a variety of materials, supplies, and reagents (Table 19). The aboveground storage tanks will be installed on containments sized to contain 110 percent of the capacity of the tank. Refueling will occur on concrete-paved areas designed to contain refueling spills (i.e., berms around their perimeters). There will be no below ground fuel storage or piping used for refueling. Storage management will be outlined in the SPCC Plan. The storage tank facility for gasoline, diesel fuel, and propane will be located near the maintenance workshop with additional propane storage at the ore processing facility area, the underground portal area, and the worker housing facility.

Table 19. Proposed Materials, Supplies, and Reagents.

Common Name	Units	Annual Use	Delivery Form	Typical Vehicle Payload	On-site Storage Capacity	Storage Method	On Site Mine Uses	Estimated Deliveries per Year
Diesel Fuel	Gallons	5,800,000	Bulk liquid	10,000	200,000	Tanks	Mine Site	580
Lubricants	Gallons	296,000	Bulk liquid	3,000	30,000	Tanks, Totes, Drums	Truck Shop	99
Gasoline	Gallons	500,000	Bulk liquid	5,000	10,000	Tanks	Mine Site	100
Antifreeze	Gallons	40,000	Bulk liquid	3,000	4,000	Tanks, Totes, Drums	Truck Shop	13
Propane - Buildings	Gallons	560,000	Bulk liquid	6,000	30,000	Tanks	Buildings	93
Propane – Lime Plant	Gallons	1,463,000	Bulk liquid	11,000	30,000	Tanks	Lime Plant	133
Solvents	Gallons	1,000	Bulk liquid	200	1,000	Totes or Drums	Truck Shop	5
Tires	Each	246	Bulk solid	Variable	59	Laydown	Mining	47
Batteries	Units	Variable	Pallets	Variable	500 units	Pallets	Mining	25
Light Ballasts	Pounds	25	Pallets	Variable	1,000	Pallets	General Operations	5
Pesticides/Insecticides	Pounds	250	Pallets	Variable	1,000	Pallets, drums	General Operations	1
Herbicides	Pounds	1,000	Pallets	Variable	2,000	Pallets, drums	Environmental	1
Fertilizer	Pounds	2,500	Pallets	Variable	5,000	Pallets, drums	Reclamation	1
Ammonium Nitrate	Tons	7,300	Bulk solid	24	200	Secured Silos	Open Pits - blasting	304
Explosives	Tons	100	Boxes	5	20	Secured Magazines	Open Pits - blasting	20
Grinding media, SAG Mill	Tons	4,449	Bulk solid	24	200	Bunkers and Bins	Mine Process Area	186
Grinding media, Ball Mill	Tons	3,566	Bulk solid	24	200	Bunkers and Bins	Mine Process Area	149
Grinding media, LS Ball Mill	Tons	34	Bulk solid	24	200	Bunkers and Bins	Mine Process Area	2

Common Name	Units	Annual Use	Delivery Form	Typical Vehicle Payload	On-site Storage Capacity	Storage Method	On Site Mine Uses	Estimated Deliveries per Year
Primary crusher liners	Tons	62	Set	24	1 set	Laydown	Mine Process Area	3
Pebble crusher liners	Tons	84	Set	24	1 set	Laydown	Mine Process Area	4
SAG liners	Tons	801	Set	24	1 set	Laydown	Mine Process Area	34
BM liners	Tons	1,424	Set	24	1 set	Laydown	Mine Process Area	60
LS primary crusher liners	Tons	9.16	Set	24	1 set	Laydown	Mine Process Area	1
LS secondary crusher liners	Tons	9.32	Set	24	1 set	Laydown	Mine Process Area	1
LS Ball mill liners	Tons	27.8	Set	24	1 set	Laydown	Mine Process Area	2
Lime Slaker liners	Tons	3.5	Set	24	1 set	Laydown	Mine Process Area	0.25
Sodium Cyanide	Tons	4,000	Bulk containers	24	300	Tanks, bins	Mine Process Area	167
Activated carbon	Tons	500	Super sack solid	22	100	Supersacks	Mine Process Area	23
Copper sulfate	Tons	1,250	Supersacks, 1,000 kg	22	100	Supersacks	Mine Process Area	57
Lead nitrate	Tons	800	Supersacks, 1,000 kg	22	25	Supersacks	Mine Process Area	37
Aerophine 3418A	Gallons	10,500	Bulk liquid	200	400	Tanks	Mine Process Area	53
AP 3477	Gallons	60,000	Bulk Liquid	3,000	6,000	Tanks	Mine Process Area	20
Methyl isobutyl carbonyl	Gallons	120,000	Bulk liquid	3,000	6,000	Tanks	Mine Process Area	40
Flocculent (Unnamed)	Tons	300	Supersacks	22	50	Supersacks	Mine Process Area	14
Sodium metabisulfite	Tons	2,000	Supersacks	22	200	Supersacks	Mine Process Area	91
Potassium amyl xanthate	Tons	1,350	Bags in boxes	20	40	Stacked boxes	Mine Process Area	68
Sodium hydroxide	Tons	330	Supersacks	22	40	Supersacks	Mine Process Area	15
Nitric acid	Gallons	65,000	Bulk liquid	3,000	6,000	Tanks	Mine Process Area	22
Scale control reagents	Pounds	5,000	Drums or totes	1,000	1,000	Drums or totes	Mine Process Area	5
Sulfuric acid	Gallons	12,000	Bulk liquid	3,000	8,000	Tanks	Water Treatment	5
Hydrogen peroxide	Gallons	7,100	ISO totes	3,660	10,000	ISO totes	Mine Process Area	2

Common Name	Units	Annual Use	Delivery Form	Typical Vehicle Payload	On-site Storage Capacity	Storage Method	On Site Mine Uses	Estimated Deliveries per Year
Sodium hypochlorite	Gallons	2,000	Totes	1,000	1,000	Totes	Water treatment	2
Magnesium chloride, 33%	Gallons	250,000	Bulk liquid	4,500	20,000	Tanks	Road surfaces	56
Ferric Sulfate	Gallons	23,000	Bulk liquid	3,000	6,000	Tank	Water Treatment	17
Polymer	Gallons	1,000	Drums	200	3	Drums	Water treatment	5
Organic Sulfide	Gallons	4,000	Drums	200	3	Drums	Water treatment	5
Sodium Bisulfite	Tons	0.2	Drums	-	2	Drums	Water Treatment	1
Lime	Tons	150	Bulk Solids	24	30	Silo	Water Treatment	7
Sodium Carbonate	Tons	430	Bulk Solids	24	30	Silo	Water Treatment	18
Carbon Dioxide	Tons	14	Bulk Liquid	3	3	Tanks	Water Treatment	5
Microsand	Tons	6.58	Bags	-	7	Bags on pallets	Water treatment	1

Source: Perpetua 2021a.
Key: AP = AP 3477 is dialkyl dithiophosphate, a reagent used in the flotation circuit; BM = ball mill; ISO = International intermodal container that is manufactured according to the specifications outlined by the International Organization for Standardization (ISO); kg = kilogram; LS = limestone; SAG = semi-autogenous grinding

1.7.14.2. **Explosives Storage**

Ammonium nitrate prill will be received in bulk in tanker trucks and transferred into storage silos. Other blasting supplies used for mine blasting operations will include blasting emulsion products, detonating cord, cast primers, and blasting caps. These products will be delivered in boxes or other approved containers on trucks. The explosives storage facility will include two silos containing ammonium nitrate on a concrete pad and two buildings, one for explosives and one for detonators. Components of bulk explosive material will be stored in separate and isolated containers, sized, and designed to meet Bureau of Alcohol, Tobacco, Firearms, and Explosives and MSHA requirements. The explosives storage facility will be fenced and securely gated. An explosives contractor will provide the products and manage the explosives storage facility.

1.7.14.3. **Miscellaneous Oils, Solvents, and Lubricants**

Various oils including motor oils, lubricants, antifreeze, and solvents will be shipped to the SGP on trucks. These will be stored in approved containers located within, or directly adjacent to, the maintenance shop and contained within secondary containments to prevent spills into the environment. All used petroleum products, waste antifreeze, and used solvents will be collected in approved containers, transported off site, and disposed or recycled.

1.7.14.4. **Miscellaneous Consumables**

Lime will be produced on site and stored in silos at the ore processing facility. Silos will be equipped with air emission controls. Sodium cyanide will be transported as dry cyanide briquettes to the SGP. Nitric and sulfuric acid will be transported in tanks designed to prevent spills even in the event of rollovers. Nitric and sulfuric acids will be stored in specialized non-corrosive, polyethylene-lined tanks located within the ore processing facility and will have secondary containment.

1.7.14.5. **Waste Handling**

Wastes anticipated to be generated at the SGP include fluorescent bulbs, batteries, and empty aerosol containers which will be managed in accordance with the appropriate regulatory standards. Materials that are not consumed will be recycled, to the extent practical, or disposed of in accordance with applicable regulations.

Used petroleum products will be stored on site in approved containers that will be separate from other trash and garbage products. Used petroleum products will be transported off site for recycling or disposal in an approved facility. Other legacy materials could be encountered during construction and operations. If encountered, these materials will be characterized to determine potential for re-processing, reuse, or on-site or off-site disposal.

1.7.15. Temporary Closure of Operations

No periods of temporary or seasonal closure are currently planned; however, a description of temporary closure is required for the SGP cyanidation permit if applicable. In the event of temporary suspension of mining activities, Perpetua will notify the USFS, USACE, IDEQ, IDWR, IDL, and Valley County in writing with as much advanced warning as possible of the temporary stop of mining activities. This notification will include reasons for the shutdown and the estimated timeframe for resuming production.

During any temporary shutdown, Perpetua will continue to implement operational and environmental maintenance and monitoring activities to meet permit stipulations and requirements for environmental protection. This will include the reclamation success monitoring.

Dewatering of the open pits may continue during temporary closure due to the negative effects that pit lake formation or highwall saturation will have on highwall stability and renewed mine operations. Since ore processing may not be occurring, excess water from the various facilities will need to be managed. The operational plans required by the Cyanidation Permit and other plans developed as part of IDEQ permits will also describe specific activities and provide details on how process water will be managed during a temporary closure. Process water will continue to be managed per IDEQ requirements during any temporary closure including water collection and water treatment of excess water volumes beyond the capacity of the system to store and recycle.

A limited potential exists that unfinished facilities (e.g., haul roads, buttress, open pits, pit backfills, GMSs, etc.) will not have the same protective measures in place (e.g., stormwater collection systems or culverts) as will exist if the facility had been finished. Therefore, Perpetua will identify interim measures that will be taken to manage stormwater, sediment, dust, and other factors while the mining is temporarily stopped. Surface water diversion structures are all proposed to be installed prior to construction of the TSF, open pits, and the TSF Buttress; hence, surface water will be diverted around these facilities regardless of the stage of their completion.

Environmental reports will be submitted per previously agreed upon schedules. Regardless of the operating status of the mine, appropriate monitoring will continue until compliance with permanent regulatory closure requirements is attained, unless modified by the required regulatory authorities.

1.8. Surface and Underground Exploration

Surface and underground exploration including development drilling will occur to evaluate potential mineralized areas outside of the proposed mining areas. New surface and underground exploration activities will be conducted during construction and operations. Any additional future expansion of mining activities will require supplemental permitting and approvals, including additional evaluation under the National Environmental Policy Act (NEPA).

1.8.1. Surface Exploration

A total of approximately 65 acres of exploration drilling disturbance within the operations area boundary is included in the activities associated with the SGP (i.e., 25 acres of temporary roads and 40 acres of drill pads) (Figure 15). With the exception of 11 planned locations, exact locations of the exploration drill pads have not been determined, although general areas for foreseeable exploration have been identified. These areas are displayed on Figure 16:

- Five areas surrounding the WEP.
- Two areas immediately east and west of the YPP.
- An area adjacent to the Fiddle Creek GMS.
- Three areas near the former townsite and electrical transmission line corridor (including the IPA and IPAB areas from the Golden Meadows Exploration Project [USFS 2016]).
- Two areas immediately north and northeast of the HFP.
- An area immediately north of the process plant.
- An area approximately a quarter mile south of the process plant.
- Two areas north and east of the Scout Prospect decline.
- Two areas in the West Rabbit and East Rabbit areas from the Golden Meadows Exploration Project (USFS 2016).
- Nine areas in southeast of the Midnight Pit area, between the pit area and the existing radio communications tower one-half mile to the southeast (including the Broken Hill, Ridgetop, Saddle, Upper Midnight, UM2, Doris K, Garnet, and West Garnet areas from the Golden Meadows Exploration Project [USFS 2016]).

These foreseeable exploration areas will be used for exploration drill holes and for installation of monitoring wells associated with permit monitoring requirements. These foreseeable drill areas are offset from flowing streams with no exploration areas along Sugar Creek.

For this exploration work, Perpetua will use the same or similar drilling methods and environmental protection measures that have been employed for exploration drilling in the past (i.e., exploration under the Golden Meadows Exploration Plan) and will use appropriate drilling equipment (i.e., helicopter-delivered drill rigs, truck or crawler-mounted drill rigs)[4]. Some drill holes will extend to 1,500 ft. or more, but the average drill hole will be approximately 800 ft. long. Drill holes will be both vertical and angled with some holes converted to monitoring wells when completed. Further exploration work will continue under the approved mine plan. The environmental commitments applicable to this exploration work are described in detail in the Decision Notice and Finding of No Significant Impact, Golden Meadows Exploration Project, Attachment A, Section 1.12 (USFS 2016).

[4] Because protection measures associated with the Golden Meadows Exploration Plan were cited for application to the SGP but not detailed in the BA, NMFS has provided additional details on the most notable operating procedures and EDFs for protection of ESA-listed species and DCH from the Golden Meadows Exploration Project in Appendix B.

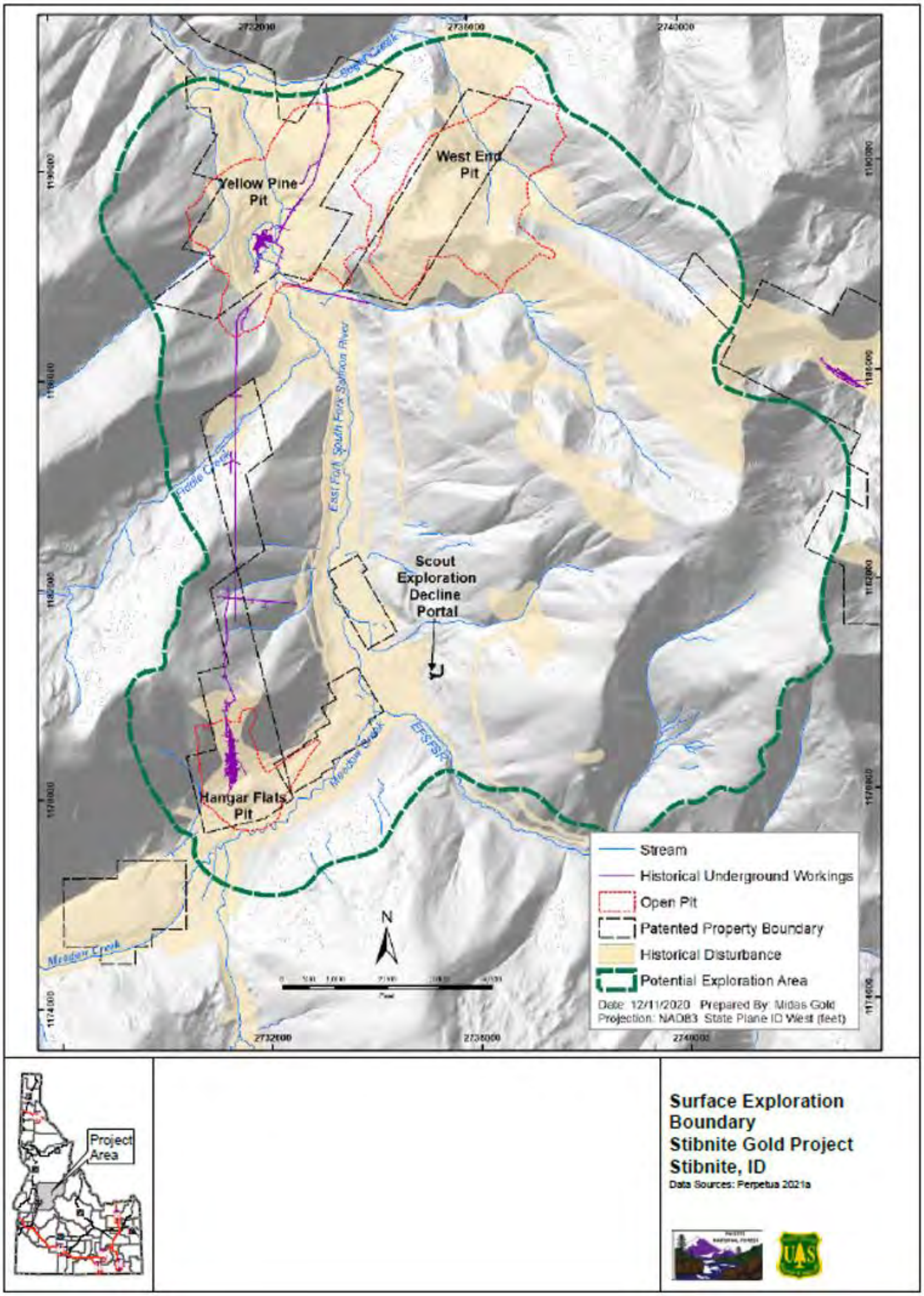


Figure 15. Surface Exploration Boundary, Stibnite Gold Project.

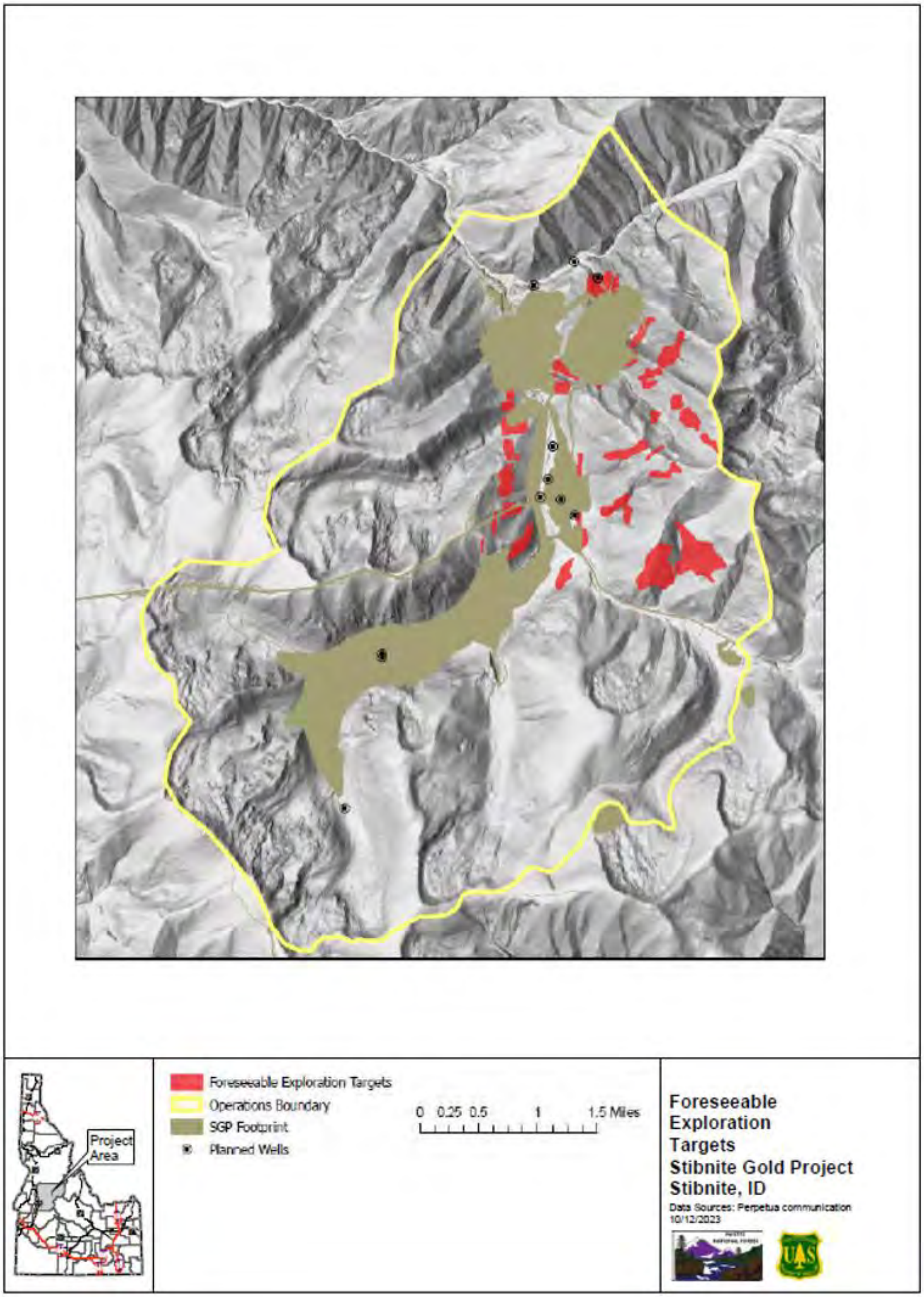


Figure 16. Foreseeable Exploration Targets, Stibnite Gold Project.

Reverse-circulation rotary or sonic drills will be used to drill pre-collars for core holes, drilling down to the depth desired for the start or core collection before mobilizing a core drill onto the hole. Pre-collared holes will have surface completions/seals and be capped when completed. In practice, pre-collared holes will only be associated with road accessible drill sites.

Standard drilling procedures utilize crews consisting of a drill operator plus one or two assistants. A geologist oversees drilling activities and compliance with permit requirements, environmental protection measures, and safety procedures.

Drilling support equipment will include helicopters, water trucks, crew trucks, portable mud tanks, pipe trucks or skids, portable toilets, light plants, portable generators, motor graders, excavators, dozers, and product storage pallets. Perpetua will maintain a helipad for exploration and medical evacuations adjacent to the administration offices and warehouse facilities. Helicopter support for exploration activities will occur during daylight hours.

Where practicable, Perpetua will establish drill pads in reclaimed roadbeds and only open temporary roads in the vicinity of authorized mine disturbance in order to access exploration targets. Each drill pad will have between one and five drill holes depending on its location and exploration needs. Placement of drill pads will be guided by exploration requirements, geotechnical studies, geochemical sampling, and groundwater monitoring needs. Perpetua will utilize a rolling maximum of five acres of active temporary road disturbance (10,500 liner ft. of road) and eight acres of active drill pad disturbance (140 pads) within the total 65-acre authorization, and will reclaim road and pad disturbance to remain below that rolling maximum of active disturbance. This reclamation of exploration disturbance will be conducted as soon as practicable following data collection and at least three growing seasons will be needed to establish vegetation and determine reclamation success.

New drill pad disturbance will be kept to the minimum acreage necessary for safe access and working area for equipment and crews. Drill pad sizes will vary depending on the type of drilling work being conducted. Truck-mounted or crawler-mounted drill rigs typically require a 75 to 100-ft.-long by 50 to 60-ft.-wide working area (less than 0.15 acres). Drill pads supported by helicopter require working areas approximately 45 ft. long by 35 ft. wide working areas (less than 0.05 acres). The actual disturbance of each drill pad is dependent on the drill rig utilized, the number and orientation of drill holes on the pad, the steepness of the area topography, and the location of existing access roads.

Water and non-toxic approved drilling fluids will be utilized for all drilling activities. Drilling water will be obtained from currently approved sources plus new approved sources associate with the Project, subject to water rights and appropriations.

Sediment basins and traps (i.e., excavated sumps and/or portable tanks) will be used at each drill site to collect drill cuttings and to manage and circulate drilling fluids. Typical dimensions of road access drill sumps are 16 ft. long, by 8 ft. wide, by 8 ft. deep, with helicopter supported drill sumps being approximately 12 ft. long, by 6 ft. wide, by 3 ft. deep. If needed to manage excess water produced from the exploration drill hole, larger and/or additional sumps will be installed. Upon completion of drilling, sumps will be backfilled and reclaimed.

Exploration drill holes will be abandoned by backfilling holes with drill cuttings, concrete, cement grout, or bentonite grout consistent with IDAPA 20.03.02.060.06(c). Dewatering and monitoring wells will be abandoned with surface completions/seals and be capped consistent with IDAPA 37.03.09 – Well Construction Standards Rules. Pre-collared holes will only be associated with track or truck mounted drilling equipment.

Areas disturbed for exploration will be contoured to blend into surrounding terrain; water bars and surface water channels will be retained to handle flows through the area. Compacted areas will be decompacted as necessary prior to fertilizing and seeding. Previously approved activities (i.e., approved exploration activities and associated reclamation obligations) will continue as well.

1.8.2. Burntlog Route Geotechnical Investigation

The BRGI is a specific case of surface exploration activity that will take place in MY -3 to conduct geophysical investigations to explore and characterize geotechnical conditions along the Burntlog Route to confirm that conditions align with engineering designs for the roadway and stream crossings. The BRGI, will review locations for rock quarries, bridge abutments, and cut slopes. Four geophysical investigation methods will be used: dynamic cone penetrometer testing (DCPT); test pits; drilling with truck and track mounted rigs; and helicopter supported drilling. The geotechnical investigation will assess 24 locations along the Burntlog Route via 40 borings, test pits, or cone penetrometer tests (Figure 17), including:

- Four DCPTs using handheld equipment;
- 14 test pits approximately 3 ft. wide, 10 to 15 ft. deep, and 10 ft. long, using a track mounted excavator;
- Eight boreholes using truck or track mounted hollow stem augur/core rig; and,
- 14 boreholes using a helicopter assisted core rig.

The investigation will result in approximately 0.6 acres of total ground disturbance. Nine locations (B2, B7, B9, B10, B20, and B22), will be located within RCAs, resulting in approximately 0.1 acres of disturbance within the RCAs. Six of the locations selected to characterize geotechnical conditions for stream crossings (B1, B2, B4, B5, B7, and B22) are located within 50 feet of flowing water. Two locations will require access by via off-road travel through areas with wetlands characteristics (601 feet of travel to B3 and 432 feet of travel to B22).

The Burntlog Geotechnical Investigation will be conducted in conformance with all project requirements and EDFs (see Table 21 and Appendix A). In addition to those Project-wide requirements, there are specific standard operating procedures (SOPs) and requirements applied to the geotechnical investigation (Table 20). Additional detail regarding this portion of the proposed action has been excerpted from the BNF's original BA for the project (BNF 2022) and is included below.

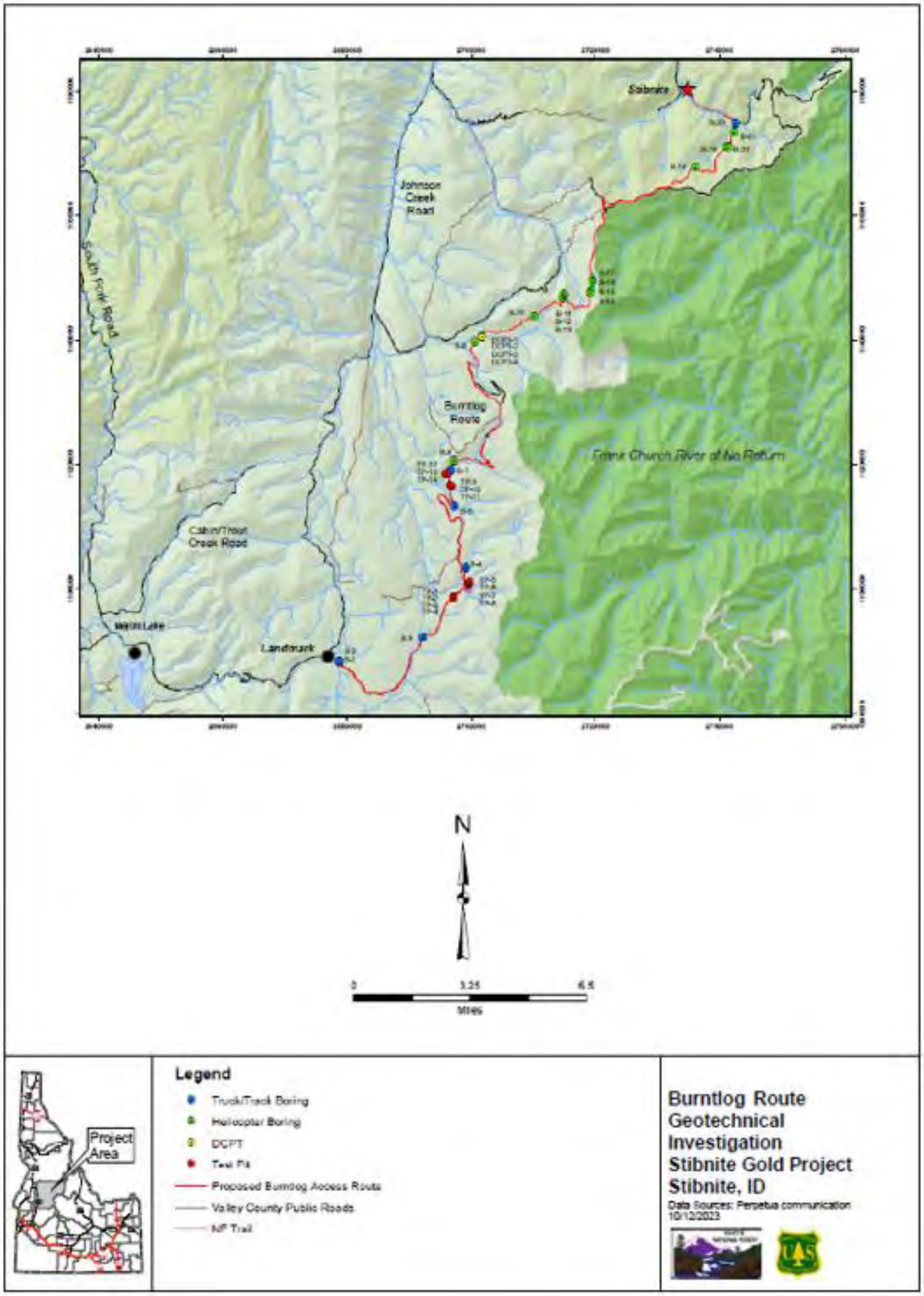


Figure 17. Burntlog Geotechnical Investigation, Stibnite Gold Project, Stibnite, Idaho.

Table 20. Additional Standard Operating Procedures and Requirements for the Burntlog Geotechnical Investigation (Stantec 2024; BNF 2022).

Standard Operating Procedures
Any soil disturbance will be completed with hand tools or the smallest equipment needed. Any areas leveled for drill pads and platforms will be re-contoured as per Idaho Administrative Procedures Act (IDAPA) 20.03.02.060.06(a), after holes are plugged and the platforms are removed.
Topsoil and any brush removed will be stockpiled separate from fill material and used in reclamation.
Hand tools or a heli-portable backhoe will be used for sump construction at helicopter supported drill pads.
To reduce the potential of slope failure associated with saturated sump pits on steep slopes, a remote sump or portable recirculation tank would be used if stability considerations warrant it. On slopes greater than 35%, the selected locations would be reviewed and approved by U.S. Forest Service (USFS) specialists.
Drill sites and other reclaimed drill areas will be monitored during spring runoff to ensure that best management practices (BMPs) are in place and working so that soil erosion is minimized.
Drill pads would be sited to avoid high landslide prone areas. To minimize the potential of slope failure associated with drill pads and sumps on moderate landslide potential areas, the selected locations would be reviewed and approved by USFS personnel.
For the borrow source, standard reclamation practices will be followed, including segregating and stockpiling topsoil, implementing stormwater and sediment BMPs, backfilling and placing topsoil, and revegetation.
Proper BMPs will be used to prevent sediment from escaping sump locations. Activities will include, but are not limited to, the following: drill pads and sumps will be constructed to minimize erosion; erosion of pad fill slopes will be minimized by directing pad surface drainage either to the sump or to a small sediment trap located on a corner of the pad where it meets the existing slope.
Perpetua will monitor stormwater runoff and stormwater BMPs as per the stormwater pollution prevention plan (SWPPP) that falls under the 2015 Multi-Sector General Permit (MSGP) for Industrial Activity (Sector G – Metal Mining for exploration activities).
Drilling fluid will be mostly water, with various drilling additives to increase viscosity or reduce fluid loss. These additives will consist of the following trade-named products or their equivalents: Benseal, Holeplug, Quikgel, Benseal, Cal Seal, IDP-399, N Seal, Quik Mud, and Quik Trol Gold. All products are to be NSF/ANSI-60 Certified.
Water for drilling will be recycled, to the extent possible and practical, to minimize the need for active water withdrawals, by routing drill return water to a drill sump below the rig platform, a remote sump, or a portable recirculation tank.
Water for drilling would be recycled through a “closed loop” drilling fluid system to minimize the need for active water withdrawals, by routing drill return water to a sump or portable recirculation tank.
Withdrawals of water from streams or the Gestrin well for exploration activities would be in accordance with water rights (both temporary and permanent) and the biological assessment (BA). For water withdrawals from streams, a 5 to 10 feet long section of well screen, which acts as a diffuser to reduce impingement, with a 0.02-inch slot size would be placed on water pump intake hoses for drill water withdrawals to reduce risk to aquatic species that might be present by entrapment in the suction hose as per recommendations from the NMFS aquatics biologist. The pump would have an approach velocity of 0.2 feet per second or less (passive screen criteria) to eliminate the risk of impingement or entrapment of aquatic species, and the screen will be checked and cleaned every four hours when in operation.
Surface water withdrawal intake hoses will be situated so as to prevent generation of turbidity in bottom sediments during pumping.
Pumps will be turned off when not in use.
Intake pumps will not be situated within the active stream/ditch channel and will be placed within containment vessels capable of holding 120 percent of the pump engine’s fuel, engine oil and hydraulic fluid. The smallest practical pump and intake hose will be used.
Following large storm events, the intake pumps will be inspected to determine if stream flow has encroached into the pump area and if the pump needs to be moved so it remains above flowing water. Pump placement will generally be placed above the Ordinary High-Water Mark.
A spill prevention and clean-up kit would be placed at the intake pump site and will consist of absorbent pads and/or boom (which would be sufficient length for a worst-case scenario), drip pan, a shovel, and a fire extinguisher.

Standard Operating Procedures
Spare fuel for the water intake pump will be stored in approved [29 CFR 1926.152(a)(1)] fuel storage containers placed into a secondary containment vessel capable of holding at least 120% of the volume of the fuel in the fuel container.
Fuel would be stored on private property in sealed 55-gallon steel drums, approved double-walled fuel tanks, or in approved single-walled tanks within secondary containment. Fuel would be managed, tanks would be inspected, and any oil release would be responded to in accordance with the SPCC plan.
Bulk fuel tanks (storage vessels greater than 55-gallons) will be stored in approved double-walled fuel storage containers sitting inside tertiary containment on private property, outside the riparian conservation areas (RCA).
Intake pumps, fuel storage, and containments will be inspected at each refueling and periodically between refueling.
Any on-site portable toilets will be located away (generally 100 feet) from any surface water bodies and will be serviced by a state licensed sewerage waste disposal contractor.
A portable toilet would be set-up adjacent to select drill sites or at the closest feasible location, serviced by a licensed contractor, and removed upon completion of drilling at each site.
Boreholes are promptly abandoned as required by the Idaho Rules Governing Exploration, Surface Mining, and Closure of Cyanidation Facilities (IDAPA 20.03.02) after reaching their total planned depth. Borehole abandonment will generally take place within hours of borehole completion to avoid the need to bring the drilling rig back to the site later. If the annular space of the casing has been sealed with cement (as is the case with boreholes expected to encounter artesian conditions), the casing is left in place. If the annular seal is bentonite, the temporary surface casing is removed before abandonment.
Each drill hole will be abandoned from the bottom to the collar by filling the hole with a thickened grout mixture or bentonite chips.
Once the drill hole is completely sealed the project geologist or drilling manager will approve the hole-plugging operation prior to the rig being moved off site to ensure integrity of the hole plugging process. The timing for initiating and completing borehole abandonment is as soon as practicable after the geologic information has been interpreted. Abandonment of each borehole will be properly documented.
Exploration drilling will not occur when saturated roads SOPs apply.
Petroleum products used to support drilling activities would be transported in accordance with Idaho and U.S. Department of Transportation regulations and handled and stored as required by state and federal petroleum product storage and handling laws and regulations.
Petroleum products would be kept in containment and spill prevention kits would be available on site.
On drilling sites where sumps are necessary but impractical due to slope or soil conditions, a casing diverter and a hose will be used to divert drilling water to a sump located in an adjacent and appropriate site.
The following SOPs are designed to minimize the risk of drilling mud discharging at the ground surface: • Drill pad locations within RCAs would require USFS concurrence that no reasonable alternative location exists. • Drillers would be informed of these locations and would exercise increased vigilance for instances of lost circulation at shallow depths. • The casing would be advanced simultaneously behind the core drill through the alluvial section of all drill holes.
If drilling fluid should discharge at the ground surface despite the above preventative SOPs, the following new response SOPs have been developed to minimize the risk of drilling fluid subsequently reaching live water. • Adjacent slopes below the drill rig and stream channels (if drilling in RCAs) in these areas would be regularly monitored during drilling by environmental technicians for any evidence of surface leakage. • Silt fence, straw wattles, portable sumps, pumps, and hoses would be pre-staged for emergency use. These materials and tools would be used to quickly construct temporary sumps to capture drilling fluid and return it to the drill rig. • For locations that are deemed to be of sufficient risk to warrant the pre-staging of response materials, a USFS representative would verify that such measures are in place on the ground prior to drilling. • Prestaging of response materials will occur at all drilling sites.
Section 6 of Idaho Department of Land's (IDL' Best Management Practices for Mining in Idaho (IDL 1992), would be observed, including if water is encountered in exploration holes; it would be sealed off during abandonment to prevent crossflow.

Standard Operating Procedures
All activities would be conducted in accordance with Idaho environmental anti-degradation policies, including Idaho Department of Environmental Quality (IDEQ) water quality regulations at IDAPA 58.01.02 and applicable federal regulations.
Stormwater monitoring, inspections, and reporting would be conducted in accordance with the National Pollutant Discharge Elimination System Multi-Sector General Permit (MSGP) and the SWPPP.
To minimize the risk of noxious weed infestations or spread of weed seeds, equipment would be inspected and cleaned prior to mobilizing onto the Forest. All access routes, platforms, locations and sump construction sites also would be inspected prior to project-related activities and if they are found to be weed-infested, then the weed infestation would be treated by manually removing infestations using hand tools prior to ground disturbing activity. Herbicide use, where prescribed, would be in accordance with the South Fork Salmon River Sub Basin Noxious and Invasive Weed Management Program (USFS 2007). Infestations within 100 feet of live water would be controlled by hand pulling. Disposal of weeds also would be in accordance with the above plan.
For drill areas in RCAs: • Pads will be sited to minimize the need to remove any large trees. • Any tree that is felled will be left in the RCA. • Silt fencing will be placed around pads and straw bales or wattles placed and staked between the stream and drill pad. • When applicable, cross drains will be installed within the pad area to ensure drainage away from the RCA and stream.
Sightings of listed or sensitive fish and wildlife species will be reported to the USFS.
Employees and staff will receive training and direction to avoid spawning adult Chinook salmon, bull trout and steelhead.
If USFS administration of this project identifies unanticipated impacts to fish or fish habitat, the surface activity will be suspended by the Cascade or Krassel District Ranger until corrections can be made. A BNF or PNF fisheries biologist will be contacted and consultation will be reinitiated if necessary
If surveys or tracking of noxious weeds and/or rare plants occurs, this information will follow Forest Service protocol and be submitted to the Forest Service botanist and Weed coordinator.
For those drill pads within RCAs of stream channels, visual turbidity monitoring would occur immediately upstream and downstream of active drilling operations every 15 minutes. An annual report would be provided to the Level 1 Team that documents the results of visual observations. If operations are shown to be generating visible turbidity in a stream channel downstream of drilling that is greater than upstream levels, operations would cease until the source of sediment can be identified and mitigated. While actions are taken to stop the turbidity plume, the visual observations of upstream and downstream turbidity would be measured with a turbidity meter at 15-minute intervals until the downstream plume subsides. The USFS will be consulted before drilling resumes at sites B-1, B-2, B-4, B-5, B-7, and B-22. If a turbidity plume occurs due to drilling, the Level 1 Team will be promptly provided with a report that includes an account of the event, measures taken to stop the plume, and turbidity data.
Straw bales and wattles will be used to minimize mobilization of sediment from test pit excavated materials.
No toxic or hazardous substances will be used on site, except for standard petroleum fuel and lubricant products (diesel, gasoline, grease and hydraulic oils), and "over-the- counter" retail products. Use of all chemicals will be in accordance with manufacturer label.
Ground pressure reducing mats will be used when crossing areas delineated as having wetland characteristics.
Test pit disturbance will be backfilled and replanted with certified weed-free seed mix.
The operator will immediately report any fuel, oil, or chemical discharges or spills greater than 5 gallons on land, or any spill directly in a stream to IDEQ and BNF/PNF as required by applicable federal and state regulations by phone and/or fax (or as soon as possible after on-site containment efforts are implemented as per the Spill Prevention, Control, and Countermeasure [SPCC] plan), and the BNF or PNF will initiate emergency consultation.
Concurrent reclamation will be conducted where possible and practical to offset potential erosion or sediment release, or as soon as possible.
The instantaneous diversion rate will always be less than or equal to 0.4 percent of the flow or less in Johnson Creek at the point of diversion and the total diversion from Johnson Creek will be less than 6,050 gallons (drilling plus dust abatement water). If drilling (and water use) occurs during the late August through September timeframe, USFS personnel will take flow measurements in Johnson Creek at the water withdrawal site.

Standard Operating Procedures
All USFS, county, and state speed limits, road restrictions, and load limits will be observed during travel. If appropriate, during equipment mobilization and demobilization, pilot cars will be used to ensure there are no conflicts or incidents along the narrow access roads leading into the project area.
Staff and contractors will follow speed limits. If significant dust generation is produced, vehicles will be requested to slow down to speeds necessary to minimize the fugitive dust generation or the route will be watered. Up to 2,000 gallons of water would be used for dust abatement.
At project completion, all equipment, supplies, and refuse will be removed from the project site and disposed of according to established solid and liquid waste management practices and applicable local, state and federal laws and regulations. Project activities will not generate materials regulated as "hazardous" or "toxic" waste with the exception of the handling of fuel-related products.
A standard marine-type fuel containment boom (which would be sufficient length for a worst-case scenario), spill prevention kit, and fire kit will be stored at the re-fueling site and will be readily available during off- loading of fuel from the fuel truck or during re-fueling operations.
A spill prevention and cleanup kit consisting of absorbent pads, absorbent booms (which would be sufficient length for a worst-case scenario), shovels and a fire extinguisher will be placed at the fuel storage site (private property), at the core shack (private property), and drill sites or any other areas where fuel and/or petroleum products are present.
After completing operations, all empty fuel and lubricant containers will be removed from the operations area and transported and disposed in accordance with local, state, and federal requirements.
Annual spill awareness/response training will be required for on-site personnel and suppliers/providers.
Two or more stored spill containment/response caches will be placed along each of the fuel delivery routes.
Typically, fuel would be delivered to the drill rig in a 100-gallon doubled-wall tank mounted to a pick-up truck, tracked vehicle, or by helicopter.
Fuel containment sites, engines, and other equipment with fuel or lubricants would be periodically (during fueling activities or daily inspection of the drill rigs) checked for leakage or spillage and in accordance with the SPCC plan.
The SPCC plan would be kept at the core shack or office trailer. Staff handling fuel or petroleum products would be trained to successfully implement the SPCC plan. Inspections of fuel storage and handling areas would be conducted as specified in the SPCC plan. Appropriate warning signs would be placed around fuel storage facilities.
All contractors and company staff involved in handling oil and other chemicals would be made aware of the site SPCC plan, spill kit locations, and appropriate emergency response procedures, and would be required to abide by all applicable federal, state, and local laws and regulations pertaining to their respective operations.
Should any oil or chemical discharges or spills occur, the release would be reported to IDEQ, and the USFS (the USFS will contact NMFS and USFWS) and other appropriate agencies as required by applicable federal and state regulations by phone and/or fax immediately (or as soon as possible after on-site containment efforts are implemented as per the SPCC plan). Spill response would be in accordance with the SPCC plan, which includes a trained on-site emergency response team. Spills or discharges would be documented in writing.
Drilling mud and hole plug products would conform to American Petroleum Institute guidelines for ensuring groundwater integrity. Material Safety and Data Sheets for all products would be posted and available on site with the SPCC plan.
A fuel management plan has been created for the project that analyzes measures for minimizing the potential for fuel spills along the main routes into the activity area. The fuel management plan also outlines the times of year and the routes that would be used to deliver fuel into the project area. The fuel plan would be followed for all activities associated with fuel delivery.

1.8.2.1. **Dynamic Cone Penetration Test**

The portable DCPT is used to determine underlying soil strength by measuring the penetration of the device into the soil after each hammer blow. The DCPT consists of two ½-in. diameter shafts coupled near the midpoint. The lower shaft contains an anvil and a 0.787-in. cone, which is driven into the soil by dropping a 17.6-pound sliding hammer contained on the upper shaft onto the anvil. The test involves raising and dropping the hammer to the drive cone on the lower shaft and recording the amount of penetration observed. The DCPT equipment is manually operated, requires no specialized equipment for transport, will not occur in streams, and will not result in ground disturbance.

1.8.2.2. **Test Pits**

A total of 14 test pits will be excavated, all located adjacent to Forest Service Road (FR) 447 (Figure 17). The distance of the pits to the closest streams ranges from approximately 50 ft. to approximately 1,680 ft. All of the sites that are within 200 ft. of streams are on the upslope side of FR 447, such that the road will be between the site and the stream. Excavated material will be temporarily placed next to the test pit. Straw bales and wattles will be used to minimize mobilization of sediment. After completion of the test, the excavated material will be placed back into the pit and tamped down with the excavator bucket. Each pit will be active for approximately one day. After the tests are complete, the disturbed ground will be re-planted with certified weed-free seed mixes that are appropriate for the sites.

1.8.2.3. **Track/Truck Mounted Drilling**

Drilling will be conducted with track and truck mounted drilling rigs at seven sites (Figure 17). One site (B-3) is more than 500 ft. from the nearest stream, but the other six sites are within 50 ft. of streams. Of the six sites within 50 ft. of streams: two (B-1 and B-2) are at the FR 447 crossing of Johnson Creek; one (B-4) is at the FR 447 crossing of Burntlog Creek; one (B-5) is at the FR 447 crossing of East Fork Burntlog Creek; one (B-7) is at the FR 447 crossing of an unnamed tributary to East Fork Burntlog Creek; and one (B-22) is located on the EFSFSR approximately 3.8 miles upstream from the Yellow Pine Pit (YPP). Sites B-3 and B-22 are the only sites that are not on or immediately adjacent to FR 447, and site B-22 is the only site that is in a wetland area. Access to site B-3 will require a tracked drill rig to travel approximately 600 ft. off road and approximately 400 ft. on an existing closed road. Both the B-3 site and the access routes are entirely outside of riparian conservation areas (RCAs). Access to site B-22 will require a tracked drill rig to travel approximately 250 ft. on an existing closed road and approximately 200 ft. off road through a riparian wetland adjacent to the EFSFSR. Pressure reducing mats will be used at site B-22 to reduce the effects on wetland soils and vegetation. Accessing the B-22 site might require felling of a few small trees.

Drilling will commence with an auger and will transition to a core drill when bedrock is encountered. Standard penetration testing, consisting of driving a thick-walled sampling tube approximately 18 in. into the bottom of the borehole using a slide hammer, will be conducted every 2.5 ft. during augur drilling. When bedrock is encountered, drilling will transition to core drilling. The core drilling assembly will consist of auger flights, drill rods, water trough, water line, water pumps, tools, and ancillary equipment. Additional supplies will include drilling mud, bentonite (clay) hole plug material, and small amounts of biodegradable lubricants (rod grease) that are certified for use in potable drinking water. Drilling muds (if needed) will be recirculated using pumps and above ground troughs, precluding the need for excavating sumps. Auger drilling requires little or no water and core drilling requires approximately ten gallons of water per ft. drilled. Drill holes will be approximately eight in. in diameter and a maximum of 70 ft. deep.

Silt fences and straw bales will be used to minimize the chance of water or sediment exiting the site and reaching streams. Streams adjacent to the drilling sites will be visually monitored for turbidity plumes and drilling will cease if turbidity is detected. If drilling ceases due to detection of turbidity, it will not begin again until the source of the turbidity is identified and addressed, and BNF resource advisor agrees that it is safe to resume drilling.

After the tests are complete, each drill hole will be backfilled to within 3 ft. of the ground surface, capped with concrete from the top of the backfill to a few inches of below the ground surface, and monumented with a steel chain for survey purposes. Native material will be mounded on top of the concrete cap during final reclamation. If artesian or geothermal waters are encountered during drilling, the hole will be sealed with cement grout or quick-setting bentonite to prevent cross-flow and/or mixing of groundwater aquifers.

1.8.2.4. **Helicopter Supported Drilling**

Helicopter supported drilling will be conducted at 14 sites (Figure 17). The closest helicopter supported drilling site to a stream is approximately 155 ft. from an unnamed tributary to Riordan Creek. All of the other sites are more than 200 ft. from streams. All drilling will utilize casing advancer/core drilling methods. Drilling equipment will consist of a portable drilling platform, drill rig, drill rods, water trough, water line, water pumps, fly fuel tank (i.e., fuel tank flown in with the helicopter), fuel for the drill rig, water storage tank, tools, and ancillary equipment. The platforms will be supported by four adjustable legs with the base of each leg being approximately one square ft. in area. The platforms will be flown in and set with a helicopter and all of the drilling equipment and supplies will be transported to and from the sites via helicopter. The drill platform will occupy an area of approximately 400 ft^2 at each site. Minor brush clearing and tree cutting may be required to clear the areas for the drill platforms and to provide a safety zone around the platform. Silt fences and straw wattles will be used to minimize chance of water or sediment exiting the site and the drill holes will be reclaimed as described for the auger/core drilling.

1.8.2.5. **Water Diversion and Use**

Approximately 4,050 gallons of water will be needed for drilling and up to 2,000 gallons may be used for dust abatement. Water will be withdrawn from an existing well at the Stibnite Mine site and will be diverted from Johnson Creek at the FR 447 Bridge using a pump with a rating of up to 150 gallons per minute (0.33 cubic ft./second [cfs]). The pump intake will be screened to NMFS' criteria for mesh size and approach velocity and the screen will be inspected every four hours of pump operation and cleaned as needed. A maximum of 6,050 gallons will be diverted from Johnson Creek.

1.8.2.6. **Vehicle Trips**

There will be approximately 145 light vehicle trips and approximately 16 heavy vehicle trips. Most of the travel will be via the Johnson Creek Road (FR 413), Stibnite Road (FR 412) and Burntlog Road (FR 447). However, heavy vehicles traveling to the southern portion of the study area will also use Warm Lake Road (FR 579) to minimize wear on Johnson Creek Road.

1.8.2.7. **BRGI Monitoring**

For those drill pads within RCAs of stream channels, visual observations for changes in turbidity will occur immediately upstream and downstream from active drilling operations. An annual report will be provided to the district fisheries biologist or hydrologist that documents the results of the visual observations. If operations are shown to generate a visible increase in turbidity in the water downstream from the drilling activity that is greater than upstream levels, operations will cease until the source of turbidity can be identified and mitigated. While actions are taken to stop the turbidity plume, the upstream and downstream turbidity will be measured with a turbidity meter at 15-minute intervals until the downstream plume subsides. The USFS will be consulted before drilling resumes at sites B-1, B-2, B-4, B-5, B-7, and B-22. If a noticeable increase in turbidity occurs due to drilling activities, the district fisheries biologist or hydrologist will be promptly provided with a report that includes an account of the event, measures taken to stop or reduce the turbidity due to drilling activities, and turbidity data (if collected).

Perpetua will continually monitor the condition of identified BMPs, ensuring they are in place, maintained, and effective. These measures are designed to ensure protection of water quality from increased turbidity or runoff.

1.8.3. Underground Exploration

Underground exploration activities will occur at the newly discovered Scout Prospect, a 1-mile, downward-sloping tunnel (a decline) (see Figure 15). The decline will be used to reach the subsurface mineralized zone known as the Scout Prospect. The decline will be accessed from a portal facility known as the Scout Portal, located south of the planned ore processing facility (Figure 15). Approximately 100,000 tons of rock will be excavated from the decline. Exploration drill holes will be installed at various locations in the decline. Selected drill cuttings or core will be removed from underground for testing.

To construct the portal facility, the hillside will be cut into to develop a flat vertical slope using conventional underground drill and blast operations with mechanized equipment. Explosives will be used in the underground development process to construct the decline. The underground development rock could be used for surface pad construction, hauled to the ore stockpile area, or hauled for storage in the TSF Buttress as appropriate.

Drilling is used in advance of the decline to ensure unexpected or unmanageable water pressures are not intersected. Water will be used in underground drilling or pumped from the collection point to the surface. Upon reaching the surface, this water will be piped to the ore processing facility to be used in the plant.

1.9. Closure and Reclamation

1.9.1. Overview

Closure and reclamation at the site will include interim, concurrent, and final closure and reclamation in order to: (1) stabilize Project-related disturbances; (2) mitigate/compensate wetland loss directly related to Project development; (3) comply with applicable water quality standards; and (4) achieve long-term post-mining land uses. Details on reclamation activities to be implemented for the SGP, including appropriate seed mixes to be used are described in the Reclamation and Closure Plan Stibnite Gold Project (Tetra Tech 2021). Interim reclamation is intended to provide shorter-term stabilization to prevent erosion of disturbed areas and stockpiles that will be more fully and permanently reclaimed later.

Concurrent reclamation is designed to provide permanent, low-maintenance achievement of final reclamation goals on completed portions of the site prior to the overall completion of mining activities throughout the SGP. Approximately 37 percent of the reclamation will be completed concurrent to mining and ore processing; remaining reclamation activities will be completed during closure.

Final closure and reclamation will involve: (1) removing all structures and facilities; (2) reclamation of those areas that have not been concurrently reclaimed such as the TSF and some backfill surfaces; (3) recontouring and improving drainages; (4) creation of wetlands; (5) reconstructing various stream channels; (6) decommissioning of the EFSFSR diversion tunnel; (7) GM placement; (8) planting and revegetation on disturbance areas; and (9) relocating Stibnite Road (FR 50-412) across the backfilled and closed YPP area.

Final reclamation of certain facilities could continue beyond the five-year closure and reclamation period. The Burntlog Route will be needed until the TSF is fully reclaimed, after which the newly constructed portions of the road will be decommissioned and reclaimed (i.e., fully obliterated), and the currently existing portions of the road will be returned to their prior use.
Surface water flow diversion of portions of the EFSFSR, Garnet Creek, Meadow Creek, Midnight Creek, and Hennessy Creek will be reclaimed and incorporated into constructed wetlands (i.e., Garnet Creek) or restored stream channels across the reclaimed TSF (i.e., Meadow Creek) or YPP backfill.

Perpetua will seed and plant stream reaches, riparian areas, and wetlands with native plant species present currently in existing wetlands and riparian areas along streams within the SGP footprint. Seed mixes, live stakes, and nursery-grown container plants and plugs of native graminoids, forbs, shrubs, and trees would be utilized for revegetation (Tetra Tech 2023). The revegetation plan has been developed for specific riparian, wetland, and upland zones to improve long-term bank stability, LWD recruitment, overhead cover, shade, and terrestrial/wetland habitat (Brown and Caldwell 2021e). In an effort to provide shade to action area streams, riparian plantings will be 18 feet wide, with a higher percentage of taller and denser species (e.g., spruce trees) than originally planned (Brown and Caldwell, Rio ASE, and BioAnalysts 2021). The riparian planting plan is described in Appendix F of the Stream Design Report, where local native seed, cuttings, and containerized materials will be used wherever feasible to increase the likelihood of survival (Rio ASE 2021).

Closure and reclamation activities will be intended to achieve post-mining land uses of wildlife and fisheries habitat and dispersed recreation at the SGP under current motorized access requirements and route designations. Dispersed recreation uses will be accessible by the relocated Stibnite Road (FR 50412) through the backfilled YPP that will facilitate recreational traffic and access to Thunder Mountain. The proposed final reclaimed condition of the site is shown on Figure 18. Concurrent and final closure and reclamation for the SGP are described in greater detail in the following sections.

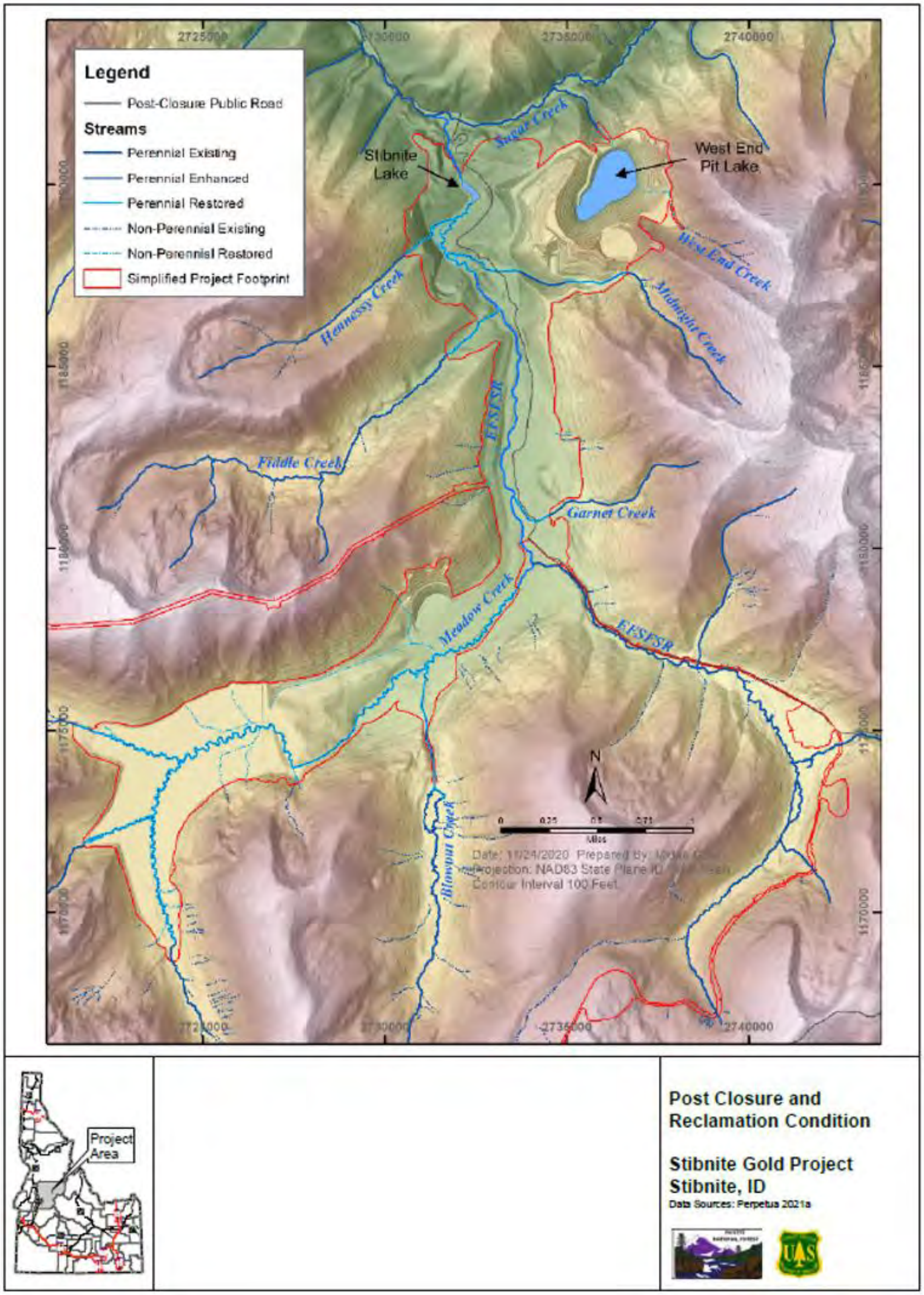


Figure 18. Post Closure and Reclamation Condition.

1.9.2. Decommissioning, Demolition, and Disposal of Facilities

Perpetua will dismantle or demolish structures and facilities not necessary for post-closure water management (e.g., certain culverts and pipelines). The materials from the dismantling or demolition of structures and facilities will be salvaged or disposed of in permitted off-site landfills. All reagents, petroleum products, solvents, and other hazardous or toxic materials will be removed from the site for reuse or will be disposed of according to applicable state and federal regulations. Concrete foundations will be broken or fractured as required to prevent excessive water retention and covered in-place with a minimum of 2 ft. of cover material (consisting of a minimum of 1.5 ft. of backfill and a minimum of 0.5 ft. GM) or will be broken up and buried in the TSF Buttress or pit backfill prior to installation of a geosynthetic liner cover. Soil/rock beneath fuel storage areas and chemical storage buildings will be tested for contamination and removed or disposed of appropriately if needed.

1.9.3. Underground Exploration and EFSFSR Tunnel

Perpetua will decommission and close underground facilities and underground support facilities, including the portals of the EFSFSR tunnel and Scout decline. To prevent future access to underground workings, the underground portals (i.e., EFSFSR tunnel and Scout decline) will be closed using concrete block bulkheads, rockfills, or a combination of rockfill and low-permeability foam. The downstream (north) EFSFSR portal and the Scout decline will be closed with bulkheads inside the portals (where overhead cover was at least 3 times the tunnel height) or backfilled with clean rockfill starting inside the portals and working outward, and up against the portal headwalls. Surface swales will be installed to direct surface water around the backfilled portal, and the exterior backfill, and surrounding disturbance will be graded to blend with adjacent topography, covered with GM, and revegetated. At the EFSFSR upstream (south) portal, the control weir will be left in place, and the fishway weir notch raised with concrete, creating an approximately 4-ft.-high sill to exclude river water or alluvial groundwater, and low-permeability geofoam or similar will be installed inside the portal after the initial backfill or bulkhead, to prevent water entry. Then, the portal area will be filled, regraded, and revegetated as described for the other openings.

1.9.4. Yellow Pine Pit

During MYs 5 through 11, the majority of the YPP backfill material (90 percent) will be WEP development rock. The balance of YPP backfill will include development rock from the HFP (5 percent) and the YPP (5 percent). Backfill will be placed in lifts not exceeding 100 ft. in vertical height with the large equipment, to include selective placement of the top lifts by direct dumping to better control the type of rock that will be placed near the surface. This placement method also will limit subsidence of the backfill and the amount of regrading necessary prior to placement of GM (Tetra Tech 2021). This material will not be compacted beyond that which occurs during placement, subsequent routing of trucks, burial, and consolidation. Portions of the highwalls on the east and west sides of the pit will remain above the backfilled portion of the pit and will not be reclaimed. A sinuous channel will be constructed through the backfilled area for the reconstructed EFSFSR with an average valley gradient approximating the historical, pre-disturbance river gradient (Tetra Tech 2023). A low permeability geosynthetic liner will be incorporated into the cover over the entire surface of the backfilled YPP, including the reconstructed channel floodplain corridor to reduce the infiltration of meteoric water into backfill material, which could dewater the restored stream channel and result in additional metal leaching from the underlying backfill. Above the geosynthetic liner in the stream corridor, a layer of relatively fine material will be placed to protect the stream liner from puncture, followed by coarse rock armor to protect from exposure via stream scour, followed by floodplain alluvium at a minimum thickness equal to the maximum estimated scour depth of the proposed stream channel. GM will then be placed and the area revegetated. The lined corridor will be wide enough to accommodate future channel migration, evolution, and over-bank flooding. The cover system outside the stream/floodplain corridor will be similar to that described for the TSF Buttress (Section 1.9.6). Portions of Hennessy and Midnight Creeks will be restored over the backfilled area along with the reconstructed EFSFSR.

Hennessy Creek will cascade over the approximately 275-ft. tall west highwall of the YPP to a restored 0.17-mile section of low-gradient channel on the western edge of the reconstructed EFSFSR floodplain before joining the restored EFSFSR channel. Midnight Creek will be restored across the 0.14-mile southeastern portion of the reconstructed EFSFSR floodplain. After closure of the EFSFSR tunnel, backfilling of the YPP, and restoration of the EFSFSR and Hennessy Creek across the backfill, the Hennessy Creek diversion will be decommissioned and the area reclaimed, along with the adjacent operations-phase public access road.

To accommodate migrating fish, including Chinook salmon and bull trout, step pools will be established within the constructed EFSFSR channel consistent with NOAA 2022 fish passage guidelines (NMFS 2022a). The vertical relief (drop) between successive pools will not exceed published fish passage criteria. Detailed hydrologic and hydraulic analyses will inform the overall channel and floodplain design and construction, with channel bankfull width approximately 25 to 30 ft., and average depth of approximately 2 ft. The lined Stibnite Lake, of similar size to the existing YPP Lake, will be constructed within the lined corridor (Perpetua 2023; Tetra Tech 2023 [Attachment D of the CMP]).

Access through the site to Thunder Mountain Road (FR 50375) will utilize an access road through the backfilled area, replacing the segments of the Stibnite Road (FR 50412) that were removed by mining.

1.9.5. West End Pit

This area includes the WEP, the Midnight Pit, the sidehill pit, and the development rock from legacy mining activity (Figure 4). Reclamation will occur at the conclusion of mining operations. The WEP will not be reclaimed; instead, a pit lake about 400 ft. deep will be allowed to form in the northern portion of the pit below the highwall, which will be about 800 ft. above the pit lake surface. The WEP lake will fill gradually up to 400-ft.-deep, and lake levels will fluctuate seasonally and with longer-term climate variations; however, the lake will not be expected to completely fill with water or spill due to its limited catchment area.

To account for model uncertainty, lake levels will be monitored after closure, as specified in the Environmental Monitoring and Management Plan (EMMP) (Brown and Caldwell 2021c), and a threshold water level will be established, sufficient to contain the predicted runoff volume from a high-snowpack year without discharge. If water levels approach the threshold, either or both surface water diversion and water treatment could be implemented to prevent the lake from spilling. If needed, a temporary treatment unit will be mobilized to the site to treat and discharge the pit lake water until the lake level falls below the threshold discharge level, thus preventing untreated discharge in potential subsequent wet weather years and enabling gradual and predictable water treatment rather than treatment at higher but variable and uncertain peak spring runoff rates.

The Midnight Pit, the approximately 6-acre, 100-ft.-deep southeastern portion of the overall WEP within the Midnight Creek catchment, will be backfilled during operations with approximately 6 million tons of development rock from the WEP. The backfill will be placed to achieve a mounded final reclamation surface to promote drainage away from the WEP and prevent formation of a pit lake within Midnight Pit. Portions of the backfill will be covered with GM and revegetated, and the remainder covered with talus like development rock to mimic a natural talus slope.

The floor of the sidehill pit southwest of the main WEP will be graded to drain, covered with GM, and revegetated. No backfilling will occur for the main WEP. At closure, the remaining road into the pit and access to highwalls will be blocked with large boulders and/or earthen berms to deter motorized vehicle passage into the pit.

1.9.6. Tailings Storage Facility and TSF Buttress

Perpetua proposes to complete tailings reclamation approximately 9 years after ore processing operations cease. After tailings consolidate sufficiently to use heavy equipment on top of the tailings, predicted to be within 3 to 5 years after the end of deposition, Perpetua will begin with placement of cover material, then construct wetlands and restore Meadow Creek and its tributaries within appropriately sized lined floodplain corridors, place GM, and revegetate the area.

Once ore processing operations have ceased, Perpetua will begin removing the remaining supernatant water pool and ongoing accumulation of meteoric water and consolidation water through a combination of spray evaporators (similar to snowmaking misters) operated within the TSF boundary and an active water treatment that meets IPDES discharge limits, followed by discharge to the EFSFSR or Meadow Creek. Removal of the remaining supernatant water from the TSF will allow the surficial layers of the tailings to dry and gain strength, which will allow equipment to operate on the tailings surface for grading and the placement of the geosynthetic liner, overlain by unconsolidated overburden and GM. Concave areas in the consolidated tailings surface will be filled to create suitable drainage conditions prior to liner and cover installation in the area designed to become restored stream channel. Cover placement and minor grading of tailings will occur, beginning within 3 to 5 years from the end of deposition, as portions of the TSF surface dry enough to allow equipment traffic, working inward from the facility perimeter. The cover material overlying the geosynthetic liner will be sourced from unconsolidated overburden or other appropriate material stored in a GMS on top of the adjacent TSF Buttress.

Perpetua will restore appropriately designed meandering stream channels (Meadow Creek and tributaries) within a stream and floodplain corridor across the top of the lined TSF surface (Rio ASE 2021). Pools and riffles will be constructed within the channel. Measures to create aquatic habitat will include side channels, oxbows, boulder clusters, root wads, and large woody debris (LWD). This will allow for the post-closure development of riparian habitat, convey water off the facility, and minimize potential interaction of surface water with the underlying tailings. Given the nature of the surface of the TSF, the constructed channel will have a shallow gradient.

Detailed hydrologic and hydraulic analyses will inform the overall channel and floodplain design, which will necessitate the construction of defined channels ranging from approximately 5 to 15 ft. in bankfull width, with average bankfull depth reaching approximately 2 ft. A connected floodplain up to 200 ft. wide will convey higher flows during a 100-year flood event.

Consolidation of the tailings will continue after cover placement and surface reclamation, at gradually declining rates, until approximately MY 40. To prevent tailings consolidation water from mixing with surface water on the cover, potentially leading to water quality impacts if discharged to streams, the consolidation water will be collected for treatment, using shallow wells and gravel or geosynthetic drains. Initially, collected flows will be routed to a WTP for treatment and discharge. Treatment will no longer be required after approximately MY 40, at which time the treatment facility will be decommissioned and the WTP site reclaimed.

Final slopes of the TSF Buttress will be variable, to blend with the surrounding terrain to the extent practicable, produce a permanent and stable landform, provide access for future maintenance on the TSF and buttress, and provide for non-erosive drainage across the reclaimed face of the buttress. Upon completion of final grading of the TSF Buttress, a low permeability geosynthetic cover will be placed over the facility, which will be designed to limit infiltration through the underlying development rock. The geosynthetic liner will be overlain by an inert soil/rock layer (non-PAG/metal leaching development rock, fill, or alluvium) and GM and revegetated. Similar to that for the TSF, a channel and floodplain corridor will be established for Meadow Creek across the top of the lined buttress. The channel will have a low gradient and wide floodplain across the top of the buttress, then drop more steeply to the valley floor near the south abutment. The steep channel segment will consist of a boulder chute that will flow through multiple energy-dissipating basins (one mid-slope and one at the toe of the TSF Buttress) before being discharged to a restored Meadow Creek on the valley bottom.

1.9.7. Hangar Flats Pit

In MYs 6 and 7, HFP will be backfilled up to the valley bottom elevation or slightly higher and no pit lake is anticipated. Following closure, the western pit highwall will remain exposed above the backfill area. The already-established Meadow Creek diversion channel and floodplain corridor will be retained around HFP as the final configuration, and the segment of Meadow Creek between the toe of the TSF Buttress and the entrance to the HFP diversion will be restored along with adjacent riparian wetlands. At closure, the entire surface of the backfilled HFP will be covered with a low permeability geosynthetic liner overlain with seed bank material to establish wetlands. Non-perennial drainages in adjacent upland areas will be routed to facilitate development of the wetland hydrology. Meadow Creek downstream of the HFP diversion, to the confluence with the EFSFSR, will be enhanced during mine operations with LWD, boulder cluster habitat structures, and riparian plantings.

1.9.8. Transmission Line and Electrical Infrastructure

The Johnson Creek and Stibnite substations will not be decommissioned immediately during mine closure; the transmission line between these substations will remain to provide power for post-closure water treatment. Once there is no longer a need for active water treatment, Perpetua, in coordination with IPC, will disassemble the approximately 9-mile transmission line between the Johnson Creek and Stibnite substations. The substations, switchgear, and power line will be removed. The transmission line ROW and associated access roads will be recontoured to match surrounding topography and revegetated. As part of revegetation, the transmission line structure pads and access roads will be scarified and revegetated. Revegetation will not be required on affected lands, or portions thereof, where planting is not practicable or reasonable because the soil is composed of excessive amounts of sand, gravel, shale, stone, or other material to such an extent to prohibit plant growth (IDAPA 20.02.02).

1.9.9. Burntlog Route

Once all final mine closure/reclamation work has been completed, Perpetua will reduce the 21-ft.-wide travel way of 19.8 miles of Burntlog Road (FR 447), 1.3 miles of Meadow Creek Lookout Road (FR 51290), and 2 miles along Thunder Mountain Road (FR 375) of the Burntlog Route to their approximate pre-mining width. The public use status of these existing road segments will be unchanged from the current motor vehicle use map. Returning this 23 miles of existing road to pre-mining condition will entail grading and/or scarification along the outside edges of the road followed by seeding with the species listed in the Reclamation and Closure Plan (Tetra Tech 2021) or as approved by the USFS. Perpetua will remove ditches, cross drains, culverts, safety berms, mile markers, guardrails, and signs on roads if these features are no longer needed. These roads will retain the flatter grades and gentler curves constructed for mine operations.

The approximately 15 miles of Burntlog Route that was newly constructed for the SGP, connecting Burnt Log Road (FR 447) to Meadow Creek Lookout Road (FR 51290) and Thunder Mountain Road (FR 50375) will be fully decommissioned. The road will be decommissioned by pulling back and recontouring road cuts to slopes that are similar to, but not necessarily matching, pre-project conditions, and that will be consistent with the surrounding terrain as practicable. Surface water diversions, cross drains, culverts, safety berms, mile markers, guardrails, and signs will be removed. Soil nail walls, constructed of anchors bolted into the ground with a sprayed concrete surface, will remain to support slopes in areas with soft soils or weathered rock. Water bars or other erosion and sediment control structures, armored stream crossings, and stormwater crossings will be included where necessary. The reclaimed areas will be scarified, and 6 inches of GM will be placed in upland areas, followed by seeding and certified weed-free mulching on slopes over 30 percent. Revegetation will not be required where planting is not practicable or reasonable due to excessive amounts of sand, gravel, shale, stone, or other material to such an extent to prohibit plant growth (IDAPA 20.02.02).

1.9.10. Post Closure Public Access

As mentioned in Section 1.9.4, a service road will be established over the backfilled YPP to allow public access through the reclaimed site and connect Stibnite Road (FR 50412) to Thunder Mountain Road (FR 50375) (Figure 19).

1.9.11. Off-site Facilities

Following mine closure and reclamation, the Burntlog Maintenance Facility buildings will be removed. The sewer system and septic tanks for the Burntlog Maintenance Facility will be decommissioned. All reagents, petroleum products, solvents, and other hazardous or toxic materials will be removed from the site and disposed of according to applicable state and federal regulations. Soil/rock beneath fuel storage areas and chemical storage buildings will be tested for contamination and treated if necessary. After demolition of the buildings and facilities, the site will be graded, revegetated, and drainage restored.

1.9.12. Contouring, Grading, Growth Medium Placement, and Seeding

Except for the HFP highwall above the valley bottom, the WEP, and a portion of the YPP highwall, Perpetua will contour and grade disturbed areas to blend into the surrounding topography and terrain. Compacted areas such as roads, ore stockpile areas, parking lots, fuel storage areas, and building sites will be prepared prior to placement of growth media and revegetation. Haul routes and access roads will be recontoured to establish natural drainage patterns.

Growth media suitability criteria include U.S. Department of Agriculture (USDA) texture, percentage of organic matter, course fragment percentage and acidity (pH). Root zone material suitability guidelines include USDA texture, course fragment percentage, soil acidity (pH), electroconductivity, sodium adsorption ratio, Net Acid Generation pH, bulk density and arsenic, antimony, and mercury levels. Perpetua will manufacture GM material using screened fines from glacial till sources, available mulched vegetation, and off-site composted material from private lands (e.g., composted food waste from the Worker Housing Facility). Off-site sources for composting feedstock materials will be in compliance with USFS requirements.

Planting, seeding, and mulching will be conducted in the fall and early winter to take advantage of snowpack and springtime moisture. Where cover crops are used in lieu of mulch, seeding will occur in the spring or fall followed by seeding of the permanent mixture. The forbs, grass species, seed amounts, and the trees and shrubs planned for planting on reclaimed areas are described in Tetra Tech (2021) and will be approved by the USFS.

1.9.13. Weed Treatment

Perpetua will be responsible for noxious weed control within areas disturbed by proposed activities, and establishment and spread of noxious weeds and invasive plant species on Project areas will be prevented. Perpetua will inspect and remove vegetation material (including noxious weeds) from mechanical equipment and properly dispose of it to minimize the spread of unwanted vegetation. Additionally, Perpetua will limit preconstruction weed treatments, such as mechanical control and herbicide application, to areas expected to have unavoidable ground-disturbing activities.

As identified below in the Reclamation Maintenance Procedures (Section 1.10.3.3), noxious weed and invasive plant species control will be conducted per USFS-approved methods described in the 2020 Programmatic Activities BA (PNF 2020) and corresponding Opinion from NMFS (WCR-2020-01560) (NMFS 2020). These documents are included in the proposed action and are incorporated by reference, although a brief summary of the approved active ingredients, surfactants, and treatment approaches follows.

The PNF approach to weed treatment allows for: (1) mechanical control, using hand-operated power tools to cut, clear (pull, grub or dig out), mow, or prune weeds; (2) biological control, allowing for release insects or pathogens that are parasitic and "host specific" to target weeds; (3) cultural control, allowing for implementing measures to prevent weed introduction or minimize the rate of weed spread (e.g., clean equipment before and after use, use only weed-free seed and mulch material, etc.); or (4) chemical control, allowing for the use of 14 active ingredients and specific adjuvants.

Active ingredients allowed for use can be found in Appendix C, Table 1; and the list of approved adjuvants are described in Appendix C, Table 2. Appendix C, Table 3 identifies mitigations and BMPs necessary for weed treatment. In addition to complying with these elements of the proposed action, the following key project design features for minimizing effects of herbicide treatment shall also be applied to the SGP:

- Herbicide applications will comply with applicable laws, policy, guidelines, and product label directions.
- Herbicide applications will comply with the buffer restrictions in Appendix C, Table C-1.
- Low pressure and larger droplet size will be used to the extent possible, to minimize herbicide drift during broadcast spraying.
- Mixing/filling will be limited to locations where drainage will not allow runoff or spills to move into live water and in locations where potential contamination of groundwater will not occur.
- No ester formulations of 2,4-D or triclopyr-butoxyethyl ester will be used.
- The polyoxyethylene tallow amine adjuvant will only be used in uplands where there is no potential for movement into aquatic systems.
- Invasive weed treatment with the potential for ground disturbance will be conducted only in areas where a 25-ft. vegetated buffer strip can be maintained. Proper erosion and sediment control BMPs will be employed.

1.9.14. Post Closure Water Treatment

Evaluation of post-closure water treatment is ongoing. For the proposed action, Perpetua has indicated that sources of water that could require treatment during closure and reclamation and through the post-closure period include TSF runoff and tailings consolidation water, plus any TSF Buttress toe seepage. Other development rock will be backfilled into the open pits and closed with synthetic geotextiles, growth media, surface grading, and/or revegetation to preclude contact between the development rock and surface runoff.

As previously described, consolidation water will be withdrawn from beneath the TSF geosynthetic cover using a combination of wells, wicks, and/or gravel drains, and routed to water treatment. Collected flows will be routed to the water treatment plant for treatment and discharge. Once it is determined that treatment is no longer required based upon agency approvals, the treatment facility will be decommissioned and the WTP site reclaimed. Water treatment will be provided during the reclamation and closure and post-closure phases until waters requiring treatment are no longer being generated. Life-of-mine water treatment of the TSF and other facilities is discussed in Section 1.7.10.

As described in Section 1.9.5, if spillage of surface water from the WEP lake becomes imminent, a portable system will be brought to the site to treat and discharge pit lake water to maintain levels below the rim of the lake and prevent uncontrolled release of lake water.

1.9.15. Closure and Reclamation Financial Assurance

As part of the approval for the SGP, Perpetua will be required to post financial assurance to ensure that NFS lands and resources involved with the mine operations are reclaimed in accordance with the approved plan of operations and reclamation requirements (36 CFR 228.8 and 228.13). This financial assurance will provide adequate funding to allow the USFS to complete reclamation and post-closure operation, including continuation of any post-closure water treatment, maintenance activities, and necessary monitoring for as long as required to return the site to a stable and acceptable condition in the event Perpetua was unable to do so. The amount of financial assurance will be determined in collaboration with the USFS and will "address all Forest Service costs that will be incurred in taking over operations because of operator default" (USFS 2004). The financial assurance will be required in a readily available bond or other instrument payable to the USFS. To ensure the bond can be adjusted as needed to reflect actual costs and inflation, there will be provisions allowing for periodic adjustments in the final plan of operations prior to approval. Calculation of the initial bond amount will be completed following the Record of Decision (ROD) when enough information is available to adequately and accurately perform the calculation. In addition to the USFS-required bond, mitigation under Section 404 of the CWA also requires financial assurance.

The IDL will require a bond as part of their permitting authority and IDEQ will require a bond for the cyanidation permit which will then be held by IDL. The IDWR is the state agency responsible for design review and approval of the TSF. IDWR also will require a bond so that the TSF can be placed in a safe maintenance-free condition upon decommissioning or if abandoned by the owner.

1.9.16. Closure and Reclamation Traffic

Most closure and reclamation traffic will occur May through November. Mine traffic during closure and reclamation is anticipated to result in a total AADT of 27, with 15 being from heavy vehicles and 12 being from light vehicles.

1.10. That Monitoring

Monitoring will be conducted by the Project operator and reviewed by the USFS and other regulatory agencies to ensure compliance with permits and regulations and to manage the impact of the SGP on the environment. Air emissions, groundwater, surface water, aquatic, and other environmental parameters will be monitored during mine construction, operation, closure, and post-closure as described and specified in the EMMP (Brown and Caldwell 2021c). Authorizations from federal and state agencies include monitoring requirements for resources (e.g., air emissions, surface water, and groundwater) during mine construction, operation, closure and reclamation, and post-closure.

Monitoring will be conducted following the completion of closure and reclamation of all facilities and disturbance areas to demonstrate compliance with permit requirements and to measure the success of reclamation and mitigation. Final monitoring requirements and timelines will be outlined in the final permit approval documents and the final EMMP.

The final EMMP will consist of multiple component plans, each of which will be finalized upon issuance of the related permit(s) and will contain monitoring and management requirements from each permit. In some cases, if environmental outcomes may be uncertain, the EMMP will include adaptive management planning which requires identification of performance measures, impact thresholds, and operational adjustment options, all intended to achieve and demonstrate compliance with applicable permitting and/or consistency with the environmental analysis (see also Section 3.9.1).

The EMMP (Brown and Caldwell 2021c) describes the component monitoring and management plans that have been drafted and upon finalization, will be used by Perpetua to manage water resources, manage and monitor mine facilities, and monitor environmental resources. The EMMP includes environmental tasks and lists environmental permits, licenses, authorizations, and corresponding obligations. It also establishes Perpetua's commitments to environmental monitoring and management of mine facilities and environmental resources. The EMMP will provide direction to Perpetua to monitor its operations and environmental commitments, document permit compliance, and reduce potential impacts to environmental resources. Key monitoring requirements of the EMMP are described below.

1.10.1. Water Resources Monitoring.

The Water Resources Monitoring Plan (WRMP) described the planned monitoring of surface and groundwater resources during the construction and operations phases of the SGP (Brown and Caldwell 2021c). Water resources monitoring includes five geographical areas within the Project area. The areas represent portions of the Project with internally similar Project-related activities, hydrology, and potential water quality concerns, i.e.:

- Northern Operations Area (YPP, WEP, Midnight Pit Backfill, EFSFSR diversion, and the confluence with Sugar Creek) where mining activities will expose mineralized rock materials and operations will modify groundwater levels and surface flows.
- Southern Operations Area (TSF, TSF Buttress, TSF surface diversions, HFP, Meadow Creek, and EFMC) where mining operations, development rock placement, and tailings

storage will expose mineralize rock and tailings materials and operations will modify groundwater levels and surface flows.
- Ore Processing Area (processing plant, WTP, truck shop, support facilities, and the EFSFSR below the Meadow Creek confluence) where operations will receive, store, and utilize fuels and reagents (e.g., acids, cyanide) and water treatment discharge will occur.
- Worker Housing Area (employee housing, sanitary water treatment plant) where sanitary water treatment will occur.
- Off-site Facilities (SGLF and Burntlog Maintenance Facility) where operations will store and transfer fuels and reagents for delivery to the on-site areas.

Surface water monitoring locations are described in Table 21 and are shown in Figures 19 through 22. Groundwater monitoring wells are described in Table 3.8-2 of the BA (Stantec 2024) and shown in Figures 4-4, 4-6, and 4-24 of the WRMP (Brown and Caldwell 2021c) and are incorporated here by reference. Most monitoring locations are situated downstream or downgradient from Project components with the potential to contribute constituents to nearby water resources with the remaining locations upstream or upgradient from Project components to characterize baseline conditions influent to the area. Measurements and analyte lists are based on the constituents potentially associated with the Project component and Project activities, i.e.:

- Open pits and haulage areas are focused on potential contributions of sediment and nitrogen species associated with blasting operations.
- Tailings storage, stockpiles, and development rock storage areas are focused on the potential to contribute sediment, major ions (hardness), metals and cyanide associated with leaching of mined materials.
- The processing area is focused on the potential to contribute cyanide, metals, and major ions (hardness) associated with the cyanide ore processing.
- Treatment plant outfalls are focused on collection of monitoring data for compliance with water treatment objectives (i.e., major ions, hardness, metals, temperature, turbidity, and continuous flow measurement).
- The sanitary treatment plant outfall is focused on collection of monitoring data for compliance with sanitary treatment objectives (i.e., *E. coli*, biological oxygen demand, temperature, turbidity, and continuous flow measurement).
- MSGP Stormwater Permits stormwater discharge locations are focused on monitoring data for compliance with those permits (i.e., turbidity, temperature, and metals).

The monitoring locations and parameters identified in Table 21 are proposed at this time and may change to reflect requirements by federal and state agencies through their permitting processes. Sampling frequency (and subsequent reporting frequency) will vary by permit and by monitoring location and parameter within permits. At this time, the frequency of sampling is not known for the monitoring proposed in the WRMP, but some parameters are more likely to be required to have more frequent monitoring (continuous or weekly) at some locations, such as flow, temperature, and pH. Continuous measurements are expected to be required for effluent flow for IPDES outfalls. Other physical parameters, such as temperature, may also be required to be measured continuously using a sonde at outfalls and downstream locations. A few parameters, if required, may only be monitored on an annual basis at a limited number of locations, such as

WET (Whole Effluent Toxicity) or nutrient loading. Most other parameters are likely to be monitored on a quarterly or monthly basis (Brown and Caldwell 2021c).

Each final federal or state permit/regulatory document will specify the terms of monitoring requirements, including the sampling locations, sampling frequency, sample type, water quality parameters, and other details such as laboratory methods and total versus dissolved metals. As stated on page 4-1 of the WRMP, "When all resource monitoring requirements are known, this plan will be updated to ensure that all required monitoring information is obtained." Surface and groundwater monitoring for closure and post-closure are not addressed at this time, but will be addressed in an update to the WRMP toward the end of the operations period based on site conditions at that time.

Table 21. Surface Water Monitoring Locations (listed from downstream to upstream by area).

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
North Operations Area										
EFSFSR downstream of all mining operations and the Sugar Creek confluence (existing location)	SW-9	X	X	X	X	-	-	-	-	-
Sugar Creek downstream of West End Pit (WEP) and YPP operations and above the EFSFSR confluence (existing location)	SW-8	X	X	X	X	-	-	-	-	-
Sugar Creek upstream of West End Creek (existing location)	SW-5	X	X	X	X	-	-	-	-	-
West End Creek downstream of the diversion around the WEP	SW-1	X	X	X	X	-	-	-	-	-

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
West End Creek upstream of the diversion around the WEP (existing location)	SW-6	X	X	X	X	-	-	-	-	-
EFSFSR downstream of the YPP and WEP operations and above the confluence with Sugar Creek (existing location)	SW-4	X	X	X	X	-	-	-	-	-
EFSFSR at the downstream exit of the EFSFSR Tunnel	SW-39	X	X	X	X	-	-	-	-	-
EFSFSR at the upstream entrance to the EFSFSR Tunnel and below the confluences with Fiddle Creek and Midnight Creek	SW-13	X	X	X	X	-	-	-	-	-

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
Midnight Creek downstream of diversion and upstream of the EFSFSR confluence	SW-38	X	X	X	X	-	-	-	-	-
Midnight Creek upstream of diversion (existing location)	SW-12	X	X	X	X	-	-	-	-	-
Fiddle Creek downstream of diversion plus Hennessy Creek confluence and upstream of the EFSFSR confluence	SW-27	X	X	X	X	-	-	-	-	-
Fiddle Creek upstream of diversion (existing location)	SW-26	X	X	X	X	-	-	-	-	-

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
EFSFSR upstream of the Fiddle Creek confluence and the culvert under the haul road	SW-28	X	X	X	X	-	-	-	-	-
South Operations Area										
Meadow Creek at the downstream end of the lined stream segment and upstream of the EFSFSR confluence	SW-19	X	X	X	X	-	-	-	X	X
East Fork Meadow Creek upstream of the Meadow Creek confluence	SW-20	X	X	X	X	-	-	-	-	-

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
Meadow Creek downstream of the TSF underdrain outfall plus the treated water flow augmentation outfall and upstream of the East Fork Meadow Creek confluence	SW-31	X	X	X	-	-	X	X	X	X
Meadow Creek at the outfalls for the TSF underdrain and the treated water flow augmentation	SW-40	X (plus, continuous flow)	X	X	-	-	X	X	X	X
Meadow Creek downstream of TSF operations and upstream of outfalls for the TSF underdrain and the treated water flow augmentation	SW-22	X	X	X	X	-	X	X	X	X

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
Meadow Creek downstream of TSF diversion and TSF underdrain sump	SW-41	X	X	X	X	-	-	-	X	X
TSF underdrain sump	SW-25	X (plus, continuous flow)	X	X	-	-	X	X	X	X
Meadow Creek upstream of the TSF on the southern tributary	SW-23	X	-	X	-	-	-	-	X	X
Meadow Creek upstream of the TSF on the northwestern tributary (existing location)	SW-24	X	-	X	-	-	-	-	X	X
Ore Processing Area										
EFSFSR adjacent to the downstream end of the ore processing facilities	SW-14	X	-	X	-	-	-	-	X	X

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
EFSFSR downstream of the re-routed Garnet Creek confluence	SW-15	X	-	X	-	-	-	-	X	X
Garnet Creek reconstructed segment above the EFSFSR confluence	SW-16	X	-	X	-	-	-	-	X	X
Garnet Creek segment through the upstream end of the ore processing facilities (existing location)	SW-17	X	-	X	-	-	-	-	X	X
EFSFSR downstream of the WTP outfall	SW-33	X	X	X	-	-	X	X	X	X
EFSFSR at the WTP outfall	SW-3	X (plus, continuous flow)	X	X	-	-	X	X	X	X
EFSFSR upstream of the box culvert upstream of the WTP outfall	SW-32	X	X	X	-	-	X	X	X	X

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
EFSFSR adjacent to the upstream end of the ore processing facilities and upstream of the Meadow Creek confluence (existing location)	SW-18	X	-	X	-	-	-	-	X	X
Worker Housing Area										
EFSFSR downstream of sanitary water treatment plant outfall	SW-29	X	X	X	X	X	X	-	-	-
EFSFSR at sanitary water treatment plant outfall	SW-2	X (plus, continuous flow)	X	X	X	X	X	-	-	-
EFSFSR upstream of sanitary water treatment plant outfall	SW-30	X	X	X	X	X	X	-	-	-
Off-site Facility Areas and Construction Period Monitoring										

Location Description	Location ID	Instantaneous Flow	pH, Turbidity, Temperature, Dissolved Oxygen, Total Suspended Solids	Ammonia, Nitrate, and/or Nitrite	Total Nitrogen, Total Phosphorus, Total Kjeldahl Nitrogen	E. coli, Biological Oxygen Demand	Whole Effluent Toxicity	Total Dissolved Solids, Hardness	Total Cyanide, Weak Acid Dissociable Cyanide	Metals
Multi-Sector General Permit stormwater discharge locations	-	X	X	-	-	-	-	-	-	X
Construction General Permit stormwater discharge locations (Burntlog Route construction, Worker Housing construction)	-	X	X	-	-	-	-	-	-	X

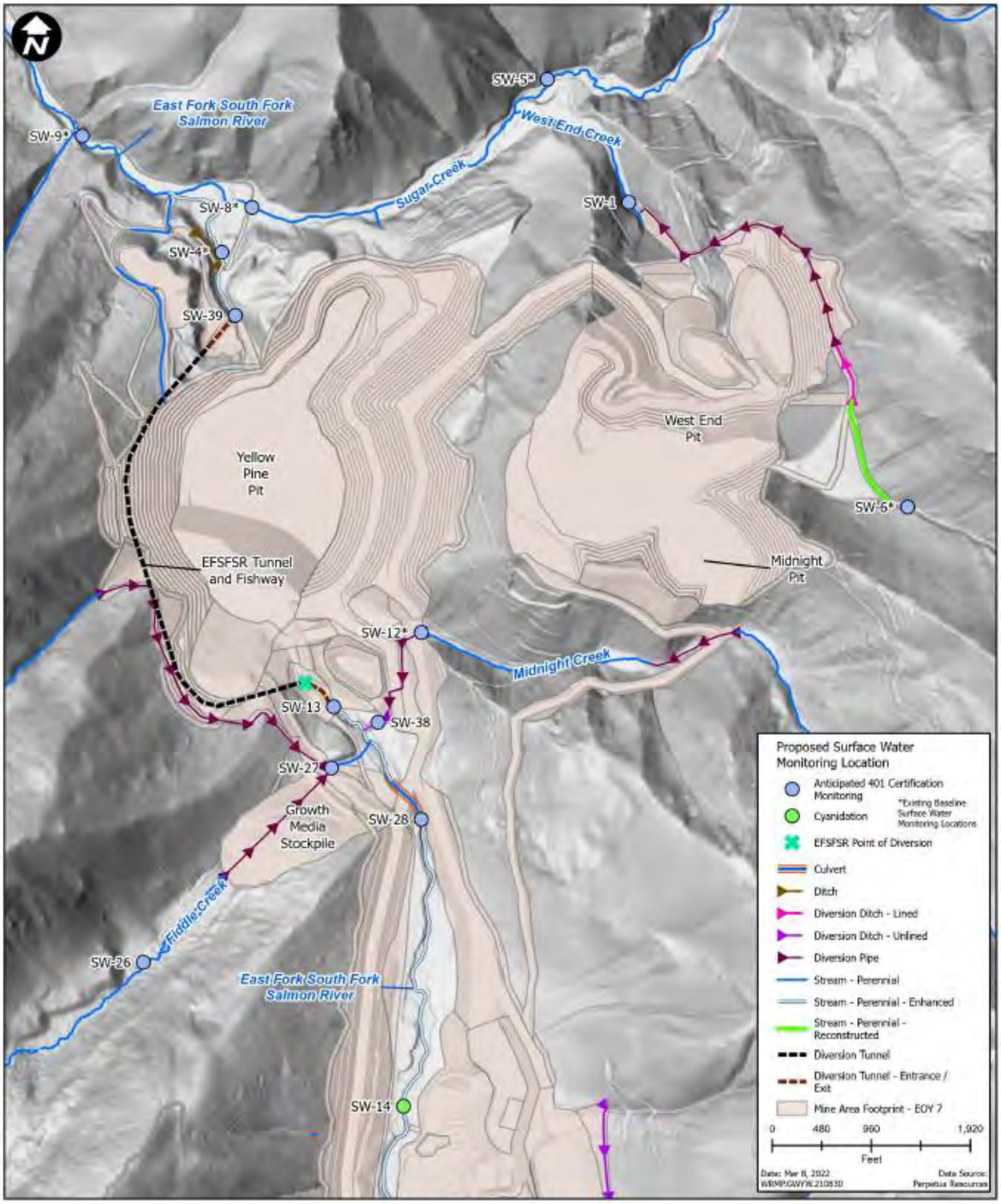


Figure 19. Northern Operations Area Surface Water Monitoring Locations.

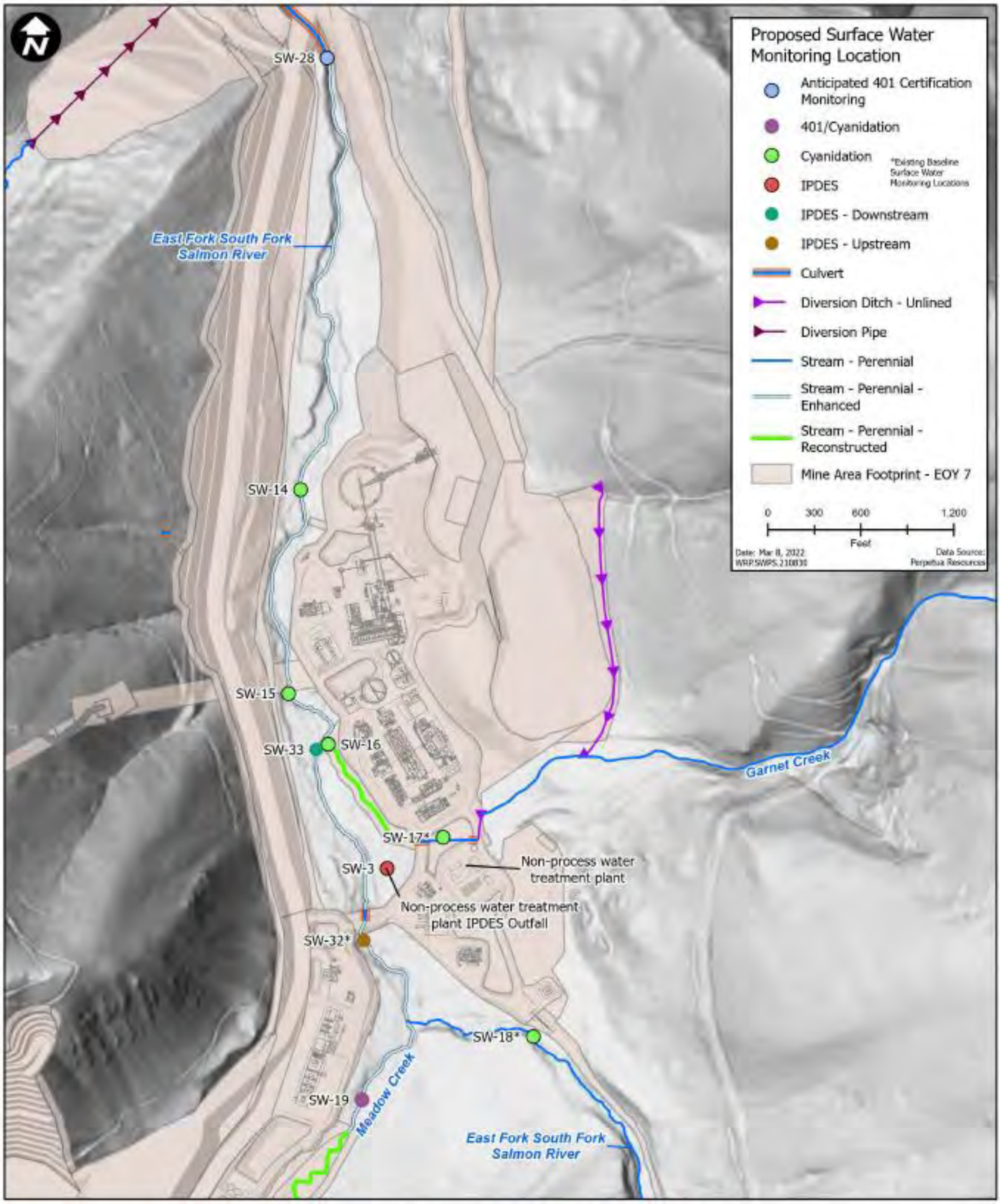


Figure 20. Ore Processing Area Surface Water Monitoring Locations.

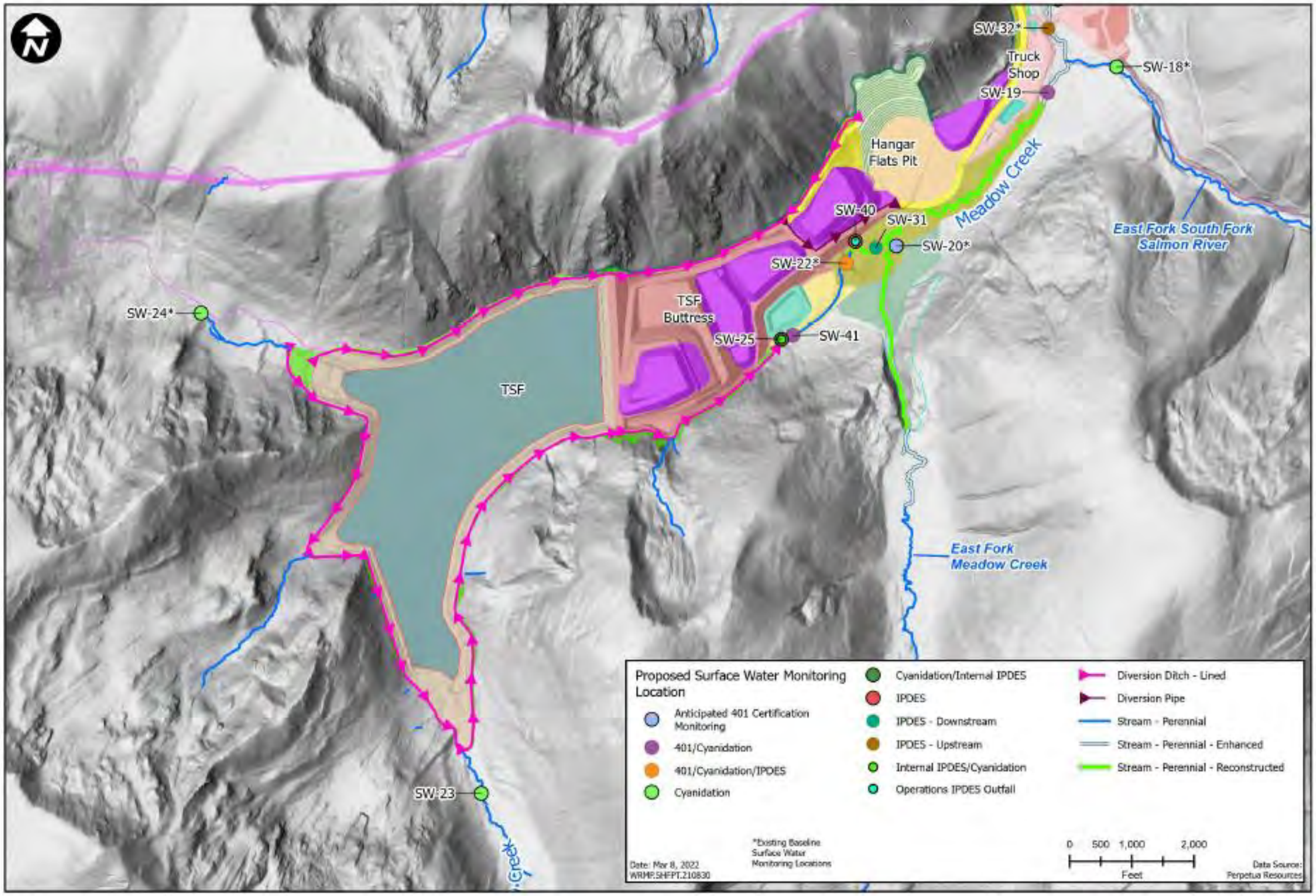


Figure 21. Southern Operations Area Surface Water Monitoring Locations During Operations.

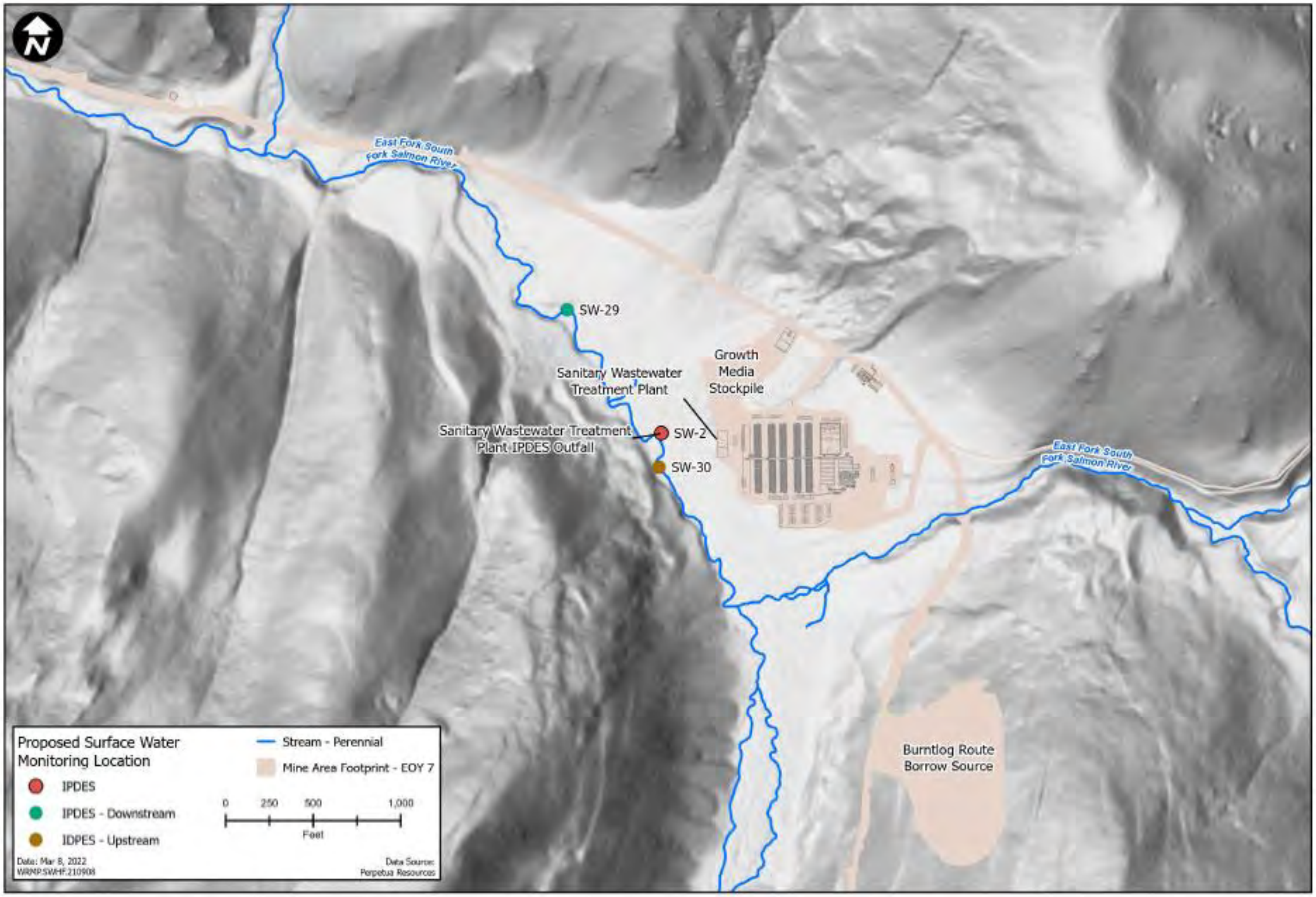


Figure 22. Worker Housing Area Surface Water Monitoring Locations During Operations.

Instantaneous flow and temperature measurements will be collected at each surface water location for each sampling. The USFS will review monitoring results for comparison to USFS requirements, the approved mine plan, modeling forecasts, and water quality standards.

The USFS will also require the following mitigation measures regarding water resources monitoring and monitoring results as follows.

1.10.1.1. Monitoring Measure - WRMP Implementation, Water Quantity

Because construction, operation, and closure of the SGP has the potential to impact surface or groundwater resources, a focused Water Resources Monitoring Plan (WRMP) will be implemented by Perpetua. As the mine owner/operator, Perpetua will be responsible for the implementation of the plan focused on confirming the predicted groundwater drawdown within allowance for model uncertainty and its relationship to discharges at proximal surface water resources. The plan will include surface water, groundwater, and meteorological monitoring requirements for the Project. Water quantity measurements will include diversion rates from groundwater pumping, water levels in groundwater monitoring wells and piezometers located within the Operations Area Boundary, and flow rates of streams and springs at USGS monitoring stations as well as spring locations characterized in the baseline program within the predicted 10-foot drawdown contour. Monitoring results will be provided to the USFS on a quarterly basis and summarized in an annual report. The mine owner/operator will be responsible for continued monitoring and reporting of changes in groundwater levels and surface water flows prior to, and during, operation and for a period of time in the post-reclamation period. The Plan will be reviewed and approved by USFS and implemented prior to the commencement of mining. State authorizations may also have monitoring requirements and these requirements along with monitoring already conducted or proposed could be applied to satisfy the needs of this mitigation measure.

1.10.1.2. Mitigation Measure – Groundwater Discharge to Surface Water

Impacts to groundwater discharge to surface water resources are predicted by the numerical groundwater flow model and are accounted for in the authorization. However, if monitoring results indicate a different nature or extent of impacts that are outside of model uncertainty and associated with Project water management, additional compensatory mitigation will be implemented to mitigate for the effects of that reduced flow on the use of the affected surface water resource. Any additional compensatory mitigation will need to be performed in compliance with applicable regulations, including 404 CWA permitting and 401 Water Quality Certification.

1.10.1.3. Monitoring Measure – WRMP Implementation, Water Quality

Because construction, operation, and closure of the proposed Project has potential to impact surface or groundwater resources, a focused WRMP for the Project will be developed by Perpetua. As the mine owner/operator, Perpetua will be responsible for the implementation of the plan for the Project incorporating the confirmation of predicted surface water and groundwater chemistry plus surface water temperature. The plan will include mined development rock and ore, surface water, groundwater, and meteorological monitoring requirements. Monitoring results will be provided to the USFS on a quarterly basis and summarized in an annual report. Perpetua will be responsible for continued monitoring and reporting of surface and groundwater chemistry and temperature prior to, during, and after operations for a period of time in the post-reclamation period. The plan will be reviewed and approved by the USFS and implemented prior to the commencement of mining. State authorizations may also have monitoring requirements and these requirements along with monitoring already conducted or proposed could be applied to satisfy the needs of this measure.

1.10.1.4. Monitoring Measure – Higher Frequency Water Quality Sampling and Analyses

In scenarios where there is a demonstrated reason for concern that water sources and discharges around Project components could have rapidly changing analyte concentrations, water quality samples will be collected and analyzed more frequently than the regular monitoring program frequency for key parameters for a limited time until monitoring parameters stabilized (e.g., weekly sampling compared to monthly or quarterly sampling). The higher frequency data collected, which may coincide with requirements under other state and federal permits, will be reviewed and compared to previously collected data, baseline concentrations, and other permit conditions. Higher frequency water quality sampling and analyses will be applied to:

- Discharges from the start-up or resumption of mine water treatment plants following an extended shut-down (pH, specific conductivity, weak acid dissociable [WAD] cyanide, organic carbon, arsenic, antimony, and mercury) until results meet IPDES permit limits or the results of monitoring are considered sufficient based on USFS review in consultation with applicable state regulatory agencies.
- Monitoring of spill indicators in affected receiving monitoring wells, contact water collection ponds, and surface waters (pH, specific conductivity, spilled material indicators) until the results of the monitoring are considered sufficient based on USFS review in consultation with applicable state regulatory agencies.

1.10.1.5. Mitigation Measure – Contingency Plan for Long-term Power Interruption

While IPDES permitting requires contingency planning for power interruption associated with discharging water treatment plants, other water management activities not associated with discharges are not required to have contingency plans under that permit. Perpetua will develop and maintain water management contingency plans for a long-term power interruption of longer than 24 hours to prevent unauthorized discharge from the following water management facilities: (1) contact water collection ponds; (2) TSF; (3) dewatering; (4) process plant water containments; and (5) any water pumping associated with a spill response.

1.10.1.6. Monitoring Measure - Updated Geochemical and Temperature Modeling

Geochemical modeling and/or temperature modeling will be updated as necessary (at the request of the USFS) if monitoring results obtained from the WRMP or other data collection indicate a change in water quality conditions that will significantly influence prediction and recognition of potential mine impacts. The USFS' review of quarterly and annual monitoring results compared to predicted conditions will provide early warning of potentially unanticipated, undesirable impacts to water resources to allow for implementation of appropriate mitigation measures. Implementation of these mitigation measures will reduce or eliminate potential impacts to water quality.

1.10.1.7. Mitigation Measure - Contingent Stream Temperature Reduction Measures

Due to inherent limitations in modeling and forecasting stream flow temperatures over a multi-decade period, effectiveness of the actual performance of TSF consolidation, stream channel restoration, riparian plantings, and other temperature reduction measures implemented may differ from forecast.

Ditches and pipelines utilized to divert water around the TSF during operations are expected to result in maintaining cooler water temperatures for downstream reintroduction into the mainstream system. In addition, these diversions will not be affected by TSF consolidation or implementation of stream channel restoration. Therefore, these surface flow diversions will not be removed/reclaimed and continue to be utilized to divert flows in part of in whole until:

- TSF consolidation appropriate for stream channel restoration could be verified via consolidation monitoring and re-modeling for the as-built tailings facility;
- Stream restoration design and implementation could be reassessed prior to construction by resurveying the as-built and partially consolidated TSF surface to determine whether design stream gradients could be achieved or whether the stream channel design will need adjustment to accommodate the gradients of the post-consolidation TSF surface; and,
- Achievement of design shading effects of riparian plants on stream temperatures could be reassessed prior to construction by measuring the success of establishing riparian plantings at locations outside the TSF footprint (e.g., HFP diversion corridor, TSF Buttress, across the YPP backfill or others) or a TSF-analogous test plot location utilizing the design cover materials and thicknesses.

Operational period maintenance practices for the diversions will remain in effect into the closure and post-closure period to prevent sedimentation and other factors from impairing the effective use of the diversions. Upon verification of the items above with any associated design adjustments, stream water temperature monitoring data in the constructed restored stream channel will be collected to confirm the performance of the temperature reduction measures. In an event where monitoring data indicated that acceptable stream temperatures will not be attained, the ditch and pipeline diversions will be recommissioned and utilized to convey surface flows in part or in whole until an effective planting design will be developed and implemented.

1.10.1.8. Mitigation Measure – Streamflow Temperature Adjustment

In the event that riparian shading does not provide sufficient shade to maintain Summer Maximum Weekly Maximum Temperature (MWMT) at or below those included in the closure plan, adaptive management in the areas of concern will be used to identify the issues and implement improvement measures. Depending on the degree and spatial extent of the mitigation needed, these measures could include supplemental plantings with larger, container plants along stream reaches, leaving low-flow diversion pipes in place for longer periods while vegetation is established, installation of temporary shade structures, storing and covering snowpack along reaches to allow melt water into the system, or retrofitting additional pond features for mixing day and night time flows to lower maximum daily stream temperatures.

In order for the USACE to issue a permit under Section 404 of the CWA and authorize dredge or fill placement in WOTUS, all unavoidable impacts to jurisdictional WOTUS must be mitigated. Perpetua proposes to accomplish compensatory mitigation for impacts to wetlands through a combination of mitigation bank credits in the North Fork Payette subbasin[5] and permittee-responsible on-site mitigation within the SFSR subbasin, plus some additional off-site mitigation outside the SFSR subbasin to account for temporal impacts (Tetra Tech 2023).

The Project includes activities that will result in permanent impacts to WOTUS including wetlands. Perpetua submitted a draft CMP (Tetra Tech 2023) that addresses compensation for lost wetland areas and functions, in addition to addressing mitigation proposed for impacted streams, to the USACE for approval on April 7, 2023. The CMP addresses compensatory mitigation for permanent impacts that will be accomplished through a combination of mitigation bank credits and the creation of new wetlands, streams, and enhancing and reclaiming existing wetlands and streams in the general vicinity of the impact areas. The CMP also addresses compensatory mitigation to reduce the temporal loss of aquatic functions and potential risks associated with actions described in the CMP. Temporal loss of functions and values is discussed further below.

The CMP describes an accounting process for tracking the various wetland impacts (losses) and associated wetland mitigation (gains), in addition to streams. The CMP uses the Montana Wetland Assessment Method (MWAM) functional assessment tool to determine functional units for each affected wetland assessment area. These units are based on a combination of MWAM scores and acres of wetlands. When these functional units will be lost due to development in the associated wetland, those losses are considered "debits." Conversely, the creation of new wetlands can result in "credits" by assessing and estimating the predicted functional scores and area of proposed wetlands that will be created, restored, or enhanced. Using this system of accounting for wetland credits and debits, the CMP provides a ledger that itemizes debits throughout the construction and operating phases and proposed credits for conceptual wetland creation actions. This system of accounting for losses and compensatory gains is intended to demonstrate a means of ensuring that adequate mitigation will be provided regardless of the final impact area. The ledger can be scaled up or down to identify the appropriate wetland credits needed to compensate for the final determination of wetland debits, which will be documented in the CWA 404 permit. The ledger system also provides a way to track and assess temporal effects which are the effects that come from the loss of wetland functions during the period between impacts and compensatory mitigation.

[5] Mitigation proposed for the North Fork Payette River subbasin is not described or discussed in detail in this opinion as it is a subbasin not occupied by ESA-listed Chinook salmon and steelhead.

Based on the CMP ledger of debits and credits, the amount of time associated with the temporal impacts related to wetlands is approximately 20 years, during which time as many as 620 functional units are outstanding (Tetra Tech 2021; 2023). These temporal effects will only occur within the Salmon River drainage. Coordination with the USACE for approval of existing and predicted wetland functional assessment scores is ongoing. The USACE may have changes to the methodology for the functional assessment evaluation which could result in changes in the final CMP to ensure mitigation reflects any resulting changes. Final impact acreages will be determined as part of the CWA Section 404 permit application process and will be agreed upon by the USACE.

The CMP describes a plan to locate the compensatory wetland mitigation sites within the same subbasins as the associated wetland impact sites. Temporal lag between effects on stream functional units and their mitigation will be addressed via off-site stream improvements located in subbasins outside the Project vicinity (Tetra Tech 2023). The proposed compensatory wetland mitigation within the Project area subbasin will be located around the mine site area where the majority of wetland impacts will occur, with no mitigation sites proposed along the access roads and the transmission line routes. The current location and configuration of mitigation sites identified in the CMP were selected based on suitable hydrology and compatibility with watershed-scale features and on the likelihood that compensatory mitigation wetlands will be sustainable within five years (Tetra Tech 2023). At the conclusion of the USFS process, final wetland impacts will be assessed, any agreed upon off-site compensatory mitigation projects will be finalized, and a final mitigation plan will be prepared, including a final assessment of functional units lost and created, and then the final credits/debits will be documented in the CWA Section 404 permit.

Monitoring associated with implementation of the CMP includes:

- Annual monitoring of stream restoration will be conducted during the low-flow period of the first five years following completion of the restoration actions with the understanding that attainment of performance standards may take a longer monitoring period. Monitoring activities and reporting will vary by year for the five-year period as follows:
    - During the first year following construction, the restored stream reaches will be assessed to determine if they had been constructed within design tolerances with any changes between design and construction noted along with the reasons for that change in an As-Built Report as part of the first annual monitoring report.
    - During the first, third, and fifth years following restoration, physical channel conditions and aquatic habitat will be monitored by measuring stream channel characteristics including bankfull width, maximum pool depth, mean pool depth, bankfull width/depth ratio (W:D), and average channel depth along with three to five perpendicular transects per stream reach coinciding with riffle and pool features. In addition, to document bedform complexity, average channel slope and pool frequency/depth, a longitudinal profile of the channel thalweg will be conducted for a representative sub-reach. During each of the five years, streambanks will be visually inspected for eroding banks and to determine LWD and rock structures remain intact.

- Riparian vegetation will also be surveyed to characterize the number of different native herbaceous, shrub, and tree species within the stream restoration reach (years 1 through 5), the percent cover of native herbaceous, shrub, and tree species observed within the restoration reach (years 2 through 5), and the percent cover of Idaho-listed noxious weed species (years 1 through 5).

- Following the fifth year of monitoring, a stream functional assessment for restoration design reaches will be completed for comparison to baseline stream functional assessments to determine whether restoration design reaches are functioning appropriately. The stream functional assessment will utilize USFS Watershed Condition Indicators (WCI), including the following parameters:
  - water temperature;
  - fine sediment;
  - chemical contaminants;
  - physical barriers located downstream;
  - substrate embeddedness;
  - LWD frequency;
  - LWD recruitment potential;
  - pool frequency;
  - pool quality;
  - off-channel habitat with cover;
  - W:D;
  - Streambank condition;
  - floodplain connectivity;
  - Change in peak/base flows;
  - change in drainage network;
  - road density and location;
  - RCAs;
  - disturbance history;
  - occupancy potential;
  - critical habitat;
  - fish use presence/absence.

- Annual monitoring of wetland restoration areas will be conducted for the first five years following completion of restoration with the understanding that attainment of performance standards, primarily for palustrine forested (PFO) wetlands may take a longer monitoring period. During the first annual monitoring, the wetland mitigation area will be assessed to determine whether site grading achieved design elevations for adequate hydrology to sustain plant communities with subsequent monitoring assessing whether restored areas are receiving adequate flow to support wetland vegetation. Monitoring will employ shallow piezometers, well points, and/or 12-inch test pits along defined monitoring transects to examine subsurface conditions in addition to surface observations of water marks, drift lines, sediment deposits, and drainage periods. Wetland vegetation will also be surveyed to characterize the number of different native submerged aquatic, herbaceous, shrub, and tree species within the restored palustrine aquatic bed (PAB), palustrine emergent marsh (PEM), palustrine scrub-shrub (PSS), and PFO wetland classifications (years 1 through 5), the percent cover of native submerged aquatic, herbaceous, shrub, and tree species observed within the restoration reach (years 2 through 5), and the percent cover of Idaho-listed noxious weed species (years 1 through 5). Soil monitoring in conjunction with vegetation monitoring along established transections will assess development of organic wetland soil by examining organic matter on soil surfaces, monitoring soil profiles to determine whether soil color meets USACE hydric soil indicated criteria (i.e., chroma less than two on the Munsell color chart) and assessing development of redoximorphic features by checking for oxidized and reduced soil zones.

- Following the fifth year of monitoring, the MWAM will be used to conduct a functional assessment of restored wetlands and the results will be compared to the results of the functions and values assessments performed prior to project construction.
- Annual monitoring reports will be submitted for stream and wetland restoration monitoring results. The first annual monitoring report will include as-built drawings of each stream and wetland restoration project completed describing site condition, topography, and planted areas, site dimensions, and water supply/water control features. Any deviations from the design will be documented. Each annual report will present monitoring results organized into the following sections: Monitoring Requirements and Performance Standards, Summary Data, Maps and Plans, and Conclusions.

Performance standards for water resources include:

- Comparison of water quality constituent concentrations to regulatory criteria;
- Comparison of predicted water quality constituent concentrations to observed conditions with further action per the project mitigation measures;
- Comparison of predicted project effects on groundwater levels and stream flows to observed conditions with further action per the project mitigation measures;
- Comparison of predicted stream temperatures to observed conditions with further action per the Project mitigation measures; and,
- Functional assessment of restored streams and wetlands compared to CMP targets for functional replacement.

1.10.2. Fisheries and Aquatic Resources

Perpetua has submitted a draft FMP (Brown and Caldwell, Rio ASE, and BioAnalysts 2021) describing the proposed monitoring of instream and riparian habitat conditions and instream biological communities. The purpose of the monitoring is to confirm proper project implementation and to document physical and biological characteristics to assess whether they are achieving the desired effectiveness. Tables 7-2 and 7-3 in the FMP summarize the monitoring proposed by Perpetua, and are incorporated here by reference. A brief summary of the habitat and biological monitoring is summarized below.

1.10.2.1. **Stream and Riparian Habitat Monitoring.**

Monitoring of stream restoration would occur annually in the low-flow period for the first 5 years following completion of restoration actions. Assessment of stream design for the restoration reaches would occur in the first year of monitoring after implementation and physical channel conditions, aquatic habitat, and riparian vegetation would be monitored annually for 5 years.

According to the Compensatory Stream and Wetland Mitigation Plan (Tetra Tech 2023), riparian vegetation performance standards include:

- Year 2: Cover of native herbaceous species at least 50 percent and cover of native woody species at least 10 percent.

- Year 3: Cover of native herbaceous species at least 60 percent and cover of native woody species at least 25 percent.
- Year 5: Cover of native herbaceous species at least 80 percent and cover of native woody species at least 50 percent.
- Years 1-5: At least five native herbaceous species and 4 native shrub or tree species present in riparian buffer.
- Years 1-5: Less than 10 percent cover of Idaho-listed noxious weed species.

1.10.2.2. **Biological Community Monitoring.**

Both fish and macroinvertebrate surveys would be performed annually to provide information about the status and trends in biological responses during mining and restoration as well as providing indicators of aquatic community health that contribute to effectiveness monitoring. Monitoring will follow protocols established and carried out during baseline monitoring studies (MWH 2017; Stantec 2019; Stantec 2020; and Watershed Solutions 2021).

Perpetua will continue to monitor aquatic communities on an annual basis (or as permit conditions dictate) during construction, closure, and restoration and enhancement phases of the project; however, Perpetua will periodically review the monitoring results and determine if the frequency and/or spatial scale of monitoring may be reduced or expanded in the future. Any revisions to the program would be discussed with appropriate stakeholders prior to implementation. Perpetua proposes to use snorkeling methodologies for monitoring.

Snorkel surveys would be performed at a subset of the 30 survey locations monitoring between 2012 and 2018 (subset locations yet to be determined). During operations, Perpetua will monitor fish use of the EFSFSR tunnel by video and with PIT-tag arrays placed at appropriate locations in and near the tunnel. Chinook salmon redd and carcass surveys will be performed annually according to Copeland et al. (2019) within the watershed upstream from the fishway. Surveys will occur at least once every 10 to 12 days during the spawning season and will include all stream reaches where there is suitable spawning habitat.

Stream macroinvertebrate community composition will be monitored annually throughout construction, closure, and restoration phases of the Project as an indicator of water quality and overall stream habitat condition. Monitoring will occur at a subset of the 11 locations previously surveyed within Meadow Creek, EFSFSR, Sugar Creek, and Tamarack Creek. The metrics and indices of the macroinvertebrate community that will be used to assess conditions are listed below and are based on those used in the baseline aquatic biological surveys (MWH 2017).

Total Taxa Richness
Ephemeroptera Taxa Richness
Plecoptera Taxa Richness
Percent Plecoptera
Trichoptera Taxa Richness
Hilsenhoff Biotic Index
Percent 5 Dominant Taxa
Scraper Taxa Richness
Clinger Taxa Richness
Long-lived Taxa Richness
Metals Tolerance Index
Intolerant Taxa Richness
Percent Tolerant Individuals
Shannon-Weaver H' (log e)
Percent Filterers
Percent Gatherers
Percent Predators
Percent Scrapers

Percent Shredders
Percent Unclassified
Filterer Richness
Gatherer Richness
Predator Richness
Scraper Richness
Unclassified Richness
PIBO Observed/Expected Index

Perpetua will prepare annual summary reports of the stream habitat and biological monitoring for submittal to the USFS, permitting agencies, and other stakeholders. The specifics of monitoring reports and their details remain to be further refined.

1.10.3. Dust Monitoring

In addition to air quality monitoring requirements associated with the IDEQ's Air Quality Permit to Construct, the USFS will require off-site dust monitoring to determine the effectiveness of dust control measures in protecting USFS vegetation and visual resources that include the following:

1.10.3.1. **Monitoring Measure - Fence-Line Dust Control Monitoring Plan Implementation.**

Because dust emissions from the Project may impact air quality, a dust monitoring plan was developed by Perpetua. As the mine owner/operator, Perpetua will be responsible for the implementation of the dust monitoring plan, including installation of dust monitors at two locations near the mine operations boundary. One location will be south of the mine boundary close to the Burntlog Route. The other location will be between the eastern mine boundary and wilderness areas. The plan will include dust and meteorological monitoring during operations and quarterly reports to the USFS; monitoring and reporting will occur during non-winter periods and be implemented prior to commencement of mining. After five years of monitoring and every three years thereafter, the USFS and Perpetua will review this plan to determine if sufficient information was acquired and the monitoring may be removed.

1.10.4. Reclamation Monitoring

Prior to reclamation monitoring and maintenance programs, the USFS and IDL will agree to specific quantitative and qualitative reclamation monitoring plans and standards. Reclamation monitoring will begin during concurrent reclamation at SGP facilities. Quantitative and qualitative monitoring of reclamation success will begin the first growing season after concurrent or final reclamation is completed and will continue until success criteria are satisfied. The Reclamation and Closure Plan (RCP) (Tetra Tech 2021) presents the quantitative and qualitative reclamation monitoring that will be conducted and the performance standards that will be used (with USFS and IDL approval) to determine when maintenance activities are necessary, or reclamation is complete. These monitoring requirements are summarized below.

1.10.4.1. **Erosion and Sediment Control Monitoring**

Soil stability will be estimated for all reclaimed areas using qualitative descriptors examining soil movement, surface rock, pedestaling, flow patterns, and rilling/gullying. A reclamation specialist will observe each reclaimed area and assign qualitative descriptors. Soil stability monitoring will be completed twice annually for erosion control purposes, once in the spring and once in the fall, during the period when reclamation activities are being implemented. Once reclamation activities are completed soil stability observations will be made as part of performance monitoring after three years and will recur every three years until stabilization objectives have been met. For performance monitoring, the observations will be made at the same time the vegetation success observations are made. The monitoring results will be used to aid in determining the cause of any failures that are encountered and to locate problem areas before erosion becomes widespread enough to affect reclamation success.

1.10.4.2. **Slope Stability Monitoring**

Slope stability will be monitored during the erosion observations. Qualified staff will look for signs of slope movement, cut slope and rock face failures, and other indications of slope instability. The location and dimensions of significant surface cracks and fill slope bulges will be monitored. This information will be used to determine if surface cracks are the result of differential settling of fill material or slope instability. The appropriate regulatory agency will be notified, and corrective plans will be developed.

1.10.4.3. **Reclamation Maintenance Procedures**

Details pertaining to reclamation maintenance practices appear in Appendix A, Table A-6. To maintain normal conditions for reclaimed areas per their designs and/or if the performance of reclaimed areas is not satisfactory, appropriate maintenance activities will be implemented. Maintenance activities may include one or more of the following:

- Sediment removal from sediment basins, stormwater drainage channels, and diversions as necessary to maintain their design capacity;
- Diverting surface water away from reclaimed areas where erosion jeopardizes attainment of reclamation standards;
- Stabilizing rills, gullies, and other erosion features or slope failures that have exposed development rock;
- Noxious weed and invasive plant species control (per the USFS-approved methods and the 2020 Programmatic Activities Biological Opinion); and,
- Re-seeding or re-applying reclamation treatments in areas where it is determined through monitoring and agency consultation that reclamation will not meet standards.

1.10.4.4. **Annual Report**

Perpetua will submit an annual report to the USFS and the other federal and state agencies that are responsible for issuing authorizations applicable to reclamation for the preceding calendar year. The annual report will contain descriptions of the reclamation activities completed during the previous year, a summary of areas reclaimed, a discussion of the results of the reclamation monitoring conducted, and corrective actions implemented.

Perpetua’s proposed performance standards for reclamation include:

- Physical stability of reclaimed facilities free from erosion features that will affect revegetation and risks for mass slope failures;
- Comparison of predicted revegetation of riparian shade areas to observed conditions and the shading effects on stream temperatures with further action per the project mitigation measures; and,
- Achievement of 70 percent of the pre-existing vegetation cover for general revegetation areas (i.e., areas not associated with the establishment of riparian shading to achieve target stream temperatures).

1.11. Environmental Design Features

The SGP must comply with all laws and regulations that apply to the proposed activities with prominent requirements relevant to the effect's analysis summarized in Table 22. This table has been modified in this opinion to only include EDFs relevant to minimizing or avoiding adverse effects to ESA-listed salmonids. For the complete table, please refer to BA Table 3.9-1. Standards and guidelines in the Boise and Payette Forest Plans (USFS 2003; 2010a) that are designed to reduce or prevent undesirable impacts resulting from proposed management activities are incorporated into the Proposed Action by reference. In addition, BMPs outlined in the Best Management Practices for Mining in Idaho (IDL 1992) will be implemented where appropriate and applicable for operations to minimize site disturbance from mining and drilling activities.

Perpetua will implement the mitigation measures/EDFs described in this section. Based on the application of permits and regulatory compliance requirements to the Project, regulatory requirements, standards and guidelines, BMPs, and permit conditions are listed in Table 22. The EDFs beyond regulatory requirements that have been proposed and committed to by Perpetua are listed in Appendix A. In particular, activities associated with the CMP for impacts on wetland resources are summarized in Table 23. The effects analysis in the BA takes these EDFs as well as regulatory requirements into consideration, such that the identified potential impacts of the SGP will be those that remain after their application. These EDFs and regulatory requirements will be applied to reduce and minimize impacts to resources from the SGP.

Table 22. Prominent Regulatory and Forest Plan Requirements.

Description	Type	Reference
The proponent will prepare a dust mitigation plan with appropriate schedule or triggers for control deemed adequate by IDEQ to achieve the level of control of 93.3 percent of dust (as required in conditions 2.1-2.8 of the Permit to Construct from IDEQ). Additionally, the proponent will employ particulate matter or opacity monitors deemed adequate by the Forest Service USFS and immediately apply water or chemical dust control when PM or opacity monitors reach levels within 10 percent of the threshold determined by IDEQ.	IDEQ Permit	IDEQ Permit to Construct
During Project planning, affected tribe(s) shall be consulted regarding opportunities for restoration, enhancement, and maintenance of native plant communities that are of interest to tribe(s) when proposed activities may affect those plant communities.	FP Component	BNF and PNF: TRST04
When taking water from fish-bearing waters for road and facility construction and maintenance activities, intake hoses shall be screened with the most appropriate mesh size (generally 3/32 of an inch), or as determined through coordination with National Oceanic and Atmospheric Administration Fisheries and/or USFWS.	FP Component	BNF and PNF: FRST01 TEST32
Fish passage shall be provided at all proposed and reconstructed stream crossings of existing and potential fish-bearing streams.	FP Component	BNF and PNF: SWST08
Surface water withdrawal intake hoses will be situated so as to prevent generation of turbidity in bottom sediments during pumping.	Design Feature	
Where settlement ponds, tailing dams, or impoundments are planned, each will be located, designed, constructed, and inspected under the supervision of a professional engineer.	FP Component	BNF and PNF: MIGU03
Prohibit solid and sanitary waste facilities in RCAs. If no alternative to locating mine waste (waste rock, spent ore, tailings) facilities in RCAs exists, then: Analyze waste material using the best conventional methods and analytic techniques to determine its chemical and physical stability characteristics. Locate and design waste facilities using the best conventional geochemical and geotechnical predictive tools to ensure mass stability and prevent the release of acid or toxic materials. If the best conventional technology is not sufficient to prevent such releases and ensure stability over the long term, and such releases or instability will result in exceedance of established water quality standards or will degrade surface resources, prohibit such facilities in RCAs. Monitor waste and waste facilities to confirm predictions of chemical and physical stability and make adjustments to operations as needed to avoid degrading effects to beneficial uses and native and desired non-native fish and their habitats. Reclaim and monitor waste facilities to ensure chemical and physical stability and revegetation to avoid degrading effects to beneficial uses and native and desired non-native fish and their habitats. Require reclamation bonds adequate to ensure long-term chemical and physical stability and successful revegetation of mine waste facilities.	FP Component	BNF and PNF: MIST09
Transport hazardous materials on the Forest in accordance with 49 CFR 171 in order to reduce the risk of spills of toxic materials and fuels during transport through RCAs.	FP Component	BNF and PNF: SWGU11

Description	Type	Reference
A SPCC shall be prepared in accordance with 49 CFR parts 171 through 180, including packaging, transportation, incident reporting, and incident response. Include the following items within the SPCC Plan: During off-loading of fuel from fuel vehicles or during refueling operations have a standard marine-type fuel containment boom (which will be of sufficient length for a worst-case discharge), spill prevention kit, and fire kit readily available on site. Store two or more spill containment/response caches along each of the fuel delivery routes. Spill response team will carry sufficient containment equipment for one full fuel tanker. Include the Forest Service as a party to be notified in the event of a hazardous materials spill. Intake pumps, engines, fuel storage, fuel containment site, and other equipment with fuel or lubricants will be inspected at each refueling and periodically between refueling for leakage or spillage. Pilot and emergency spill response vehicles will carry appropriate containment and first aid equipment. All fuel containers will be marked with contents, owner's name and contact information. Material Safety and Data Sheets for all products will be posted and available on site with the SPCC plan. Intake pumps will not be situated within the active stream/ditch channel and will be placed within containment vessels capable of holding 120 percent of the pump engine's fuel, engine oil and hydraulic fluid. The smallest practical pump and intake hose will be used. Following large storm events, the intake pumps will be inspected to determine if stream flow has encroached into the pump area and if the pump needs to be moved so it remains above flowing water. A spill prevention and clean-up kit will be placed at the intake pump site and will consist of absorbent pads and/or boom (which will be sufficient length for a worst-case discharge), drip pan, a shovel, and a fire extinguisher. Spare fuel for the water intake pump will be stored in approved [29 CFR 1926.152(a)(1)] fuel storage containers placed into a secondary containment vessel capable of holding at least 120 percent of the volume of the fuel in the fuel container. A copy of the SPCC plan will be kept at an appropriate on-site facility.	Regulatory Requirement and Design Features	49 CFR 171
Unless otherwise authorized, all garbage or refuse should be removed from NFS lands. This includes, but is not limited to, empty fuel and lubricant containers. Food and garbage will be stored either indoors, in vehicles, or if outside, in wildlife-proof containers. No garbage will be burned.	FP Component and Design Features	Design Feature developed for compliance with BNF and PNF: MIGU04
The operator shall comply with all applicable Federal and State fire laws and regulations and shall take all reasonable measures to prevent and suppress fires on the area of operations and shall require their employees, contractors and subcontractors to do likewise.	Regulatory Requirement	36 CFR 228.11
The operator shall comply with State of Idaho fire protection procedures (as outlined in IDAPA 20.04.01) and any local Valley County Fire District regulations and shall require their employees, contractors and subcontractors to do likewise.	Regulatory Requirement	IDAPA 20.04.01
Several fire-response kits will be spaced strategically around the Project area and be inspected annually.	Design Feature	

Description	Type	Reference
Reclamation cover material (e.g., growth media) used in places including but not limited to the TSF and TSF Buttress will be evaluated for contaminants prior to use during reclamation. Acceptable metal/contaminant concentrations and sampling and testing methodology will be documented in a sampling and analysis plan developed prior to reclamation.	Design Feature	
Topsoil and any brush removed will be stockpiled separate from fill material and used in reclamation.	Design Feature	
Measures such as, but not limited to, segregating and stockpiling topsoil, implementing stormwater and sediment best management practices (BMP), backfilling, revegetation and concurrent reclamation will be conducted, where possible and practical, for areas where the soil has been exposed by ground-disturbing activities. These areas/sites include, but are not limited, to borrow sites, utility corridors, skid trails, firebreaks, temporary roads, cut and fill slopes, and areas where construction activities have occurred.	Design Feature	Design Feature developed to lessen impacts under BNF and PNF: SWST03, SWGU05
Applicable road obliteration for all roads proposed for obliteration including temporary roads and applicable sections of the Burntlog route will be fully recontoured, including full bench constructed road segments. Road obliteration through recontouring is the reclamation of a road template through the following: deep decompaction (36") of the inside half of the road surface; excavate road fill down to the natural ground level and then place on top of the decompacted inside half of the road surface on the cut slope side of road; reestablish the natural slope profile; and vegetation clump planting. **Decompaction:** All compacted road surfaces that will be covered with excavated material, for example the inside half of the road surface, shall be decompacted to a depth of 36 inches or to a restrictive layer (bedrock). This is to promote water infiltration, breakup any potential landslide slip surface between the road surface and excavated and placed fill material and allow deep root vegetation establishment. **Excavation:** After decompaction of the roadway, the outside road fill material shall be excavated and placed on roadbed between the top of cut and natural ground, forming a slope approximating natural contours. No ditches, water traps, or berms shall remain. Finished product should blend in with the surrounding terrain. **Soil-Vegetation Plug Transplanting:** Excavate soil-vegetation plugs from adjacent natural and undisturbed ground having a minimum surface area of 9 square feet to a depth beyond the vegetation rooting zone (plug size is dictated by excavator bucket size). The plug transplant shall be of sufficient depth that will maintain the root system and contain adequate soil to enhance favorable growth. Soil-vegetation plug transplanting will be done at a minimum rate of 15 plantings per 100 lineal feet evenly distributed along the width and length of the recontoured surface. The plugs will be transplanted to a depth even with the surrounding recontoured ground level. This work will be accomplished with an excavator. **Surface Ground Cover:** Ground cover across the entire recontoured or disturbed surface (this will include all scarified ground, de-compacted roads and skid trials), by order of priority, shall be achieved using a combination of clump planting, native mulch, coarse woody debris and certified weed free agriculture straw to reach a minimum of 50 percent to the maximum 80% coverage of the recontoured surface or disturbed area. Apply native seed mix, hydromulch or organic fertilizer. This order or priority shall be given to vegetation plug planting, native mulch, coarse woody debris, and straw. When applying coarse woody debris, use various size classes at levels similar to surrounding undisturbed ground and placed at various orientations. The desired result of road obliteration through recontouring is to restore slope contours the natural slope profile, improve soil productivity, improve soil-water infiltration, and reestablish ground water flow paths and hydrologic function.	Design Feature	

Description	Type	Reference
Road rutting from operations, outside the mine site, will be minimized by construction and maintenance of surface drainage structures, application of surfacing material, and by restricting road use when conditions are unacceptable due to moisture that is leading to the onset of rutting and concentrated turbid flow. (Note typical guidance is 'no use' if ruts deeper than 4" are created.) This design feature does not apply to the mine site.	Design Feature	Design Feature developed to lessen impacts under BNF and PNF: SWST02 SWST03
Handling of road waste material (e.g., slough, rocks) will avoid or minimize delivery of waste material to streams that will result in degradation of soil, water, riparian, and aquatic resources.	Design Feature	Design Feature developed for compliance with BNF and PNF: FRST05
Mitigate degrading effects from locatable mine operations situated within RCAs by identifying reasonable locations for access, processing, and disposal facilities outside of RCAs, wherever possible.	Design Feature	BNF and PNF: MIST04, LSST07, MIST08, FRGU06
To minimize the degradation of watershed resource conditions, prior to expected water runoff, water management features will be constructed, installed, and/or maintained. Activities and features include, but are not limited to, water bars, rolling dips, seeding, grading, slump removal, barriers/berms, distribution of slash, and culvert/ditch cleaning in all applicable areas.	FP Component	BNF and PNF: MIST04, LSST07, MIST08, FRGU05
To accommodate floods, including associated bedload and debris, new culverts, replacement culverts, and other stream crossings will be designed to accommodate a 100-year flood recurrence interval unless site-specific analysis using calculated risk tools or another method, determines a more appropriate recurrence interval.	Design Feature	Design Feature developed for compliance with BNF and PNF: SWST01 and SWST04
To minimize sediment runoff from the temporary roads and roadbeds, water management features will be constructed, installed, and/or maintained on authorized temporary roads and roadbeds, on completion of use, before expected water runoff, or before seasonal shutdown. Activities and features could include, but will not be limited to, water bars, silt fencing, certified weed-free wattles, and/or weed-free straw bales, rolling dips, seeding, grading, slump removal, barriers/berms, distribution of slash, and culvert/ditch cleaning. These features will be installed in strategic downslope areas and in RCAs, where and when appropriate.	FP Component	BNF and PNF: FRST02

Description	Type	Reference
Snow removal will be accomplished in accordance with the following standards of performance: All debris, except snow and ice, that is removed from the road surface and ditches will be deposited away from stream channels at approved locations. During snow removal operations, banks will not be undercut, and gravel or other surfacing material will not be bladed off the roadway surface. Ditches and culverts will be kept functioning during and following plowing. Berms left on the shoulder of the road will be removed and/or drainage openings will be created and maintained. Drainage openings will be spaced to maintain satisfactory surface drainage without discharge on erodible fills. Dozers will be used on an as-needed basis for plowing snow. The dozer operator will maintain an adequate snow floor over the gravel road surface. Snow will not be totally removed to the gravel road surface. Appropriate snow floor depth will be maintained to protect the roadway. Damage of roads from, or as a result of, snow removal will be repaired in a timely manner. Culverts and stream crossings will be clearly marked before snow removal begins to avoid placing berm openings in locations that will allow runoff to enter drainages directly at the culverts or stream crossings. Excessive snow will not be plowed into locations that will impact operation of the culverts or prevent positive drainage from drainage areas. Some snow is necessary around culvert openings and in the bar ditches as this will insulate the ditch and culvert and will prevent the water in the ditch and culvert from freezing. No ice and snow removal chemicals will be used on roads. Traction material will be 3/8-inch diameter gravel or greater.	Design Feature	Design Feature developed for compliance with BNF and PNF: SWGU06
When available and not cost-prohibitive, seeds and plants used for seedings and plantings in revegetation projects should originate from genetically local sources of native species. When project objectives justify the use of non-native plant materials, documentation explaining why non-natives are preferred should be part of the project planning process.	FP Component	BNF and PNF: BTGU03
Noxious weeds and undesirable non-native plants will be eradicated in the Operations Area boundary, within permitted use areas, and the cut/fill slopes of roads and trails used by mine and mine facility related traffic. Where it is not practical to eradicate existing infestations, infestations will be managed to prevent seed production and spread. In areas of existing extensive infestation, mitigation for noxious weed prevention will be incorporated into road layout, design, and project evaluation.	Design Feature	Design Feature developed for compliance with BNF and PNF: FRGU02, TEST10
Clean borrow and gravel sources on Forest should be maintained as noxious weed free through an inspection and treatment program. Off-Forest inspections and treatments should be coordinated with county weed agents.	FP Component	BNF and PNF: NPGU02
All seed used on National Forest System lands will be certified to be free of seeds from noxious weeds listed on the current All States Noxious Weeds List.	FP Component	BNF and PNF: NPST02
Materials such as hay, straw, or mulch that are used for rehabilitation and reclamation activities shall be free of noxious weed seed and shall comply with the 1995 weed-free forage special order against use of non-certified hay, straw, or mulch. Materials that are not covered under a weed seed free certification, and that have the potential to contain noxious weed seed, shall be inspected and determined to be free of weed seed before purchase and use.	FP Component	BNF and PNF: NPST01, NPST06
Source sites for gravel and borrow materials shall be inspected for noxious weeds before materials are processed, used, or transported from the source site into the project area or onto the National Forest.	FP Component	BNF and PNF: NPST07

Description	Type	Reference
Gravel or borrow material source sites with noxious weed species present shall not be used unless effective treatment or other mitigation measures are implemented.	FP Component	BNF and PNF: NPST08
To prevent invasion/expansion of noxious weeds, the following provisions will be included in the plan of operating where land-disturbing activities are associated with the authorized land use: a) Re-vegetate areas, as designated by the Forest Service, where the soil has been exposed by ground-disturbing activity. Implement other measures, as designated by the Forest Service, to supplement the influence of re-vegetation in preventing the invasion or expansion of noxious weeds. Potential areas will include: construction and development sites, underground utility corridors, skid trails, landings, firebreaks, slides, slumps, temporary roads, cut and fill slopes, and travel ways of specified roads. b) Earth-disturbing equipment used on National Forest System lands--such as cats, graders, and front-loaders shall be cleaned to remove all visible plant parts, soil, and material that may carry noxious weed seeds. Cleaning shall occur prior to entry onto the project area and again upon leaving the project area if the project area has noxious weed infestations. This also applies to fire suppression earth-disturbing equipment contracted after a Wildland Fire Situation Analysis/Wildland Fire Implementation Plan has been completed.	FP Component	BNF and PNF: NPST03
Integrated weed management shall be used to maintain or restore habitats for sensitive plants and other native species of concern where they are threatened by noxious weeds or non-native invasive plants. Specific measures to reduce the potential for spread and establishment of noxious weed infestations could include, but are not limited to, determining the presence, location, and amount of noxious weed infestations in the Operations Area, developing management strategies such as, methods and frequency for treating infestations, treatment procedures and restrictions, reporting requirements, and follow-up or monitoring requirements. Herbicide applications will be by or under the direct supervision of licensed Idaho professional herbicide applicators with Aquatic Pest Control certifications and will be consistent with the BNF Invasive Species Management Plan and PNF guidance.	FP Component and Design Features	Design Feature developed for compliance with BNF and PNF: NPST11
Public firewood cutting and gathering along the Burntlog route will not be allowed.	Design Feature	
Section 6 of IDL's Best Management Practices for Mining in Idaho (IDL 1992) will be observed, including if water is encountered in exploration holes, water zones will be sealed off during abandonment to prevent crossflow.	Regulatory Requirement	Section 6 of IDL's Best Management Practices for Mining in Idaho (IDL 1992)
The proponent will implement surface water quality baseline turbidity monitoring, as defined in the IDEQ permit clauses.	Design Feature	
Do not authorize storage of fuels and other toxicants or refueling within RCAs. Storage of fuels and other toxicants or refueling sites within RCAs shall be approved by the responsible official and have an approved spill containment plan commensurate with the amount of fuel.	FP Component	BNF and PNF: SWST11
Dust abatement chemicals will be used in accordance with the applicable road maintenance Biological Assessment. Apply dust-abatement additives and stabilization chemicals (typically $MgCl_2$, $CaCl_2$, or lignin sulphonates) to avoid run-off of applied dust abatement solutions to streams. Spill containment equipment will be available during chemical dust abatement application. Where the road surface is within 25 feet (slope distance) of surface water, dust abatement will only be applied to a 10-foot swath down the centerline of the road. The rate and quantity of application will be regulated to insure all of the chemical is absorbed before leaving the road surface.	Design Feature	

Description	Type	Reference
Drilling mud and hole plug products, if utilized, will conform to American Petroleum Institute guidelines for ensuring groundwater integrity.	Design Feature	American Petroleum Institute guidelines
Trees or snags that are felled in RCAs will be left unless determined not to be necessary for achieving soil, water, riparian, and aquatic desired conditions. Felled trees or snags left in RCAs will be left intact unless resource protection (e.g., the risk of insect infestation is unacceptable) or public safety requires bucking them into smaller pieces.	FP Component	BNF and PNF: SWST10
The proponent will monitor stormwater runoff and stormwater BMPs as per the Stormwater Pollution Prevention Plan (SWPPP). Stormwater monitoring, inspections, and reporting will be conducted in accordance with the IPDES MSGP and the SWPPP.	Permitting Requirement	IPDES MSGP and the SWPPP
All activities will be conducted in accordance with Idaho environmental anti-degradation policies, including IDEQ water quality regulations at IDAPA 58.01.02 and applicable federal regulations.	IDAPA 58.01.02	
If additional water rights are applied for, the Forest Service will be informed to determine if additional analysis or consultation is necessary prior to use.	Design Feature	
Road reconstruction and/or upgrades to NFR 51290 (Meadow Creek Lookout Road) on the ridgeline dividing Meadow Creek from the Indian Creek drainage will be restricted to 30 feet either side of the centerline of the existing alignment to prevent potential for direct impacts to the Frank Church River of No Return Wilderness.	Design Feature	Design Feature developed for compliance with BNF and PNF: LSST03, LSST05
Communication towers should not be sited in or near wetlands, or other known bird concentration or high use areas (e.g., riparian corridors), in known migratory or daily movement flyways. Towers should not be sited in areas with a high incidence of fog, mist, and low ceilings.	Design Feature	
To minimize adverse effects of noise to TEPC, where necessary and in accordance with MSHA and OSHA, the proponent could utilize actions in line with, but not limited to, the below: Construction equipment engines will be equipped with adequate mufflers, intake silencers, and engine enclosures when feasible. When practicable, pumps, generators, and engines will be turned off when not in use. Temporary wooden structure could be erected around portions of the drill, pumps, and heaters, with acoustic absorbent panels. These temporary structures will not be put in place if they created safety issues related to exhaust vapor build-up. When feasible, activities such as helicopter use and blasting, could be scheduled at the same time.	Design Feature	Design Feature developed for compliance with BNF and PNF: WIST03, WIST04 TEST29
Design and implement projects within occupied habitats of Sensitive species to help prevent them from becoming listed. Use Forest Service-approved portions of Conservation Strategies and Agreements, as appropriate, in the management of Sensitive species habitat to keep management actions from contributing to a trend toward listing for these species.	FP Component	BNF and PNF: WIST02

Table 23. Overview of Specific Activities in the Compensatory Mitigation Plan.

Activity	Description	Reference
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Meadow Creek and Tributaries (see Figure 23)	Stream channel restoration and enhancement of: • 24,164 feet of perennial channel; • 9,204 feet of non-perennial channel; • 1,293 feet of transitional perennial channel; and • 159 feet of transitional non-perennial channel. Transitional channel refers to the portions of Hennesy Creek and Midnight Creek where stream restoration will entail recontouring mine disturbance to match existing slopes and grades. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 7 through 42 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Hangar Flats Pit (HFP) Backfill (see Figure 23)	Stream channel restoration and enhancement of: • 8,798 feet of perennial channel; • 6,324 feet of non-perennial channel; and • 5,418 feet of transitional non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 43 through 61 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: East Fork Meadow Creek (Blowout Creek) (see Figure 23)	Stream channel restoration and enhancement of 5,452 feet of perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 62 through 71 and 112 through 132.

Activity	Description	Reference
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Garnet Creek (see Figure 23)	Stream channel restoration and enhancement of: • 3,800 feet of perennial channel; • 193 feet of transitional perennial channel; and • 1,185 feet of transitional non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 100 through 107 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Fiddle Creek (see Figure 23)	Stream channel restoration and enhancement of 1,798 feet of perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 86 through 90 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: East Fork South Fork Salmon River (see Figure 23)	Stream channel restoration and enhancement of: • 15,204 feet of perennial channel; and • 1,958 feet of non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 72 through 85 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Hennessy Creek (see Figure 23)	Stream channel restoration and enhancement of: • 1,345 feet of perennial channel; and • 692 feet of transitional perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 97 through 99 and 112 through 132.

Activity	Description	Reference
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: Midnight Creek (see Figure 23)	Stream channel restoration and enhancement of: • 1,331 feet of perennial channel, and • 2,549 feet of transitional perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., large wood debris, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 91 through 96 and 112 through 132.
Permittee-Responsible On-Site Stream Channel Restoration and Enhancement: West End Creek (see Figure 23)	Stream channel restoration and enhancement of 1,690 feet of non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates and an energy dissipation pool that accounts for sediment transport.	CMP, Appendix D, Sheets 108 through 111 and 124 through 130.
Permittee-Responsible On-Site Wetlands Restoration Meadow Creek (see Figure 23)	Wetlands restoration of: • 3.07 acres of palustrine aquatic bed (PAB) Riparian Fringe and Floodplains Wetlands; • 26.33 acres of palustrine emergent marsh (PEM) Riparian Fringe and Floodplains Wetlands; • 21.68 acres of palustrine shrub-scrub (PSS) Riparian Fringe and Floodplains Wetlands; • 83.03 acres of palustrine forested (PFO) Riparian Fringe and Floodplains Wetlands; • 1.56 acres of PEM Valley Margin Wetlands; • 1.10 acres of PSS Valley Margin Wetlands; and • 1.36 acres of PFO Valley Margin Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands. Deposition/placement and revegetation of fan-like landforms at locations where rivulets from the native steeply sloping valley side walls meet the reclaimed margins of the TSF will develop Valley Margin Wetlands.	CMP, Appendix D, Sheets 133 and 134.
Permittee-Responsible On-Site Wetlands Restoration HFP Backfill (see Figure 23)	Wetlands restoration of • 20.04 acres of PEM Riparian Fringe and Floodplains Wetlands; • 2.55 acres of PSS Riparian Fringe and Floodplains Wetlands; and • 14.46 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.

Activity	Description	Reference
Permittee-Responsible On-Site Wetlands Restoration EFMC (Blowout Creek) (see Figure 23)	Wetlands restoration of • 4.34 acres of PAB Riparian Fringe and Floodplains Wetlands; • 1.03 acres of PEM Riparian Fringe and Floodplains Wetlands; and • 3.28 acres of PSS Riparian Fringe and Floodplains Wetlands. A grade control and groundwater cutoff structure will raise the water level in EFMC and allow shallow groundwater to recharge. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 135.
Permittee-Responsible On-Site Wetlands Restoration Fiddle Creek (see Figure 23)	Wetlands restoration of • 1.35 acres of PSS Riparian Fringe and Floodplains Wetlands; and • 1.27 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
Permittee-Responsible On-Site Wetlands Restoration EFSFSR (see Figure 23)	Wetlands restoration of: • 19.44 acres of PEM Riparian Fringe and Floodplains Wetlands; • 2.80 acres of PSS Riparian Fringe and Floodplains Wetlands; and • 7.43 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
Permittee-Responsible On-Site Wetlands Restoration YPP backfill and Stibnite Lake feature (see Figure 23)	Wetlands restoration of 1. 0.07 acres of PAB Riparian Fringe and Floodplains Wetlands; 2. 2.26 acres of PEM Riparian Fringe and Floodplains Wetlands; 3. 0.80 acres of PSS Riparian Fringe and Floodplains Wetlands; and 4. 16.70 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
Permittee-Responsible Off-Site Stream Channel Restoration and Enhancement: Upper Lemhi River (see Figure 24)	The existing single-threaded channel of a reach of the Upper Lemhi River will be bifurcated and obstructed using natural materials at multiple locations to induce flow into relic channels on the floodplain. This activity will be augmented by 5,721 feet of complete channel excavation and 6,663 feet of partial channel excavation on private land. A conservation easement for the private land is being pursued to ensure the durability of the activity.	CMP, Section 9.1.2.1

Activity	Description	Reference
Permittee-Responsible Off-Site Fish Barrier Removal: Hargrave Creek and Big Creek (Payette River Subbasin)	One culvert on Hargrave Creek (second order stream) will be installed per Aquatic Organism Passage Design Criteria to remove a complete barrier and allow volitional fish passage to 7,895 feet of stream. Two culverts on Big Creek (second order stream) will be installed per Aquatic Organisms Passage Design Criteria to remove two complete barriers and allow volitional fish passage to 2,268 feet of stream and 7,827 feet of stream, respectively.	CMP, Section 9.1.2.2 SGP Payette Watershed Fish Passage Evaluation
Permittee-Responsible Off-Site Wetlands Credit Purchase North Fork Payette River	1.6 acres of wetlands credits (12.58 wetland functional units) will be purchased from the Salmon Meadows Wetland Bank.	CMP, Section 2.2.1 404(b)(1) Evaluation Framework, Section 4.2.3
Permittee-Responsible Monitoring Plan for Restored Stream Channels	Following completion of restoration construction, annual monitoring will be implemented for a period of five years followed by bi-annual monitoring thereafter until stream restoration achieves designed ecological performance standards. The stream monitoring will include: a. restored stream channel as-builts (first year only); b. physical channel conditions (widths, slopes, bank conditions); c. riparian vegetation (number of species, percent cover, noxious weeds); and d. functional assessment (after year five).	CMP, Section 12.1
Permittee-Responsible Monitoring Plan for Wetlands	Following completion of wetlands restoration, annual monitoring will be implemented for a period of five years followed by bi-annual monitoring thereafter until stream restoration achieves designed ecological performance standards. The stream monitoring will include: • hydrology (water levels, water marks, drift lines, sediment deposits, drainage patterns); • riparian vegetation (number of species, percent cover, noxious weeds); • soils (organic wetland soil, organic matter on soil surfaces, soil color as an indicator of hydric soil, development of redoximorphic features); • wetland delineation (after year five); and • functional assessment (after year five).	CMP, Section 12.2

Activity	Description	Reference
Permittee-Responsible Maintenance Plan for Restored Channels and Wetlands	Per restored stream channel and wetland monitoring results, periodic maintenance will be conducted including: 1. repair of damaged, eroded, or unstable slopes; 2. removal of excess silt and/or debris; 3. soil treatments; 4. noxious weed control; 5. vegetation protection; 6. supplemental irrigation; 7. supplemental planting and/or seeding; 8. garbage removal; and 9. vandalism damage repair.	CMP, Section 10
Permittee-Responsible Long-Term Management for Restored Channels and Wetlands	Following attainment of performance objectives, the Mitigation Area (i.e., restored streams and wetlands) will be inspected every 10 years in perpetuity by Perpetua Resources or its designated contractor until responsibility is relinquished to an appropriate and approved third party through a conservation easement or similar real estate agreement. The management will include evaluation of: 1. Does the floodplain contain streams, wetland, and riparian areas as originally designed? 2. Do the Mitigation Area floodplains remain free from excessive erosion? 3. Do the vegetation communities in wetlands appear health and remain intact? 4. Do the Mitigation Areas remain free of Idaho-listed noxious weeds? 5. Is signage and placarding in place and legible? 6. Are any trails or viewpoints in good repair and safe? 7. Do the Mitigation Areas remain free of any unintended roads, trails, or camping areas? Excluding any act of God, it will be the responsibility of the conservation easement holder to ensure the Mitigation Area is returned to as near the original design and associated success criteria as possible.	CMP, Sections 5 and 13
Adaptive Management Plan	An adaptive management plan will identify potential reasons the Mitigation Area is failing to meet its objectives, corrective actions to be implemented, and a timeline for completion of adaptive management actions by the party responsible for the Mitigation Area. An initial register of potential restoration risks and adaptive management measures has been incorporated into the Compensatory Mitigation Plan. If it is determined that the original performance measures may not be attainable, new performance measures may be developed based on the site evaluations. Adaptive management will phase out as mitigation measures meet their prescribed performance standards.	CMP, Sections 14 and Appendix E
Financial Assurances	The on-site financial assurance amount will be estimated as part of the reclamation and closure cost estimate for review and acceptance by each stakeholder regulatory agency. The stakeholder agencies will collectively determine which agency will hold and manage the financial assurance. The off-site financial assurance amount will be estimated separately from the on-site reclamation and closure cost estimate. The USACE will approve and hold this financial assurance and will lead or designate the lead agency for the off-site work.	CMP, Sections 15

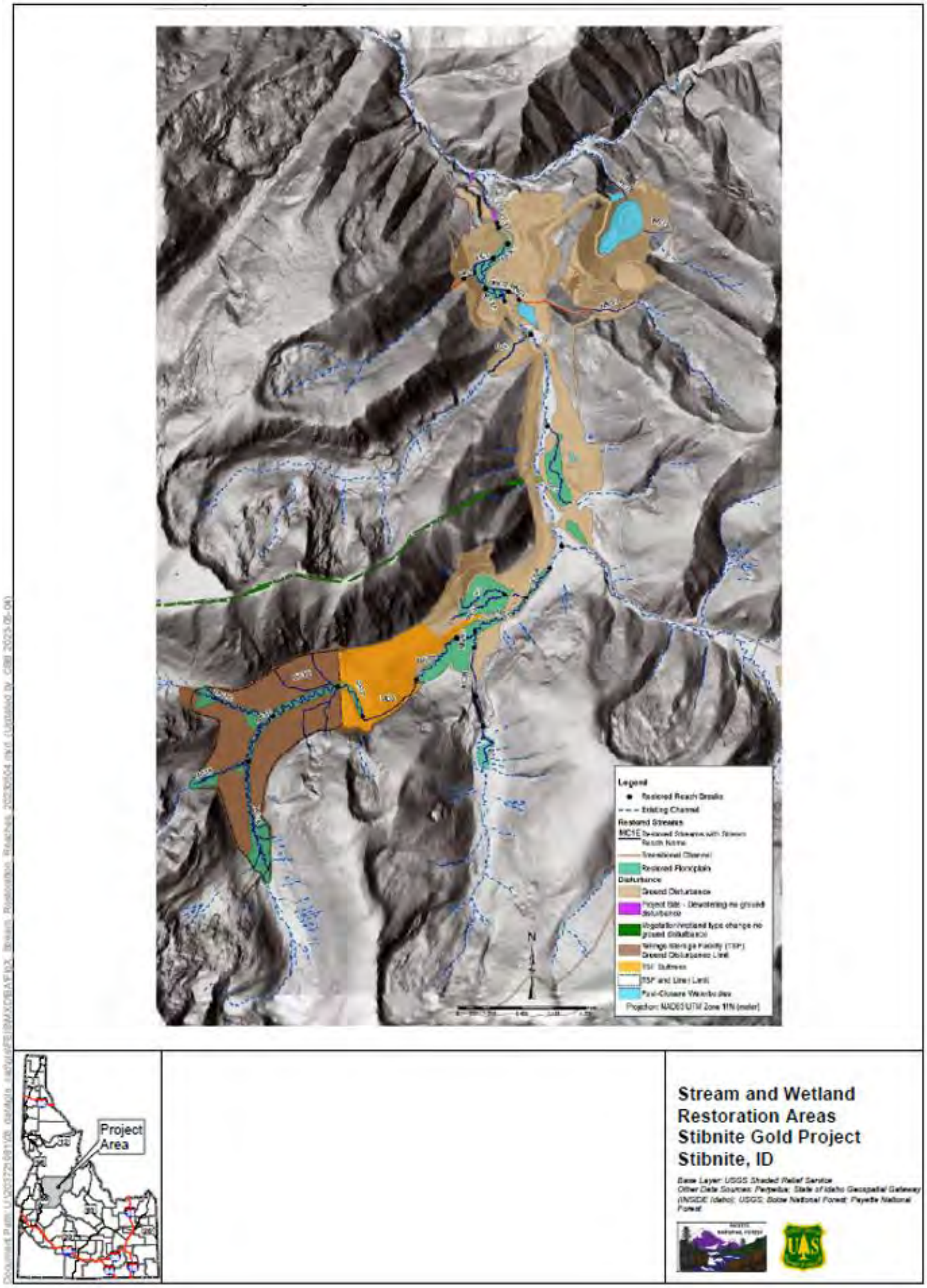


Figure 23. Stream and Wetland Restoration Areas, Stibnite Gold Project.

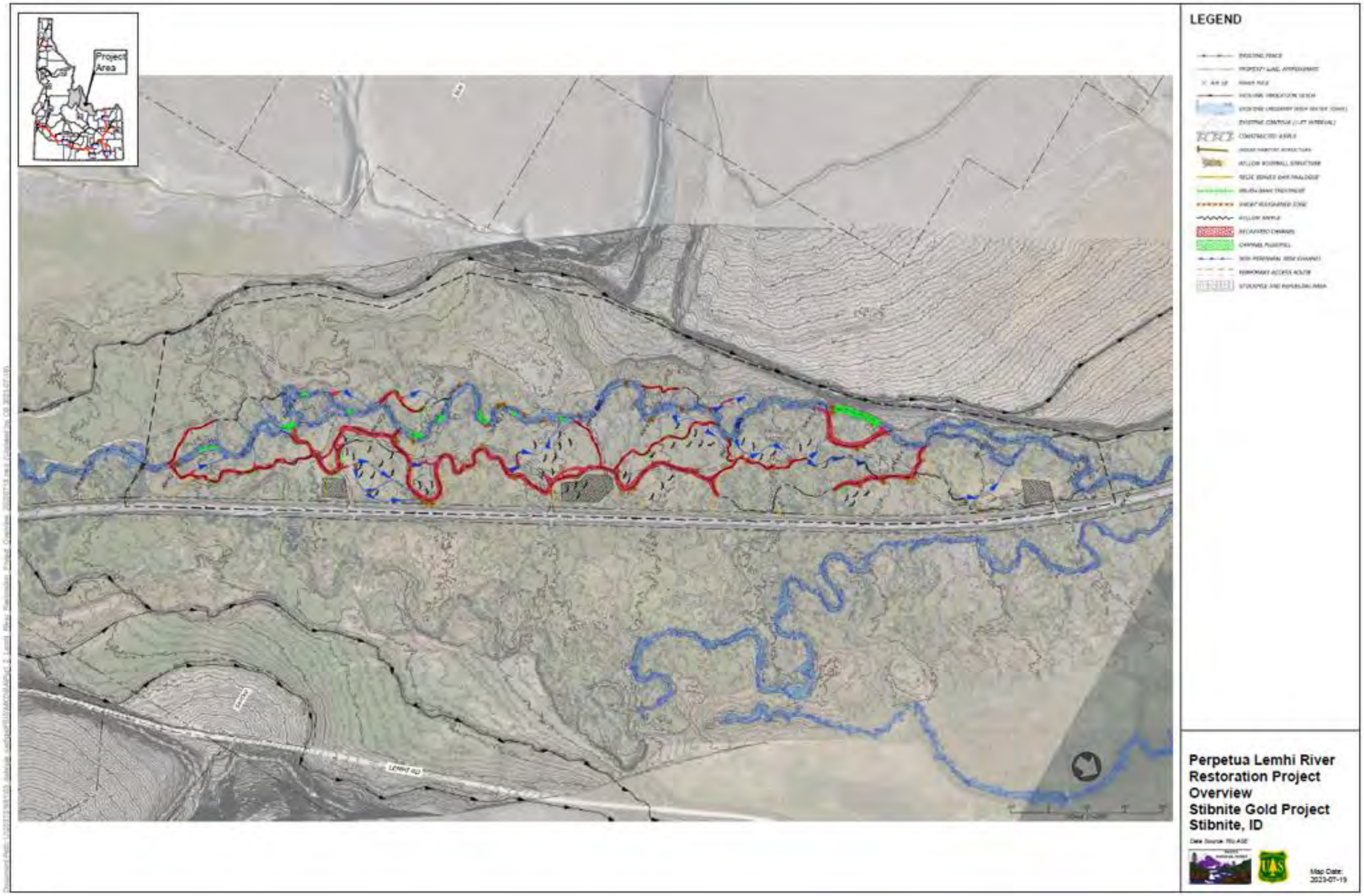


Figure 24. Perpetua Lemhi River Restoration Project Overview, Stibnite Gold Project.

1.11.1. Agency Requirements

Mitigation measures required by the USFS will represent reasonable and effective means to reduce the impacts identified in the resource analysis or to reduce uncertainty regarding the forecasting of impacts into the future. If environmental impacts are inevitable, certain regulatory programs may require compensatory mitigation of the impacts. Any mitigation measures are in addition to the regulatory requirements (Table 22) and Project EDFs (Appendix A) accounted for in the impact analysis.

The Project contains a number of EDFs, operational activities, best practices, mitigation measures, and monitoring plans intended to reduce impacts to the environment. An IARB will be formed to provide oversight for the Project's environmental-related activities including adaptive management. The IARB will consist of all permitting agencies including IDEQ, IDWR, NMFS, USFWS, EPA, Valley County, and the USFS[6].

Member agencies on the IARB will have access to Project design reports, Project as-built drawings, monitoring reports, model updates required by mitigation measures, and any environmental action plans. These agencies will also have the opportunity to provide input where appropriate on Project documentation. Specific construction stage documentation subject to IARB review upon their completion include:

- Construction design of the water treatment plants;
- Construction design of the TSF;
- Construction design of the processing plant facility components;
- Construction design of the Burntlog Route;
- Construction design of the fish tunnel;
- Construction design of the EFSFSR water intake;
- The final Stormwater Pollution Prevention Plan (SPPP);
- The final CMP;
- Monitoring and mitigation plans under the EMMP (including adaptive management); and,
- Engineering as-builts for completed facilities.

1.11.2. Stibnite Gold Mitigation Plan

The basis of the Perpetua's proposed EDFs are impact avoidance and minimization up front or as part of operations. The potential impacts of the SGP remaining after applying the avoidance and minimization measures were addressed by Perpetua on a resource-basis by further avoidance, minimization, and/or compensatory mitigation described in proponent-proposed specific resource mitigation plans. The following mitigation plans have been developed for the SGP:

[6] The proposed action refers in several places to IARB "approval" of several plans and designs. NMFS role in that process will be to provide verification prior to finalization and implementation of plans and designs that will affect ESA-listed species that the effects remain consistent with the effects analysis and extent of take provided in this opinion.

- Stibnite Gold EMMP (Brown and Caldwell 2021d);
- Fisheries and Aquatic Resources Mitigation Plan (Brown and Caldwell, Rio ASE, and BioAnalysts 2021);
- Fishway Operations and Management Plan (FOMP) (Brown and Caldwell, McMillen Jacobs Associates, and BioAnalysts 2021);
- Compensatory Mitigation Plan (Tetra Tech 2023).
- Snow Avalanche Hazard Assessment for Access Roads (DAC 2021);
- Development Rock Management Plan (Brown and Caldwell 2022);
- Environmental Legacy Management Plan (Perpetua 2021c);
- Reclamation Closure Plan (Tetra Tech 2021);
- Transportation Management Plan (Perpetua 2022);
- Water Management Plan (Brown and Caldwell 2021b);
- Water Resources Monitoring Plan (Brown and Caldwell 2021c); and,
- 404 permit application including a draft CMP (Perpetua 2023).

Below is a brief discussion of the FMP, FOMP, CMP, and the Lemhi Restoration Project. The Water Resources Monitoring Plan was described in section 1.10.1.1.

Perpetua will integrate all required USFS and USACE requirements and mitigation commitments into the current draft EMMP (Brown and Caldwell 2021c). This EMMP consists of a program framework and appendices containing component monitoring and management plans. Perpetua will use the EMMP to guide monitoring, document permit compliance, implement impact reduction procedures, and address adaptive management thresholds and responses where impacts and mitigation effectiveness carry substantial uncertainty.

1.11.2.1. **Fisheries and Aquatic Resources Mitigation Plan**

Perpetua's FMP (Brown and Caldwell, Rio ASE, and BioAnalysts 2021) describes the measures that Perpetua has proposed to minimize adverse impacts on fisheries and aquatic resources. Additional details regarding how these plans address specific activities and impacts are also summarized in Appendix B of the BA (Stantec 2024).

The FMP actions will begin during construction and continue throughout mine operations and into closure and reclamation. The FMP includes water quality protection; fish protection, salvage, and relocation during diversions and dewatering activities; a process of protection and salvage for draining of the YPP; measures to avoid impacts during blasting; monitoring streamflow; restoring passage in stream channels with fish passage impediments; and monitoring of fish and aquatic biota. The FMP and its components will continue to be refined in consultation with natural resource and regulatory agencies.

1.11.2.2. **Fishway Operations and Management Plan**

Perpetua has proposed a fishway for upstream and downstream passage of anadromous and migratory fish in the EFSFSR during construction and mine operations, to be part of the tunnel that diverts the EFSFSR around the YPP. Additional details regarding how these plans address specific activities and impacts are also summarized in Appendix B of the BA (Stantec 2024).

Perpetua's FOMP (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021) outlines the operation of the fishway and monitoring for effective fish passage as well as an adaptive approach to provide for fish trap and haul operations as an alternative, using the same facilities consistent with 2022 NMFS guidelines for fish passage. Fish protection measures for the EFSFSR tunnel and YPP dewatering are outlined as well, such as a temporary fish barrier downstream of the YPP during tunnel construction carefully sequenced dewatering of the YPP, and start of fishway operations.

Measures to avoid and minimize impacts to fish habitat are detailed in the FMP and FOMP (Brown and Caldwell, Rio ASE, and BioAnalysts 2021; Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021). These measures include the following:

- Water quality protection - measures designed on managing contact and non-contact water to maintain and improve water quality while supplying sufficient water for mining and ore processing. Diversions, ditches, and other mine facilities will be lined and/or water collected and treated to protect water quality. Riparian corridors will be restored and enhanced, and certain diversions piped, to reduce stream temperatures. Water treatment will continue during both operations and the post-closure phase.
- Fish protection, salvage, and relocation during dewatering and diversions - measures for screening or excluding of fish from diversion channels, water withdrawals, low-flow pipes, and the YPP dewatering to exclude and protect fish. Work windows have been developed based on fish periodicity to account for the different life stages of the targeted fish species. During diversions and dewatering activities in fish bearing streams, fish handling and salvage protection measures have been identified to safely isolate, collect, handle, and transport the fish.
- Instream work window has been established to protect spawning and incubation. The instream work window is from May 1 to August 1, providing there are no incubating eggs (i.e., redds) within the construction area. If incubating eggs are present, the work window will be from June 15 to August 1. September 15 to April 30 could be an alternate work window that will avoid spawning adults and minimize impacts to juveniles as long as there is no documented spawning and therefore no incubation occurring in the affected stream section.
- Trap and haul protocols at the fishway (if needed) - the primary goal is operating and maintaining the EFSFSR fishway during construction and operations, and later in the mine life by restoring the EFSFSR stream channel over the backfilled YPP to provide permanent, volitional upstream and downstream fish passage and access to important stream habitats of the upper EFSFSR and portions of Meadow Creek. If fish are not able to use the fishway during any period, trap and haul procedures have been developed to safely collect, handle, and move fish upstream of the fishway. Details regarding the proposed use of trap and haul were described in Appendix C of the FOMP (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021), operating as follows:
    - Trap and haul will only be used when deemed necessary to avoid further delay of adult passage near or during the spawning period. At one week prior to the spawning period, if adults present in the resting pool below the fishway have not entered the fishway over a 48-hour period and proceeded up the fishway they will be collected and transported upstream without further delay.

- The migration period (i.e., Chinook Salmon: Jul. 7 – Sep. 15; Steelhead: Apr 1. – May 31); will be monitored via fishway video and Passive Integrated Transponders (PIT) tag detections in the fishway. In addition, environmental staff will also provide input on visual observations of adults near the fishway entrance. Arrivals at the fishway and redd surveys will be conducted to refine migration and spawning periods of fish passing the EFSFSR tunnel. Information will be presented annually to the IARB and periods of migration and spawning will be adjusted as needed.
  - Fish will be crowded within the first fishway pool with removable picket panels and netted with a large sanctuary dip net. Once in the sanctuary dip net, fish will be removed and placed into a wetted transfer boot to move fish from the capture pool to the transport tank. Water-to-water transfer is the goal.
  - If necessary, trap and haul is only expected to occur once per day but may occur twice if target species need to be separated (i.e., bull trout and Chinook salmon) or there is sufficient fish onsite that require more than one transport.
- Avoidance measures during blasting activities - measures to largely avoid or minimize the potential effects from blasting activities using appropriate setback distances from aquatic habitats to limit blast-related air overpressure and ground vibrations to harmless levels. Other additional blasting techniques can also be used to reduce these levels, and BMPs and site-specific modification of methods can further minimize or prevent damage to fish and the aquatic environment.
- Monitoring streamflow - activities for maintaining, to the extent practicable, appropriate streamflows and streamflow monitoring in natural or restored channels where fish are present.
- Stream restoration and enhancement - design elements for stream restoration and enhancement based on natural channel design principles intended to restore permanent fish passage at YPP, improve fish habitat site-wide for spawning and rearing salmonids, and provide a net ecological benefit relative to current conditions.
- Restoring passage in stream channels - removing existing passage barriers within the mine site to allow for fish movement between streams and areas of the mine site where access is currently blocked or impeded within the SGP footprint as well as along the Burntlog Route.
- Monitoring fish and aquatic biota - provide the data necessary to evaluate how the various mitigation and protection measures are implemented, and to assess the status and trends and ongoing effectiveness. To address the potential for variances in the outcome of these measures, an adaptive management approach is outlined that will provide the mechanism to modify or adjust these measures or approaches in response to monitoring and evaluation as well as new information or technologies that may become available over the more than 20 years of construction, mining, reclamation, and restoration.

When diverting and restoring stream channels, cofferdams will isolate portions of the stream channel slated for restoration within the existing ordinary high-water mark (OHWM) to keep water and fish out of the new channel until construction is completed. Once the new channel is completed (including prewashing the substrate), water will be slowly reintroduced into the new channel (one-third of the flow initially), with seine block nets keeping fish from entering the new channel. Seine block nets will be placed in the upstream end of the original channel, which will then be electrofished to remove all fish before all flow can be rerouted into the new channel. Any fish captured will be moved upstream of the seine block net. Once the original channel is cleared, two-thirds of the flow will be released into the new channel, and then ultimately all flow will be released into the new channel and the seine block net to the new channel removed. The original channel will be permanently blocked from the new channel and then filled with clean native alluvium as the new floodplain. Steps for isolating the stream channel include:

- Temporary cofferdams placed between the actively flowing river surface water and all active work areas. Temporary cofferdams may be placed at additional locations to achieve required water quality standards, or to simplify construction determined by the contractor.
- Fill material for bulk bags or 'super sacks," if used, shall be clean, washed, and rounded material similar in gradation to existing channel substrate, and not contain fines. Material must be approved before use.
- Cofferdams and diversion dams must be built in a manner to meet turbidity limits as defined in the project specifications. Use of gravel and soil to build a pushup type cofferdam or flow diversion dam are acceptable at all locations not connected to surface water flow but will not be allowed in the actively flowing channel.

When reintroducing water to dewatered areas and newly constructed channels, a staged rewatering plan will be applied. The following will be applied to all rewatering efforts:

- Turbidity monitoring protocol will be applied to rewatering effort.
- Pre-wash the area before rewatering. Turbid wash water will be detained and pumped to the floodplain or sediment capture areas rather than discharging to fish-bearing channels.
- Install seine nets at upstream end to prevent fish from moving from downstream until 2/3 of the total flow is restored to the channel.
- Starting in early morning, introduce 0.33 of new channel flow over period of 1 to 2 hours.
- Introduce second third of flow over the next 1 to 2 hours and begin fish salvage of bypass channel if fish are present.
- Remove upstream seine nets once 2/3 flow in rewatered channel and downstream turbidity is within acceptable range (less than 40 NTU) or less than 10 percent of the background condition).
- Introduce final third of flow once fish salvage efforts are complete, and downstream turbidity verified to be within acceptable range.
- Install plug to block flow into old channel.
- Follow same steps when rewatering mainstem.

Turbidity monitoring will include:

- Record turbidity reading, location, and time for background reading approximately 100 ft. upstream from the project area using a recently calibrated turbidimeter or via visual observation.

- Record the turbidity reading, location, and time at the measure compliance location point.
    - 50 ft. downstream for streams less than 30 ft. wide;
    - 100 ft. downstream for streams between 30 and 100 ft. wide; and,
    - 200 ft. downstream for streams greater than 100 ft. wide.
- Turbidity will be measured (background location and compliance point) every 4 hours while work is being implemented.
- If exceedances occur for more than two consecutive monitoring intervals (after 8 hours), the activity will stop until the turbidity level returns to background. The Idaho Office of Species Conservation (OSC) will be notified for all exceedances and corrective actions at project completion.
- If turbidity controls (cofferdams, wattles, fencing, etc.) are determined ineffective, crews will be mobilized to modify, as necessary. Occurrences will be documented in the project daily reports.

1.11.2.3. **Compensatory Mitigation Plan**

Construction of the SGP will permanently impact wetlands and other WOTUS subject to regulation under Section 404 of the CWA and requires a USACE permit pursuant to Section 404. Perpetua's CMP (Tetra Tech 2023) provides detailed descriptions of proposed restoration, establishment, enhancement, and/or preservation of aquatic resources to compensate for unavoidable impacts to WOTUS associated with activities that will be authorized by a USACE permit. Additional details regarding how these plans address specific activities (Table 24) and impacts, including protection measures, are summarized in BA Appendix B. The CMP can be updated and revised until the USACE has determined all mitigation requirements. The CMP demonstrates the feasibility of achieving the amount and types of mitigation to offset the impacts in a manner consistent with the 2008 Mitigation Rule. The CMP provides detailed descriptions of proposed restoration, establishment, enhancement, and/or preservation of aquatic resources to compensate for unavoidable impacts to WOTUS associated with activities that will be authorized by a USACE permit (Tetra Tech 2023).

Table 24. 404 Permit Activities.

5th Order (HUC 10)	Delineated Streams (Linear Feet within Project Footprint)	Delineated Wetlands (Acres within Project Footprint)	Other-Native Soil and Rock to be discharged below the ordinary high-water mark and/or wetlands (cubic yards)	Impacts to Water of the United States – Filling (cubic yards)	Impacts to Water of the United States – Land Clearing (acres)	Impacts to Water of the United States – Excavation (cubic yards)	Impacts to Water of the United States – Draining (acres)
Lake Fork Creek – North Fork Payette River (1705012302)							
Stream	648.43	-	778.19	-	0.15	-	-
Wetland	-	0.58	1,397.50	-	0.58	-	-
Sub-Total			2,175.69	-	0.73	-	-
Gold Fork River (1705012303)							
Stream	-	-	-	-	-	-	-
Wetland	-	0.57	1,386.19	-	0.57	-	-

5th Order (HUC 10)	Delineated Streams (Linear Feet within Project Footprint)	Delineated Wetlands (Acres within Project Footprint)	Other-Native Soil and Rock to be discharged below the ordinary high-water mark and/or wetlands (cubic yards)	Impacts to Water of the United States – Filling (cubic yards)	Impacts to Water of the United States – Land Clearing (acres)	Impacts to Water of the United States – Excavation (cubic yards)	Impacts to Water of the United States – Draining (acres)
Sub-Total			1,386.19	-	0.57	-	-
Cascade Reservoir (1705012304)							
Stream	742.55	-	530.82	-	0.11	-	-
Wetland	-	0.05	112.32	-	0.05	-	-
Sub-Total			643.15	-	0.15	-	-
Big Creek – North Fork Payette River (1705012305)							
Stream	7,778.11	-	4,601.46	-	1.14	28.73	-
Wetland	-	5.99	14,491,62	-	5.99	-	-
Sub-Total			19,093.08	-	7.13	28.73	-
Johnson Creek (1706020801)							
Stream	19,271.19	-	7,106.05	462.49	3.68	90.96	-
Wetland	-	16.66	40,306.53	14,735.78	10.57	-	-
Sub-Total			47,412,58	15,198.26	14.24	90.96	-
Upper East Fork South Fork Salmon River (1706020802)							
Stream	74,583.76	-	50,310.09	28,756.06	8.11	0.53	2,606.79
Wetland	-	121.39	207,551.08	11,103.58	97.49	45,816.30	0.38
Sub-Total			257,861.16	39,859.64	105.59	45,816.83	2,607.17
Upper South Fork Salmon River (1706020804)							
Stream	8,713.46	-	7,478.19	-	1.12	103.06	-
Wetland	-	5.22	12,624.13	-	5.22	-	-
Sub-Total			20,102.33	-	6.33	103.06	-
Grand Total	**111,737.49**	**150.45**	**348,674.18**	**55,057.90**	**134.76**	**46,072.58**	**2,607.17**

The CMP describes mitigation to address the requirements of the USACE and EPA under the Compensatory Mitigation for Losses of Aquatic Resources under CWA Section 404 (Final Rule) (USACE and EPA 2008). The CMP includes the 12 required elements of compensatory mitigation plans (33 CFR 332.4(c)/40 CFR 230.94(c)): objectives; maintenance plan; site selection; performance standards; site protection; monitoring requirements; baseline information; long-term management plan; determination of credits; adaptive management plan; mitigation work plan; and financial assurances.

The activity authorized under the 404 permit is summarized in Table 24. The CMP will be revised as appropriate by the USACE Regulatory Division—Walla Walla District, Boise Field Office, in compliance with the CWA Section 404/DA permit, stream and wetland delineations and jurisdictional determinations, development of the stream functional assessment for USACE-approved stream functional analysis, wetland and stream credits and debits determinations, and compliance with USACE's 404(b)(1) Guidelines (40 CFR Part 230).

1.11.2.4. **Perpetua Lemhi River Restoration Project**

Perpetua has proposed the LRLT's Little Springs Conservation Easement and Restoration Project in an effort to use offsite mitigation to offset temporal losses to fish habitat in the SFSR drainage (Figures 2 and 23). The LRLT is negotiating a perpetual conservation easement for the property to ensure the restoration benefits and associated mitigation credits persist for at least the length of the predicted temporal loss for the SGP (Tetra Tech 2023). This project reach is located on private ranch lands on the upper Lemhi River, approximately 12 miles northwest of Leadore, Idaho. The project reach extends approximately 7,000 ft. from RM 42.63 to RM 41.32 of the mainstem Lemhi River on the west side of SH 28 (Rio ASE 2023).

The primary goals of the Lemhi Project (Figure 24) are to improve habitat for limiting life stages of ESA-listed fish species (i.e., pre-smolts (over-winter rearing), parr (summer rearing), adult (spawning and holding), and parr (high flow refugia), and to restore natural stream channel processes to maintain diverse habitat over time (Rio ASE 2023). Improving stream habitat conditions are intended to help increase fish population abundance, productivity, and spatial structure. Specific Lemhi Project targets are:

- Increase habitat quality and complexity (especially for juvenile life stages) by creating multi-threaded channels and connected off-channel habitat.
- Reduced W:D where the channel is over-widened to increase hydraulic complexity, floodplain connection, pool scour potential, shade, cover, and natural channel-forming processes.
- Increased frequency, duration, and area of floodplain connection to provide high flow refugia for rearing juveniles and to improve fine sediment distribution, groundwater recharge, floodwater storage, and nutrient cycling.
- Increased instream structure, hydraulic diversity, and more variable instream velocity.
- Increased pool quantity, frequency, and complexity.
- Surface/groundwater interchange to moderate instream temperature and provide areas of localized temperature refuge.
- Increased instream cover and interstitial space along margins for rearing life stages and for adult holding and cover leading up to and during spawning.
- Creation of a riparian corridor to increase shade, provide overhead cover, stabilize banks, provide instream structure, and increase LWD recruitment potential.

Lemhi Project elements targeting these objectives are presented below and illustrated on Figure 24 and Appendix D, Figures D-1 to D-22:

- Develop a multi-threaded channel network of 12,426 ft. (2.35 mi.) perennial and non-perennial side channels and 4,965 ft. (0.94 mi.) of non-perennial tertiary channels through excavation of new channels and pilot channels to target flow into existing low areas. Tertiary channels are low depressions in the ground surface or relic channels disconnected from the mainstem that will largely exist or be constructed to convey surface water seasonally, and as such, will involve little to no excavation and/or treatment resulting in natural evolution with variable outcomes (i.e., some tertiary channels may develop into perennial side channels while the remainder become abandoned).

- Install large and small woody material (e.g., beaver dam analogues, robust beaver dams, apex log and bleeder jams, etc.) to promote in-channel complexity, force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity), and provide concealment cover for juvenile salmonids.
- Add floodplain roughness structures (e.g., logs, willow clumps, and slash) to provide high flow refugia, accommodate future channel dynamics, and promote lateral channel migration while maintaining a multi-threaded and sinuous channel character.
- Increase frequency of floodplain activation through channel constriction, blocking, and appropriate channel sizing of new channels and resizing of existing channel(s).
- Revegetation by means of planting native species within the riparian zone and transplanting local vegetation harvested near the Lemhi Project site; existing, mature riparian vegetation is limited within the Lemhi Project vicinity and will be preserved and used as floodplain roughness and/or bank roughness where available and appropriate.

This project will reconnect and/or create a series of interconnected perennial and non-perennial side channels and wetland complexes within a broad floodplain area that has been previously impacted by land use alterations, riparian vegetation clearing, levees, and grazing. The existing, single-threaded Lemhi River channel will be bifurcated and obstructed using natural materials at multiple locations to force flow into relic channels on the floodplain (Tetra Tech 2023). The amount of excavation is expected to range from full channel excavation similar to the mainstem, to small pilot channels connecting adjacent relic channels, to no excavation where channel geometry and conditions allow. Tertiary channels (i.e., low depressions or relic channels disconnected from the mainstem) that largely exist or will be constructed to convey surface water seasonally (primarily non-perennial). Little to no excavation and/or treatment is proposed for these channels, which are expected to evolve naturally over time with variable outcomes. Some tertiary channels may develop into perennial side channels while others may become abandoned. (Rio ASE 2023).

Riparian vegetation in conjunction with relic channel scars throughout the floodplain provide the framework upon which the multi-threaded channel network will be restored. The strategy for restoration therefore includes removing levees and areas of high ground to reconnect relic flow paths, while also narrowing and raising the existing mainstem channel to reduce its conveyance and force flow into the newly reconnected secondary channels and floodplain. The strategy employs both active and passive restoration, whereby excavation would be used (active restoration) to cut areas of high ground and fill portions of the existing channel. Likewise, woody debris and beaver dams will be actively installed to obstruct flow and provide instream habitat. The newly activated secondary channels and floodplain will also scour and create new channels over time (i.e., passive restoration) with riparian vegetation providing structure and habitat. The elevated groundwater table will also facilitate more rapid and expansive riparian vegetation reestablishment, which will improve channel evolution and associated development of complex habitat over time, including the maintenance of a narrow W:D, bank stabilization, and promotion of scour pool development. Improved riparian vegetation will also provide a food source for upland species and beaver and improve nutrient cycling in the river (Rio ASE 2023).

Large woody material structures are proposed in the main channel, side channels, and floodplain to provide roughness and habitat throughout the project area. There are a variety of proposed structures that will consist of key log members that act as the skeleton of the structure. The structure will then be completed with the addition of woody racking material and slash. These structures are intended to emulate natural log jams, and therefore these materials will not be permanently locked or fixed in place; pieces may move throughout the project reach as flows peak (Rio ASE 2023).

Construction is scheduled to be completed by MY -2 (Tetra Tech 2023), and will be staged so that the new channel will be created first. Once the new channel is completed, the channel will be 'pre-washed' into a reach equipped with sediment capture devices prior to the introduction of flow into the new channel. After this stage is completed, the Lemhi River bank will be breached and flow will be rerouted into the side channel. A cofferdam will be installed to block the flow in the mainstem so work can occur in the mainstem with no active flow. As flows are reintroduced to the Lemhi and other created channels, gravels will be 'pre-washed' in an effort to control turbidity (Stantec 2024).

Any topsoil and native channel material displaced by construction will be stockpiled away from the channel for use during site restoration. When construction is finished, all streambanks, soils, and vegetation will be cleaned and restored as necessary using stockpiled topsoil and native channel material to renew ecosystem processes that form and maintain productive habitats (Stantec 2024).

Fish will not have access to the construction area during construction activities. The Lemhi project will be conducted so that no work will occur in the flowing channel to minimize or avoid impacts caused by sediment and turbidity, changes to water quality (spills risk or chemical contaminants), and noise and vibration. There will be no physical barriers created or removed in the Lemhi Analysis Area other than the cofferdam to block or redirect flows depending on the construction stage. Staging construction so side channels are created before restoring the main channel is key to reducing the impacts. The text below describes the process that will be taken to avoid working in-water.

Work areas will be isolated for performing work within the in-water work window (first quarter of July (Q1) through the third quarter of August (Q3). Cofferdams will be placed within the existing Lemhi River channel to isolate areas for excavated connections between the existing and new channel. The new channel will then be activated, and additional cofferdams will be required to complete filling of the existing Lemhi River channel and installation of wood habitat structures.

Cofferdams will isolate portions of the proposed channel within the existing OHWM to keep water and fish out of the new channel until construction is completed. Once the new channel is completed (including prewashing the substrate), water will be slowly reintroduced into the new channel (one-third of the flow initially), with seine block nets keeping fish from entering the new channel. Seine block nets will be placed in the upstream end of the original channel, which will then be electrofished to remove all fish before all flow can be rerouted into the new channel. Any fish captured will be moved upstream of the seine block net. Once the original channel is cleared, two-thirds of the flow will be released into the new channel, and then ultimately all flow will be released into the new channel and the seine block net to the new channel removed. The original channel will be permanently blocked from the new channel and then filled with clean native alluvium as the new floodplain. The steps for staged dewatering include:

- Temporary cofferdams placed between the actively flowing river surface water and all active work areas. Temporary cofferdams may be placed at additional locations to achieve required water quality standards, or to simplify construction determined by the contractor.
- Fill material for bulk bags or 'super sacks", if used, shall be clean, washed, and rounded material similar in gradation to existing channel substrate, and not contain fines.
- Cofferdams and diversion dams must be built in a manner to meet turbidity limits as defined in the project Specifications. Use of gravel and soil to build a pushup type cofferdam or flow diversion dam are acceptable at all locations not connected to surface water flow but will not be allowed in the actively flowing channel.

Staged Re-watering – when reintroducing water to dewatered areas and newly constructed channels, a staged re-watering plan will be applied. The following will be applied to all re-watering efforts:

- Turbidity monitoring protocols will be applied to the re-watering effort.
- The area will be pre-washed before re-watering. Turbid wash water will be detained and pumped to the floodplain or sediment capture areas rather than discharging to fish-bearing channels.
- Seine nets will be installed at the upstream end to prevent fish from moving from downstream until 2/3 of the total flow is restored to the channel.
- Starting in early morning, 1/3 of the new channel flow will be introduced over a period of 1 to 2 hours.
- The second third of flow will be introduced over the next 1 to 2 hours and fish salvage of the bypass channel will begin if fish are present.
- Upstream seine nets will be removed once 2/3 flow in the re-watered channel and downstream turbidity is within an acceptable range (less than 40 NTU or less than 10 percent of the background condition).
- The final third of flow will be introduced once fish salvage efforts are complete, and downstream turbidity verified to be within acceptable range.
- A plug will be installed to block flow into the old channel.
- The same steps will be followed when re-watering the mainstem.

Turbidity monitoring will include:

- Record turbidity reading, location, and time for background reading approximately 100 feet upstream from the project area using a recently calibrated turbidimeter or via visual observation.
- Record turbidity reading, location, and time at the measure compliance location point, located as follows.
    - 50 feet downstream for streams less than 30 feet wide;
    - 100 feet downstream for streams between 30 and 100 feet wide;
    - 200 feet downstream for streams greater than 100 feet wide.
- Turbidity will be measured (background location and compliance point) every 4 hours while work is being implemented.
- If exceedances occur for more than two consecutive monitoring intervals (after 8 hours), the activity will stop until the turbidity level returns to background. The OSC will be notified for all exceedances and corrective actions at project completion.
- If turbidity controls (cofferdams, wattles, fencing, etc.) are determined ineffective, crews will be mobilized to modify, as necessary. Occurrences will be documented in the project daily reports.

Additional details regarding the Lemhi Project are described in Appendix D.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not.

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their DCH. Per the requirements of the ESA, federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes RPMs and terms and conditions to minimize such impacts.

The PNF and USACE determined the proposed action is not likely to adversely affect SRKW and its DCH. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.13).

2.1. Analytical Approach

This opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is “to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species” (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This opinion also relies on the regulatory definition of “destruction or adverse modification,” which “means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species” (50 CFR 402.02).

The designations of critical habitat for SR spring/summer Chinook salmon and SR Basin steelhead use the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced these terms with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term “consequences” (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this opinion, we use the terms “effects” and “consequences” interchangeably.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their critical habitat using an exposure–response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species; or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative (RPA) to the proposed action.

This opinion relies on a series of assumptions for this analysis. Deviation from these assumptions may fall outside the scope of this consultation and may trigger subsequent ESA review. NMFS’ assumptions include:

- Exploration for additional ore reserves is anticipated to continue through the life of the SGP operations. If additional ore tonnage is identified and defined, the production life of the SGP may be extended beyond the currently proposed mine life schedule. Any such extension and the associated operations and effects are beyond the scope of this consultation.
- The proposed action states that Perpetua will use the same or similar drilling methods and environmental protection measures that have been employed for exploration drilling in the past (i.e., exploration under the Golden Meadows Exploration Plan). Therefore, NMFS assumes that all environmental protection measures from the Golden Meadows Exploration Plan including, but not necessarily limited to, those specified in Appendix B will be employed.
- Noxious weed and invasive species plant control will be conducted according to methods approved in the 2020 Programmatic Activities Biological Opinion (PNF 2020). Therefore, NMFS assumes that all environmental protection measures associated with herbicide use including, but not necessarily limited to, those specified in Appendix C will be employed.
- Because Perpetua will alternatively use trap and haul to get fish upstream of the YPP cascade should tunnel passage not work as designed, NMFS assumes that ESA-listed salmonids will have access and be present in stream segments upstream of the cascade beginning in MY -1, whether the tunnel functions as intended or not.
- No untreated contact water at the ground surface (e.g., pond overflow or failures in contact water collection) will be discharged directly into surface waters.
- The SWWC model outputs represent the best available information regarding the predicted contaminant concentrations in surface waters resulting from project implementation.
- Mixing zones for IPDES discharges of pollutants will not be authorized; IPDES-authorized discharges will be required to meet end-of-pipe limits.
- A rigorous effectiveness monitoring program will be finalized with input from the IARB and implemented as designed. This program will have sufficient monitoring components to provide for early detection of unanticipated environmental impacts in surface waters.
- An effective adaptive management plan will be finalized with input from the IARB and adequate financial commitments (financial bonding) will be adhered to.
- The percent change in stream flow information presented in Table 4.1-35 of the BA are accurate and are based on the average net effect of the proposed action on flow rates in affected stream reaches.
- Riparian revegetation efforts will be successful, shade reductions assumed in the SPLNT model will be achieved, and predicted maximum weekly maximum stream temperatures will not be exceeded. If shade reductions are not realized or if actual stream temperatures are greater than predicted at any time during project implementation (including closure and post-closure), effective adaptive management actions will be implemented to reduce stream temperatures.

2.2. Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" for the jeopardy analysis. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds. The Federal Register notices and notice dates for the species and critical habitat listings considered in this opinion are included in Table 25.

Table 25. Listing status, status of critical habitat designations and protective regulations, and relevant Federal Register decision notices for ESA-listed species considered in this opinion.

Species	Listing Status[1]	Critical Habitat[2]	Protective Regulations
Chinook salmon (*Oncorhynchus tshawytscha*)			
Snake River spring/summer-run	T 4/22/92; 57 FR 14653	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160
Steelhead (*O. mykiss*)			
Snake River Basin	T 8/18/97; 62 FR 43937	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160

Note: Listing status 'T' means listed as threatened under the ESA.
[1]The listing status for Snake River spring/summer Chinook salmon was corrected on 6/3/92 (57 FR 23458).
[2]Critical habitat for Snake River spring/summer Chinook salmon was revised on 10/25/99 (64 FR 57399).

2.3. Status of the Species

This section describes the present condition of the SR spring/summer Chinook salmon evolutionarily significant unit (ESU), and the SR Basin steelhead distinct population segment (DPS). NMFS expresses the status of a salmonid ESU or DPS in terms of likelihood of persistence over 100 years (or risk of extinction over 100 years). NMFS uses McElhany et al.'s (2000) description of a viable salmonid population (VSP) that defines "viable" as less than a 5 percent risk of extinction within 100 years and "highly viable" as less than a 1 percent risk of extinction within 100 years. A third category, "maintained," represents a less than 25 percent risk within 100 years (moderate risk of extinction). To be considered viable, an ESU or DPS should have multiple viable populations so that a single catastrophic event is less likely to cause the ESU/DPS to become extinct, and so that the ESU/DPS may function as a metapopulation that can sustain population-level extinction and recolonization processes (ICTRT 2007). The risk level of the ESU/DPS is built up from the aggregate risk levels of the individual populations and major population groups (MPGs) that make up the ESU/DPS.

Attributes associated with a VSP are: (1) abundance (number of adult spawners in natural production areas); (2) productivity (adult progeny per parent); (3) spatial structure; and (4) diversity. A VSP needs sufficient levels of these four population attributes in order to: safeguard the genetic diversity of the listed ESU or DPS; enhance its capacity to adapt to various environmental conditions; and allow it to become self-sustaining in the natural environment (ICTRT 2007). These viability attributes are influenced by survival, behavior, and experiences throughout the entire salmonid life cycle, characteristics that are influenced in turn by habitat and other environmental and anthropogenic conditions. The present risk faced by the ESU/DPS informs NMFS' determination of whether additional risk will appreciably reduce the likelihood that the ESU/DPS will survive or recover in the wild.

The following sections summarize the status and available information on the species and DCHs considered in this opinion based on the detailed information provided by the *ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon & Snake River Basin Steelhead* (NMFS 2017); *Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest* (Ford 2022); *2022 5-Year Review: Summary & Evaluation of Snake River Spring/Summer Chinook Salmon (NMFS 2022b)*; and *2022 5-Year Review: Summary & Evaluation of Snake River Basin Steelhead (NMFS 2022c)*. These documents are incorporated by reference here. Additional information that has become available since these documents were published is also summarized in the following sections and contributes to the best scientific and commercial data available.

2.4. Snake River Spring/Summer Chinook Salmon

A summary of the current status of the Snake River spring/summer Chinook salmon ESU can be found on NMFS' publicly available intranet site (https://www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-spring-summer-chinook-salmon-july-2024.pdf), and is incorporated by reference here (NMFS 2024a). Overall, the species is at a moderate-to-high risk of extinction within the next 100 years. The SFSR and Upper Salmon River are two of the five MPGs that make up the ESU. Populations that may be affected by the proposed action include: EFSFSR, SFSR, and Lemhi River (Table 26) (3 of 28 extant populations in the ESU). To achieve recovery, all MPGs in the ESU must be viable. In order for the MPG to be viable, it must be comprised of multiple, relatively nearby, highly viable, viable, and maintained populations. Neither the SFSR MPG nor the Upper Salmon River MGP are viable. To support MGP viability and to achieve recovery of the species, the EFSFSR population must be maintained, and the SFSR and Lemhi River populations must reach viable status.

Table 26. Summary of Viable Salmonid Population (VSP) parameter risks and overall current status and proposed recovery goals for populations of Snake River spring/summer Chinook salmon that may be affected by the action.

MPG	Population	VSP Risk Rating[1]		Viability Rating[1]	
		Abundance/ Productivity	Spatial Structure/Diversity	2022 Assessment	Proposed Recovery Goal[2]
South Fork Salmon River	South Fork Salmon River	High	Moderate	High Risk	Viable
	East Fork South Fork Salmon River	High	Low	High Risk	Maintained
Upper Salmon River	Lemhi River	High	High	High Risk	Viable

1Risk ratings are defined based on the risk of extinction within 100 years: High = greater than or equal to 25 percent; Moderate = less than 25 percent; Low = less than 5 percent; and Very Low = less than 1 percent.
2There are several scenarios that could meet the requirements for ESU recovery (as reflected in the proposed goals for populations in Oregon and Washington). What is reflected here for populations in Idaho are the proposed status goals selected by NMFS and the State of Idaho.

2.5. Snake River Basin Steelhead

A summary of the current status of the SR Basin steelhead DPS can be found on NMFS' publicly available intranet site (https://www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-basin-steelhead-july-2024.pdf), and is incorporated by reference here (NMFS 2024b). Overall, available information suggests that SR Basin steelhead continue to be at a moderate risk of extinction within the next 100 years. The Salmon River MPG is one of six MPGs that make up the DPS. To achieve recovery, all MPGs in the ESU must be viable. In order for the MPG to be viable, it must be comprised of multiple, relatively nearby, highly viable, viable, and maintained populations. The Salmon River MPG is comprised of twelve of the 24 extant populations in the DPS. Populations that may be affected by the proposed action include: the SFSR and the Lemhi River populations (Table 27) (2 of 24 extant populations in the DPS). To support MPG viability and to achieve species recovery, the SFSR and Lemhi River populations must reach viable status.

Table 27. Summary of Viable Salmonid Population (VSP) parameter risks and overall current status and proposed recovery goals for populations of Snake River Basin steelhead that may be affected by the action.

MPG	Population	VSP Risk Rating[1]		Viability Risk Rating	
		Abundance/ Productivity	Spatial Structure/Diversity	2022 Assessment	Proposed Recovery Goal[2]
Salmon River	South Fork Salmon River	Moderate	Low	Maintained	Viable
	Lemhi River	Moderate	Moderate	Maintained	Viable

1Risk ratings are defined based on the risk of extinction within 100 years: High = greater than or equal to 25 percent; Moderate = less than 25 percent; Low = less than 5 percent; and Very Low = less than 1 percent.
2There are several scenarios that could meet the requirements for ESU recovery (as reflected in the proposed goals for populations in Oregon and Washington). What is reflected here for populations in Idaho are the proposed status goals selected by NMFS and the State of Idaho.

2.6. Status of Critical Habitat

In evaluating the condition of DCH, NMFS examines the condition and trends of PBFs which are essential to the conservation of the ESA-listed species because they support one or more life stages of the species. Proper function of these PBFs is necessary to support successful adult and juvenile migration, adult holding, spawning, incubation, rearing, and the growth and development of juvenile fish. Modification of PBFs may affect freshwater spawning, rearing or migration of ESA-listed Chinook salmon and steelhead. Generally speaking, sites required to support one or more life stages of the ESA-listed species (i.e., sites for spawning, rearing, migration, and foraging) contain PBFs essential to the conservation of the listed species (e.g., spawning gravels, water quality and quantity, side channels, or food) (Table 28).

Table 29 describes the geographical extent of critical habitat within the Snake River basin for SR spring/summer Chinook and SR Basin steelhead. Critical habitat includes the stream channel and water column with the lateral extent defined by the ordinary high-water line, or the bankfull elevation where the ordinary high-water line is not defined. In addition, critical habitat for Chinook salmon includes the adjacent riparian zone, which is defined as the area within 300 feet of the line of high water of a stream channel or from the shoreline of standing body of water (58

FR 68543). The riparian zone is critical because it provides shade, streambank stability, organic matter input, and regulation of sediment, nutrients, and chemicals.

Table 28. Types of sites, essential physical and biological features (PBFs), and the species life stage each PBF supports.

Site	Essential Physical and Biological Features	Species Life Stage
Snake River Basin steelhead[a]		
Freshwater spawning	Water quality, water quantity, and substrate	Spawning, incubation, and larval development
Freshwater rearing	Water quantity and floodplain connectivity to form and maintain physical habitat conditions	Juvenile growth and mobility
	Water quality and forage[b]	Juvenile development
	Natural cover[c]	Juvenile mobility and survival
Freshwater migration	Free of artificial obstructions, water quality and quantity, and natural cover[c]	Juvenile and adult mobility and survival
Snake River spring/summer Chinook salmon		
Spawning and juvenile rearing	Spawning gravel, water quality and quantity, cover/shelter, food, riparian vegetation, space, and water temperature.	Juvenile and adult
Migration	Substrate, water quality and quantity, water temperature, water velocity, cover/shelter, food[d], riparian vegetation, space, safe passage	Juvenile and adult

[a] Additional PBFs pertaining to estuarine areas have also been described for Snake River steelhead. These PBFs will not be affected by the proposed action and have therefore not been described in this opinion.
[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.
[c] Natural cover includes shade, large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
[d] Food applies to juvenile migration only.

Critical habitat throughout the SR Spring/summer Chinook salmon and SR Basin steelhead designations varies from excellent in wilderness and roadless areas to poor in areas subject to intensive human land uses (NMFS 2017). Critical habitat throughout much of the Interior Columbia (which includes the Snake River and the Middle Columbia River) has been degraded by intensive agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer streamflows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in non-wilderness areas. Human land use practices throughout the basin have caused streams to become straighter, wider, and shallower, thereby reducing rearing habitat and increasing water temperature fluctuations.

Table 29. Geographical extent of designated critical habitat within the Snake River basin for ESA-listed salmon and steelhead.

Evolutionarily Significant Unit (ESU)/ Distinct Population Segment (DPS)	Designation	Geographical Extent of Critical Habitat
Snake River spring/summer Chinook salmon ESU	58 FR 68543; December 28, 1993 64 FR 57399; October 25, 1999	All Snake River reaches upstream to Hells Canyon Dam; all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Salmon River basin; and all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Hells Canyon, Imnaha, Lower Grande Ronde, Upper Grande Ronde, Lower Snake–Asotin, Lower Snake–Tucannon, and Wallowa subbasins.
Snake River Basin steelhead DPS	70 FR 52630; September 2, 2005	Specific stream reaches are designated within the Lower Snake, Salmon, and Clearwater River basins. Table 21 in the Federal Register details habitat areas within the DPS's geographical range that are excluded from critical habitat designation.

In many stream reaches designated as critical habitat in the Snake River basin, streamflows are substantially reduced by water diversions (NMFS 2017). Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996). Reduced tributary streamflow has been identified as a major limiting factor for SR spring/summer Chinook and SR Basin steelhead in particular (NMFS 2017).

Many stream reaches designated as critical habitat for these species are listed on the CWA 303(d) list for impaired water quality, such as elevated water temperature (IDEQ 2022). Many areas that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures, such as some stream reaches in the Upper Grande Ronde. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Water quality in spawning and rearing areas in the Snake River has also been impaired by high levels of sedimentation and by heavy metal contamination from mine waste (e.g., IDEQ and USEPA 2003; IDEQ 2001).

The construction and operation of water storage and hydropower projects in the Columbia River basin, including the eight run-of-river dams on the mainstem lower Snake and lower Columbia Rivers, have altered biological and physical attributes of the mainstem migration corridor. Hydrosystem development modified natural flow regimes, resulting in warmer late summer and fall water temperature. Changes in fish communities led to increased rates of piscivorous predation on juvenile salmon and steelhead. Reservoirs and project tailraces have created opportunities for avian predators to successfully forage for smolts, and the dams themselves have created migration delays for both adult and juvenile salmonids. Physical features of dams, such as turbines, also kill out-migrating fish. In-river survival is inversely related to the number of hydropower projects encountered by emigrating juveniles. However, some of these conditions have improved. The BOR and USACE have implemented measures in previous Columbia River System hydropower consultations to improve conditions in the juvenile and adult migration corridor including 24-hour volitional spill, surface passage routes, upgrades to juvenile bypass systems, and predator management measures. These measures are ongoing and their benefits with respect to improved functioning of the migration corridor PBFs will continue into the future.

2.7. Climate Change Implications for ESA-listed Species and their Critical Habitat

One factor affecting the rangewide status of SR salmon and steelhead, and aquatic habitat at large is climate change. As observed by Siegel and Crozier (2019), long-term trends in warming have continued at global, national, and regional scales. The five warmest years in the 1880 to 2019 record have all occurred since 2015, while 9 of the 10 warmest years have occurred since 2005 (Lindsey and Dahlman 2020). The years 2020 - 2022 were also hot years in national and global temperatures; all ranked in the top ten hottest years in the 141-year record of global land and sea measurements and followed the warmest decade on record. The year 2023 was even warmer, marking the hottest ever year on record (https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202013). Events such as the 2014-2016 marine heatwave (Jacox et al. 2018) are likely exacerbated by anthropogenic warming, as noted in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). The U.S. Global Change Research Program (USGCRP) reports average warming in the Pacific Northwest of about 1.3ºF from 1895 to 2011, and projects an increase in average annual temperature of 3.3ºF to 9.7ºF by 2070 to 2099 (compared to the period 1970 to 1999), depending largely on total global emissions of heat-trapping gases (predictions based on a variety of emission scenarios including B1, RCP4.5, A1B, A2, A1FI, and RCP8.5 scenarios). The increases are projected to be largest in summer (USGCRP 2018).

Climate change generally exacerbates threats and limiting factors, including those currently impairing salmon and steelhead survival and productivity. The growing frequency and magnitude of climate change related environmental downturns will increasingly imperil many ESA-listed stocks in the Columbia River basin and amplify their extinction risk (Crozier et al. 2019, 2020, 2021). This climate change context means that opportunities to rebuild these stocks will likely diminish over time. As such, management actions that increase resilience and adaptation to these changes should be prioritized and expedited. For example, the importance of improving the condition of and access and survival to and from the remaining functional, high-elevation spawning and nursery habitats is accentuated because these habitats are the most likely to retain remnant snowpacks under predicted climate change (Tonina et al. 2022).

Climate change is already evident. It will continue to affect air temperatures, precipitation, and wind patterns in the Pacific Northwest (ISAB 2007; Philip et al. 2021), resulting in increased droughts and wildfires and variation in river flow patterns. These conditions differ from those under which native anadromous and resident fishes evolved and will likely increase risks posed by invasive species and altered food webs. The frequency, magnitude, and duration of elevated water temperature events have increased with climate change and are exacerbated by the Columbia River hydrosystem (EPA 2021a; 2021b; Scott 2020). Thermal gradients (i.e., rapid change to elevated water temperatures) encountered while passing dams via fish ladders can slow, reduce, or altogether stop the upstream movements of migrating salmon and steelhead (e.g., Caudill et al. 2013). Additional thermal loading occurs when mainstem reservoirs act as a heat trap due to upstream inputs and solar irradiation over their increased water surface area

(EPA 2021a, 2021b, 2021c). Consider the example of adult sockeye salmon in 2015, when high summer water temperatures contributed to extremely high losses of Columbia River and Snake River stocks during passage through the mainstem Columbia and Snake River (Crozier et al. 2020), and through tributaries such as the Salmon and Okanogan rivers, below their spawning areas. Some stocks are already experiencing lethal thermal barriers during a portion of their adult migration. The effects of longer or more severe thermal barriers in the future could be catastrophic. For example, Bowerman et al. (2021) concluded that climate change will likely increase the factors contributing to prespawn mortality of Chinook salmon across the entire Columbia River basin.

Columbia River basin salmon and steelhead spend a significant portion of their life-cycle in the ocean, and as such the ocean is a critically important habitat influencing their abundance and productivity. Climate change is also altering marine environments used by Columbia River basin salmon and steelhead. This includes increased frequency and magnitude of marine heatwaves, changes to the intensity and timing of coastal upwelling, increased frequency of hypoxia (low oxygen) events, and ocean acidification. These factors are already reducing, and are expected to continue reducing, ocean productivity for salmon and steelhead. This does not mean the ocean is getting worse every year, or that there will not be periods of good ocean conditions for salmon and steelhead. In fact, near-shore conditions off the Oregon and Washington coasts were considered good in 2021 (NOAA 2022). However, the magnitude, frequency, and duration of downturns in marine conditions are expected to increase over time due to climate change. Any long-term effects of the stressors that fish experience during freshwater stages that do not manifest until the marine environment will be amplified by the less-hospitable conditions there due to climate change. Together with increased variation in freshwater conditions, these downturns will further impair the abundance, productivity, spatial structure, and diversity of the region's native salmon and steelhead stocks (ISAB 2007; Isaak et al. 2018). As such, these climate dynamics will reduce fish survival through direct and indirect impacts at all life stages (NOAA 2022).

All habitats used by Pacific salmon and steelhead will be affected by climate dynamics. However, the impacts and certainty of the changes will likely vary by habitat type. Some changes affect salmon at all life stages in all habitats (e.g., increasing temperature), while others are habitat-specific (e.g., stream-flow variation in freshwater, sea-level rise in estuaries, upwelling in the ocean). How climate change will affect each individual salmon or steelhead stock also varies widely, depending on the extent and rate of change and the unique life-history characteristics of different natural populations (Crozier et al. 2008; Crozier and Siegel 2023). The continued persistence of salmon and steelhead in the Columbia basin relies on restoration actions that enhance climate resilience (Jorgensen et al. 2021) in freshwater spawning, rearing, and migratory habitats, including access to high elevation, high quality cold-water habitats, and the reconnection of floodplain habitats across the interior Columbia River basin.

2.8. Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The proposed action occurs on private (820 acres) (including approximately 535 acres of patented mining claims owned or controlled by Perpetua), public lands administered by the USFS (2,372 acres) and BOR (37 acres), the State of Idaho (62 acres) in Valley County, Idaho (Figure 1), and Lemhi County, Idaho (Figure 2). Figure 25 displays the Stibnite component of the action area, which reflects activities directly associated with the SGP. The action area is the area of overlap between the effects of the action and the distribution or presence of ESA-species and/or designated critical habitat, which includes portions of the SFSR subbasin (HUC 17060208) and Zeph Creek-Lemhi River subwatershed (HUC 170602040702).

The action area is comprised of two discontiguous areas. Within the SFSR subbasin, the action area includes the access routes and associated infrastructure such as borrow pits and maintenance facilities (Figure 3), the Stibnite project area (Figure 4), OSV route and associated equipment storage and parking areas (Figure 7), transmission line and associated infrastructure (Figure 8) and the BRGI investigation sites and access routes (Figure 17). The major streams in the action area include the SFSR (downstream from the Warm Lake Highway Bridge to its confluence with the Salmon River); Johnson Creek (downstream from the FR447 Bridge); the EFSFSR (from its headwaters downstream to its confluence with the SFSR), and Sugar Creek (from just upstream of West End Creek to its mouth). Tributaries to these major streams that are either directly impacted by ground disturbing activities (e.g., stream crossing work) or receive stormwater runoff are also part of the action area. Because of the flow- and water quality-related (contaminants) effects, the action area extends from the project area downstream to the mouth of the SFSR. The downstream extent of the action area ends at the mouth of the SFSR because water quality-related effects causally linked to the proposed action are not expected to occur downstream of the confluence with the Salmon River given increased flows, distance from the project area, contaminant fate and transport mechanisms, and existing variability in contaminant concentrations (resulting from other natural and anthropogenic sources, such as atmospheric deposition mercury).

The second component of the action area reflects the Lemhi restoration portion of the proposed action, and is located entirely on private lands on the Upper Lemhi River approximately 12 miles northwest of Leadore, Idaho. The reach of the Lemhi Project extends approximately 7,000 ft. from river mile (RM) 42.62 to RM 41.32 on the mainstem of the Lemhi River on the western side of SH 28. Figure 2 displays the action area for this portion of the project, defined as the Lemhi Project reach plus 100-ft. buffers upstream and to the southwest of the project, 328 ft. (100 meters) downstream of the project, and out to SH 28 to the northeast of the project) for the Proposed Action.

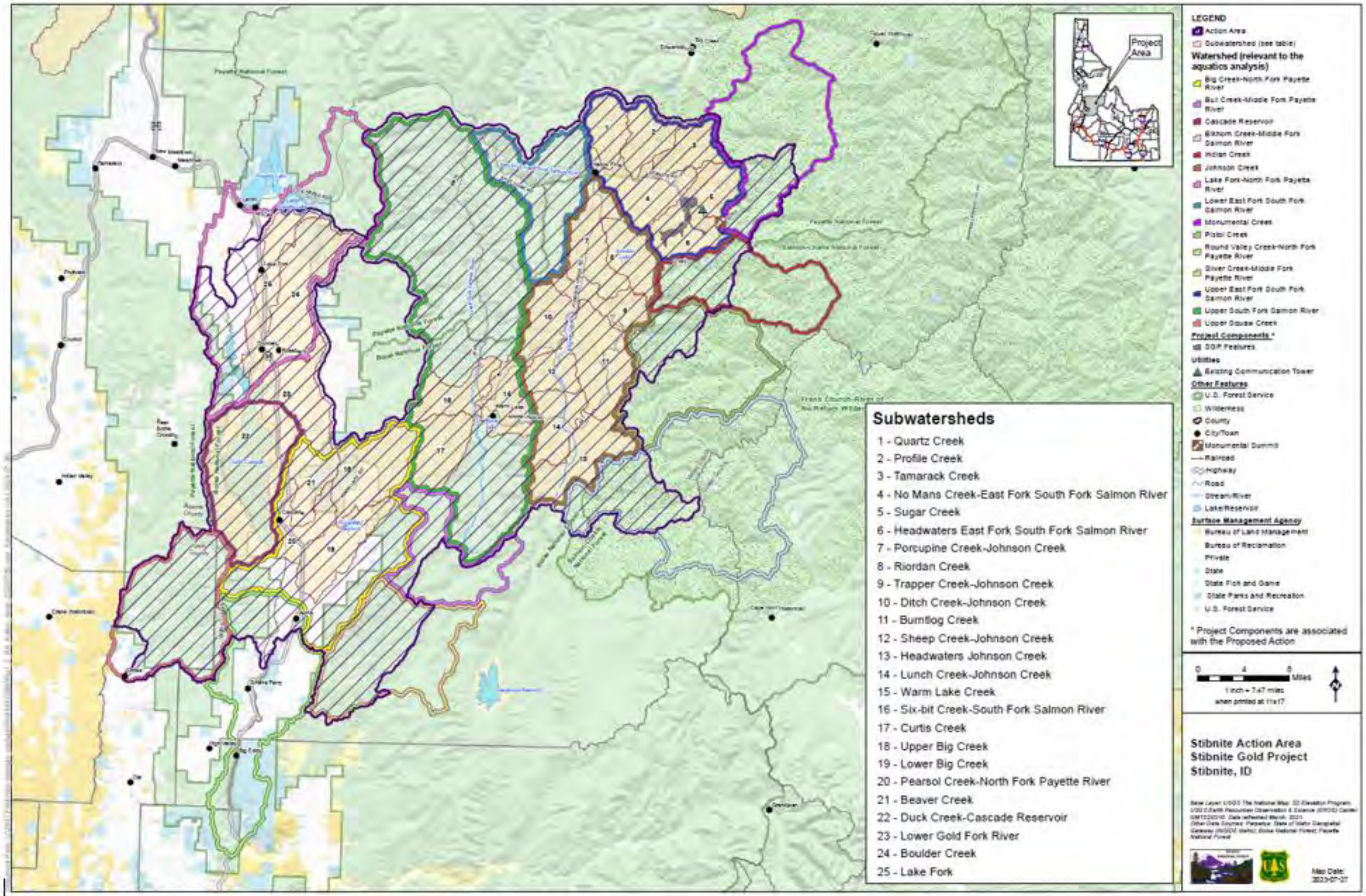


Figure 25. Stibnite Action Area, Stibnite Gold Project.

2.9. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its DCH in the action area, without the consequences to the listed species or DCH caused by the proposed action. The environmental baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of state or private actions which are contemporaneous with the consultation in process. The impacts to listed species or DCH from federal agency activities or existing Federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The action area is used by all freshwater life history stages of SR spring/summer Chinook salmon and SR Basin steelhead. Streams within the action area are DCH for each of these species. The condition of the listed species and DCH in the action area are described further below. Because climate change has already had impacts across the Snake River basin, discussions of the status of the species, status of critical habitat, and environmental baseline within the action area incorporate the current effects of climate change.

2.9.1. Condition of Species in the Action Area

All life stages of SR spring/summer Chinook salmon and SR Basin steelhead have potential to be exposed to the effects of the proposed action. The following sections provide a summary of the current status and importance of populations within the action area to the recovery of these species.

2.9.1.1. SR Spring/summer Chinook Salmon

2.9.1.1.1. SFSR and EFSFSR spring/summer Chinook salmon in the SFSR basin are part of the SFSR MPG. Two populations, the SFSR and EFSFSR populations, occur within the action area. Viable populations within the MPG should include some populations classified as "Very Large'" or "Large," and "Intermediate" reflecting proportions historically present. The SFSR population is classified as a large-size population, has hatchery influence (hatchery supplementation began in the mid-1970s), and is proposed to achieve a viable status in order to support recovery of the ESU (NMFS 2017). The EFSFSR population is also a large-size population, has hatchery influence (hatchery supplementation began in the 1998), and is proposed to achieve a maintained status in order to support recovery of the species (NMFS 2017). Both populations are currently at a high risk of extinction within the next 100 years based on information available for the 2022 5-year review (NMFS 2022b) and the viability assessment completed for Pacific salmon (Ford 2022) as part of the 5-year review effort.

Population-specific habitat concerns for the SFSR MPG, which includes the EFSFSR and SFSR populations, include: fine sediment; high stream temperatures; passage barriers; and wildfires affecting riparian zones (PNF 2020, as cited in NMFS 2022b). Although levels of fine sediment in the action area are often influenced by wildfires and rain-on-snow landslides, the PNF has not observed recent spikes in sediment levels at long-term monitoring sites.

Some of the recommended recovery strategies for this MPG include maintaining wilderness protection; providing or improving fish passage to and from areas with high intrinsic potential through barrier removal, screening and other projects; reducing or preventing sediment delivery by improving road systems, riparian communities, and rehabilitating abandoned mine sites; and improving riparian and floodplain health and function (NMFS 2017). Excess sediment, floodplain connectivity, poor water quality, and high-water temperatures are limiting factors that both of these populations share. Other limiting factors include passage barriers (EFSFSR population), channel alteration (SFSR population), and degraded riparian habitat (EFSFSR population).

Within the action area, Chinook salmon are known to spawn and rear in the SFSR, the EFSFSR, Johnson Creek, Cabin Creek, Sugar Creek, and lower reaches of Burntlog Creek, and Meadow Creek (when adults are outplanted). Chinook salmon also use the lower 500 ft. of EFMC, but no Chinook salmon occur in Hennessy, Midnight, Fiddle, or Garnet Creeks. Juvenile Chinook salmon have also been found in the lower reaches of Trapper and Riordan Creeks.

Chinook salmon in the upper EFSFSR (upstream from the YPP) were extirpated by diversion of the EFSFSR into a bypass tunnel from mining operations in the late 1930s. After cessation of mining and abandonment of the bypass tunnel, a high gradient and impassable riffle/cascade on the EFSFSR flowing directly into the YPP continued to prevent fish passage into the upper watershed. Both the riffle/cascade and the YPP were created as a result of mining operations. Chinook salmon use the SFSR and the mainstem of the EFSFSR downstream from the YPP as a migratory corridor and for spawning and rearing. Adult Chinook salmon and salmon redds have been observed in Sugar Creek (48 redds counted from 2014-2022) and in the EFSFSR as far upstream as the inlet of the YPP (i.e., downstream from the impassable cascade).

Adult Chinook salmon have been periodically introduced into Meadow Creek and the upper EFSFSR, upstream from the YPP, by the Idaho Department of Fish and Game (IDFG) in cooperation with the Nez Perce Tribe (NPT) when there is sufficient overstock from the local hatchery. These releases began in 2011, although no releases occurred between 2018 and 2021. However, in August and September, 2022, the NPT and IDFG released 387 adult Chinook salmon into the EFSFSR, just below the Meadow Creek confluence.

Since supplementation began, some adult Chinook salmon have returned to spawn in the EFSFSR, but are not able to migrate beyond the cascade that exists upstream of the YPP. The Chinook salmon transported upstream from the YPP, although introduced, are part of the ESA-listed population. The juveniles migrate downstream naturally and mix with the juveniles spawned downstream from the YPP.

The NPT surveyed stream segments above the YPP where redds were historically documented and identified 29 redds in Meadow Creek and three redds in the EFSFSR between Fiddle Creek and Meadow Creek. The PNF surveyed the EFSFSR reach between the box culvert and Meadow Creek and identified one redd. The NPT and IDFG have also conducted annual Chinook salmon redd surveys in the EFSFSR and its tributaries below the YPP. Over a 20-year period, 38 redds have been observed between the YPP and the road crossing upstream from Sugar Creek. Johnson

Creek had the highest numbers of Chinook salmon redd counts in the Upper EFSFSR watershed, ranging from 193 (2008, 2011) to 376 (2014), with an average count of 207 redds per year.

In 2018 and 2019, a total of 55 juvenile Chinook salmon were captured during sampling efforts in the YPP (Brown and Caldwell 2020b). Forty of these fish were PIT tagged, of which 27 had associated observation details in the Columbia Basin PIT Tag Information System (PSMFC 2024). Fish were documented migrating downstream in April and May the following year. Two fish were detected at McNary Dam, and one fish was detected in the Lower Columbia River estuary. None of these tagged fish were detected as returning adults (PSMFC 2024).

The 2017 NMFS Recovery Plan (NMFS 2017) identified recovery strategies for SR spring/summer Chinook salmon for the Lower EFSFSR and Upper EFSFSR watersheds (mine site location) including:

- Maintain current wilderness protection and protect pristine tributary habitat;
- Provide/improve passage to and from areas with high intrinsic potential through barrier removal;
- Reduce and prevent sediment delivery to streams by improving road systems and riparian communities, and rehabilitating abandoned mine sites; and,
- Manage risks from tributary fisheries according to an abundance-based schedule.

2.9.1.1.2. Lemhi

All life stages of Chinook salmon use the Lemhi River in the action area. Most spawning occurs in the Lemhi River upstream from Hayden Creek (which includes the restoration site) and in the Hayden Creek drainage. Historically there were at least seven other tributaries providing spawning habitat for Chinook salmon, but now spawning has been reduced to just Hayden Creek and the mainstem.

Within the Upper Salmon River MPG, the Lemhi population of SR spring/summer Chinook salmon occurs within the Lemhi portion of the action area. The Lemhi population is a very large-size population, has low hatchery influence, and is proposed to achieve a viable status in order to support recovery of the ESU (NMFS 2017). A high spatial structure/diversity risk rating for the Lemhi River population is driven by a substantial loss of access to tributary spawning and rearing habitats, and the associated reduction in life-history diversity.

Habitat concerns for the Upper Salmon River MPG include low flows from water diversions; degraded riparian conditions (losses from agriculture and overgrazing by livestock); sediment input from grazing and agricultural practices; and high-water temperatures (NMFS 2022b). Since 2016, summer instream flows have improved, tributary connectivity to the mainstem has improved, floodplain and habitat complexity has increased, and grazing management has been altered to protect riparian habitat. Overall, work in the Lemhi River basin between 2007 and 2019 has increased the summer rearing capacity for parr by 62 percent, and researchers have reported an increase in juvenile Chinook salmon productivity (Uthe et al. 2017; Haskell et al. 2019).

Juvenile survival and production data indicate that spawning and rearing PBFs will have to improve for the Lemhi River Chinook salmon population to achieve maintained status (NMFS 2017). The population is currently at a high risk of extinction within the next 100 years based on information available for the 2022 5-year review (NMFS 2022b) and the viability assessment completed for Pacific salmon (Ford 2022) as part of the 5-year review effort, remaining at high risk because of spatial structure loss.

An important opportunity to advancing the recovery of the Upper Salmon River MPG is to increase habitat complexity by creating multi-threaded channels, increase rearing habitat by increasing floodplain connectivity, reducing the width-to-depth ratio, stabilize banks, and improve willow-dominated riparian areas, as well as maintaining and improving instream flows and tributary connectivity.

2.9.1.2. **SR Basin Steelhead**

2.9.1.2.1. SFSR

The proposed action would affect individuals in the Salmon River MPG, specifically the SFSR steelhead population. This population is one of the few that has never been supplemented with hatchery fish and has high proportions of B-run[7] individuals. The SFSR population is currently at a moderate risk of extinction within the next 100 years based on information available for the 2022 5-year review (NMFS 2022c) and the viability assessment completed for Pacific salmon (Ford 2022) as part of the last 5-year review effort. The SFSR population is targeted to achieve a viable status (low risk of extinction). The 5-year geometric mean for the SFSR and Secesh River populations (combined) has steadily decreased since 2010, decreasing by 57 percent over the two most recent five-year periods (Ford 2022). Limiting factors include excess sediment, migration barriers, and degraded riparian conditions. The recovery strategy emphasizes reducing and stabilizing disturbed areas and improving and rehabilitating roads as actions for reducing sediment delivery to spawning and rearing stream reaches.

The SFSR population spawns, rears, and migrates through the action area. Steelhead spawning overlaps many of the mainstem areas used by Chinook salmon, and steelhead redds have been observed in smaller tributaries such as Camp and Fitsum Creeks (Thurow 1987). In the EFSFSR, Snake River Basin steelhead occur up to YPP, where the impassable falls/cascade (30 percent gradient) blocks upstream migration. Due to their spawn timing, spawning surveys are not typically performed; therefore, where spawning occurs in the watershed is not well documented. Steelhead redds and adults were identified in 2004 downstream from the town of Yellow Pine. Most of the observed spawning sites were in small pockets of suitable substrate, often in marginal positions rather than in well-developed spawning riffles (Nelson 2004). Some steelhead also spawn in the EFSFSR upstream from the town of Yellow Pine. Within the action area, steelhead spawning occurs in Johnson Creek, Burntlog Creek, the SFSR, Sugar Creek, and the EFSFSR below the YPP - coincident with the upstream endpoint for DCH in the EFSFSR. There

[7] Steelhead referred to as "B-run" are larger (>78 cm long), spend two years in the ocean, and appear to begin their upriver freshwater migration later in the year than steelhead referred to as "A-run." Steelhead referred to as "A-run" are smaller (usually 58 to 66 cm long), spend one year in the ocean, and begin their upriver freshwater migration earlier in the year than steelhead referred to as "B-run" (NMFS 2017).

is no recreational fishery for steelhead in the SFSR nor is the population supplemented with hatchery-produced fish.

Within the action area, steelhead are known to spawn and rear in the SFSR, the EFSFSR, Johnson Creek, Cabin Creek, and Sugar Creek. No steelhead occur in Meadow, East Fork Meadow, Hennessy, Midnight, Fiddle, or Garnet Creeks.

Although the BA indicates that streams along the Burntlog route do not support steelhead, eDNA samples indicate the presence of *O. mykiss* in upper Burntlog, East Fork Burntlog, Peanut, Trapper, and Riordan Creeks. Stantec (2024) postulated that steelhead may reach the headwaters in Johnson Creek, recognizing that there is no data documentation to verify if they are steelhead or resident *O. mykiss*. They further suggested that it is unlikely that steelhead occur in upper Trapper Creek, its tributaries, or in upper Riordan Creek due to suspected passage barriers in the lower reaches of these creeks. NMFS agrees with this characterization for Riordan and Trapper Creeks. However, because no barriers are suspected to occur in upper Burntlog Creek, East Fork Burntlog, or Peanut Creek, NMFS considers *O. mykiss* in these remaining streams as steelhead in our analysis.

Fish tissue samples and eDNA have been sampled from various locations upstream from the YPP from 2014 to 2016, and two fish tested positive for *O. mykiss* DNA, one in Meadow Creek Lake and one in the EFMC. The BA authors believe that the rainbow trout genetics detected from these locations are, in fact, California golden trout (*O. mykiss aguabonita*), a subspecies of rainbow trout that were stocked in Meadow Creek Lake by IDFG that are not native to the region. NMFS agrees with this characterization. Otherwise, no *O. mykiss* have been observed in the EFSFSR upstream from the YPP during the aquatic baseline surveys conducted since 2012, but some have been observed in the YPP and downstream from Sugar Creek (BA Table 3-4) (Brown and Caldwell 2019; MWH 2017).

The 2017 NMFS Recovery Plan for Snake River Idaho Spring/Summer Chinook Salmon and Snake River Basin Steelhead Populations included recovery strategies for Salmon River steelhead. Priorities for the SFSR steelhead population, specific to the EFSFSR watershed include:

- Collect and analyze population-specific data to accurately determine population status;
- Maintain wilderness protection and protect pristine tributary habitat;
- Eliminate artificial passage barriers and improve connectivity to historical habitat;
- Reduce and prevent sediment delivery to streams by rehabilitating roads and mining sites; and,
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans according to an abundance-based schedule.

Based on NMFS' 2022 5-Year Review (NMFS 2022c), recommended actions specific to SR Basin steelhead in the EFSFSR include improving water quality by reclaiming abandoned mine sites such as the Cinnabar Mine; continuing to conduct appropriate road maintenance, road obliteration, road relocation, and road resurfacing; improving riparian conditions in disturbed areas; eliminating passage barriers; restoring floodplains; and improving planning for potential climate change effects by continuing to monitor stream temperature and validate fish distribution in modeled cold water refugia.

2.9.1.2.2. Lemhi

All life stages of SR Basin steelhead use the Lemhi River within the action area. Steelhead within the Lemhi portion of the action area are in the Salmon River MPG, Lemhi population. The Lemhi population is a very large-size population, has hatchery influence, and is proposed to achieve a viable status in order to support recovery of the ESU (NMFS 2017). The population is currently at a moderate risk of extinction within the next 100 years based on information available for the 2022 5-year review (NMFS 2022c) and the viability assessment completed for Pacific salmon (Ford 2022) as part of the 5-year review effort.

Recommended actions for the Lemhi River population include improving riparian conditions in disturbed areas, eliminating passage barriers, and increasing winter juvenile rearing habitat by increasing floodplain connectivity and complex habitat structure; reducing W:D, increasing low- to zero-velocity pool habitat with cover, providing more side channel and multi-threaded channel habitat, and reducing the fine sediment delivery to streams (BioMark et al. 2019; NMFS 2022c). Specifically, in the upper Lemhi River, recommended actions to improve conditions for steelhead include increasing habitat complexity by creating multi-threaded channels, narrow the W:D, stabilize banks, increase willow-dominated riparian areas, maintain and improve instream flow, and improve tributary stream connections to the to the mainstem Lemhi River (Biomark et al. 2019; NMFS 2022c).

2.9.2. Condition of Critical Habitat in the Action Area

The SGP portion of the action is located in headwater tributaries of the SFSR, with proposed mining activities to take place primarily in areas previously disturbed by mining beginning around 1919. Excavation of the YPP began in 1938, and volitional passage of Chinook salmon and steelhead to the EFSFSR and Meadow Creek was eliminated at that time. Additional mining continued at the site in the 1940s, 1970s, 1980s, and 1990s. Mining, milling, smelting, and leaching activities left behind impacts including underground mine workings, multiple open pits, development rock dumps, mill tailings deposits, cyanidation heap leach pads, neutralized (spent) heap leach ore piles, a mill and smelter site, three town sites, camp sites, a washed-out earthen dam (with its associated erosion and downstream sedimentation), haul roads, an abandoned water diversion tunnel, an airstrip, and other disturbances.

Past mining activities have resulted in ongoing releases of contaminants to surface water and groundwater at the site including elevated concentrations of antimony, arsenic, copper, lead, mercury, and cyanide. Most notable are elevated concentrations of arsenic and antimony. Past mining activities have also caused alterations to stream configurations and habitat including formation of the YPP lake, creation of a fish passage barrier immediately upstream of the YPP lake, sediment and tailings deposits, development rock dumps, and channel diversions.

2.9.2.1. **South Fork Salmon River**

Streams within the action area are DCH for both SR spring/summer Chinook salmon and SR Basin steelhead. The SFSR and its tributaries offer a large amount of suitable spawning and rearing habitat. The majority of land in the lower SFSR and EFSFSR watersheds is federally managed. Historically, the area was impacted by logging, mining, grazing, and road building. Grazing no longer occurs in the action area, and prior to the proposed action, mining in the action area has not been as prevalent as it once was. Logging rarely occurs, and has most recently been performed as post-fire salvage or when reducing hazard fuels. In more recent times, wildfire has become the largest disturbance mechanism in the SFSR subbasin. Recreation and use of the existing road system are the primary human activities in the action area, although some private inholdings and associated homesteads exist. The existing network of roads and trails continue to impact aquatic habitat conditions.

Within the Stibnite project area, steelhead DCH includes the SFSR, Cabin Creek, the EFSFSR upstream to the YPP, Sugar Creek, Johnson Creek, Burntlog Creek, and lower Riordan and Trapper Creeks. Chinook salmon DCH overlaps steelhead critical habitat in each of these rivers and streams, but also extends further upstream of the YPP to include reaches of the EFSFSR and Meadow Creek.

Habitat conditions within the action area have been significantly impacted by mining activities. Open pit mining activities began upstream of the EFSFSR and Sugar Creek confluence in 1938 and continued for 14 years. Upstream fish passage was eliminated when the EFSFSR was initially diverted around the mining area. In order to expand and deepen the YPP, the EFSFSR was diverted through the Bradley Tunnel to Sugar Creek in 1943 (Hogen 2002; Midas Gold2016). When mining ceased in 1952, the Bradley Tunnel was abandoned and the EFSFSR was allowed to flow into the abandoned pit, which was 450 ft. deep. Over time, sediment transported downstream from the watershed settled in the YPP Lake. Now, the YPP Lake is approximately 5 acres in size and averages about 30 ft. deep. It is predominantly surrounded by steep, unnatural shorelines created by historical mining operations. Very little vegetation exists on the hillside and shoreline. A long, steep riffle/cascade, with a gradient of about 30 percent, exists at the inlet of the lake. This cascade is an impassible barrier to Chinook salmon, and is likely an impassible barrier to steelhead under most flows. Overtime, an alluvial fan has formed at the base of this cascade and Chinook salmon have been documented spawning at the inlet to the lake.

The BA uses the Southwest Idaho Ecogroup Matrix of Pathways and Watershed Condition Indicators (Matrix) (USFS 2003 and USFS 2010a) as a tool for assessing environmental baseline conditions and evaluating the potential effects of an action on WCIs. A WCI is a particular aquatic, riparian, or hydrologic measure that is relevant to the conservation of ESA-listed salmonids. In some instances, a WCI is synonymous to a PBF, temperature being a prime example. In other instances, many WCIs comprise a PBF. For example, the LWD, pool frequency and quality, large pools/pool quality, and off-channel habitat WCIs provide insight into the natural cover and cover/shelter features of spawning, rearing, and migration areas.

The WCIs are described in terms of their functionality, that is, functioning appropriately (FA), functioning at risk (FAR), or functioning at unacceptable risk (FUR). A watershed comprised of

WCIs that are FA is considered to be meeting the biological requirements of listed anadromous species (whereas WCIs that are FAR or FUR suggest that the relevant PBF is not in a condition that is suitable for conservation).

Over the past 20 years, various fish and aquatic habitat studies have been conducted in the SFSR subbasin which have provided a better understanding of aquatic resource baseline conditions within the analysis area. Studies have been conducted by federal, state, local, and tribal agencies (e.g., PNF, BNF, IDFG, and the NPT), as well as private entities (e.g., Perpetua).

The Stibnite portion of action area includes all of the watercourses (i.e., streams and rivers) and waterbodies (i.e., lakes, reservoirs) in the 12-digit hydrologic unit code (HUC) subwatersheds that overlap with the effects of the SGP. Because the majority of the activities and disturbance will occur at the mine site, which is located in the EFSFSR subbasin, the baseline condition within this subbasin is a primary focus. Relevant habitat conditions in other watersheds, and subwatersheds that may be impacted by SGP activities are also described, as appropriate. Chinook salmon use only the lower 500 ft. of EFMC, but no anadromous fish occur in Hennessy, Midnight, Fiddle, or Garnet Creeks. Baseline conditions for these subwatersheds can be found in section 4.1.2 of the BA (Stantec 2024), which is incorporated by reference here.

2.9.2.2. **East Fork South Fork Salmon River**

The EFSFSR watershed covers approximately 250,000 acres and enters the mainstem SFSR near the confluence of the Secesh River. Most of the watershed is administered by the USFS and managed by the PNF and BNF. Private land in the watershed includes small parcels of land along Johnson Creek, large legacy mines in the headwater drainages (e.g., Stibnite and Cinnabar mines), and the town of Yellow Pine. Predominant historical land uses occurring in this watershed include timber harvest and large-scale mining (Wagoner and Burns 2001). Extensive cattle grazing also historically occurred in the Johnson Creek watershed, but federal grazing allotments have now been retired and grazing has been reduced to private lands.

Large-scale historical mining altered stream channel conditions in the Upper EFSFSR watershed. The USFS and mine operators have since undertaken restoration work. However, habitat for migratory salmonids in the EFSFSR upstream from the YPP lake is inaccessible because historical mining excavation of the stream channel has created a gradient barrier (YPP lake cascade). While mining in the area has not occurred since about 1950, there are still significant legacy effects that continue to impact channel conditions and fish populations.

Although not formally identified as a CERCLA Superfund site, some mining operators at the site conducted activities to reduce the release of hazardous substances before 2001. Notable work included diverting Meadow Creek and stabilizing the Bradley Tailings/SODA disposal area, which was completed in 1999. In addition, the USFS began using its CERCLA authorities to address legacy mining impacts at the site since 2001. In 2002, the USFS removed tailings from a pond and soils located at the former smelter stack area, and the Meadow Creek floodplain was reconstructed in the former pond area. In 2004 and 2005, the USFS reconstructed Meadow Creek directly downstream of Smelter Flats. This included the removal of tailings from the channel and depositing this material in a new containment cell located on the SODA. The new channel banks were revegetated with willow plants and the old channel was backfilled and reclaimed. In 2009, the USFS regraded and covered a portion of the remaining tailings at Smelter Flats to prevent further erosion and exposure risk. It is in these restored stream reaches, that surplus hatchery Chinook salmon have periodically been placed by the NPT and IDFG and have successfully spawned and reared for the first time in decades.

The EFSFSR drainage has the lowest quality habitat for sensitive and protected fish in the SFSR subbasin (NPCC 2004). Primary habitat limitations in the EFSFSR drainage are reduced riparian habitat and decreased streambank stability due both to road design and the extent of the existing road system; secondary limitations include reduced instream LWD, water quality degradation, and fish passage barriers resulting from legacy mining in the area (NPCC 2004).

All IDEQ-inventoried waterbodies at the proposed mine site (except for West End Creek) are listed under Section 303(d) of the federal CWA as "impaired" due to water quality (IDEQ 2018). The causes for listing of these waters are associated with elevated concentrations of arsenic, antimony, and mercury. Each of the 303(d)-listed waterbodies has designated beneficial uses of "cold water communities," "salmonid spawning," and "primary contact recreation," and all (except Sugar Creek) have designated beneficial uses of "drinking water supply."

Wildfires have eliminated much of the tree canopy at the SGP mine site and vicinity, which has resulted in erosion and landslides. In addition, the failure of a dam on the EFMC in 1965 resulted in extensive erosion, both upstream and downstream from the former dam and reservoir site, which in turn has led to extensive and ongoing deposition of sediment in the lower reaches of Meadow Creek and downstream in the EFSFSR. Currently, while concentrations of total suspended solids and turbidity are low during some months, there is seasonal variation in these concentrations associated with high flow periods when concentrations can reach moderate to high levels.

The upper EFSFSR subwatershed is considered a priority subwatershed to the Forest's Aquatic Conservation Strategy (ACS). According to the PNF Land and Resource Management Plan, the ACS is intended to provide guidance towards long-term maintenance and restoration of characteristics found in healthy, functioning watersheds, riparian areas, and associated fish habitat. The ACS provides a scientific basis for protecting and restoring aquatic ecosystems; assisting towards the short- and long-term recovery of listed fish species; delisting of water quality impaired waters; and resource management. Priority subwatersheds are those that provide a pattern of protection/restoration across the Forest that will help lead towards the ACS goals (e.g., recovery of listed fish species, delisting of water quality impaired waters).

Habitat is generally "FAR" in the EFSFSR watershed (Table 30). Only intragravel quality, interstitial sediment deposition, LWD, W:D, and streambank condition are "FA" in the watershed. The remaining WCIs currently range from "FAR to FUR." Habitat conditions most likely to be affected by the proposed action are described in more detail below for action area watersheds used by ESA-listed Chinook and steelhead. More detail can be found for other WCIs and other subwatersheds in Appendix C of the BA (Stantec 2024).

Table 30. Summary Matrix of Watershed Condition Indicators in the Upper East Fork South Fork Salmon River and Upper Johnson Creek Watersheds.

Pathway	Indicators	Upper EFSFSR Watershed Functionality*	Upper Johnson Creek Watershed Functionality*
Water Quality	Temperature	FA - FUR	FA - FAR
	Intragravel Quality	FA	FA - FUR
	Chemical Contamination/Nutrients	FUR	FA
Habitat Access	Physical Barriers	FUR	FA - FUR
Habitat Elements	Interstitial Sediment Deposition	FA	FA
	LWD	FA	FA
	Pool Frequency	FA - FUR	FA
	Pool Quality	FAR	FA
	Off-channel Habitat	FAR	FA
	Refugia	FAR	FAR
Channel Condition and Dynamics	W:D	FA	FAR
	Streambank Condition	FA	FAR
	Floodplain Connectivity	FAR	FAR
Flow/Hydrology	Change in Peak/Base Flows	FAR	Unknown
	Increase in Drainage Networks	FAR	FUR
Watershed Conditions	Road Density and Location	FAR	FAR
	Disturbance History	FUR	FUR
	RCAs	FUR	FAR
	Disturbance Regime	FUR	FAR

Functioning Appropriately = (FA), Functioning at Risk = (FAR) and Functioning at Unacceptable Risk = (FUR).
*See Southwest Idaho Matrix of Pathways and Indicators for explanation of functionality ratings (USFS 2010a and 2010b).

Habitat is generally “FAR” in the Upper Johnson Creek watershed (Table 30). Only chemical contamination/nutrients, interstitial sediment deposition, LWD, pool frequency, pool quality, and off-channel habitat are “FA” in the watershed. The remaining WCIs currently range from “FAR to FUR.” Habitat conditions most likely to be affected by the proposed action are described in more detail below for action area watersheds used by ESA-listed Chinook and steelhead. More detail can be found for other WCIs and other subwatersheds in Appendix C of the BA (Stantec 2024).

2.9.2.2.1. EFSFSR

The EFSFSR is a tributary to the SFSR. The EFSFSR between its confluence with Sugar Creek upstream to the YPP lake is 0.75 mile, and upstream to the confluence with Meadow Creek is 3.8

miles. This stream reach includes the YPP lake, immediately upstream from which is the high gradient cascade that is a complete barrier to upstream passage for all fish species including migrating Chinook salmon and steelhead. As previously mentioned, Chinook salmon also spawn and rear in the stream reach upstream from the lake in years that they have been introduced there by the IDFG. Downstream from the YPP lake, this stream reach is accessible to all life stages of Chinook and steelhead.

Between Meadow Creek and the YPP Lake, the EFSFSR widens and has larger streambed material (including abundant cobble and boulders), relative to the upper EFSFSR. This stream reach has moderate to high stream gradients (approximately 2 to 8 percent) (HDR 2016). Moving downstream to the confluence with Sugar Creek, the EFSFSR is similar in width, gradient, and substrate material as upstream, but many of the larger boulders and cobble are sharp and more angular. Based on field surveys conducted by Rio ASE (Rio ASE 2019), there are more and deeper pools upstream from the YPP Lake. The EFSFSR generally supports a healthy riparian corridor, with the exception of areas near the YPP Lake and areas of legacy mine waste dumps along the banks upstream and downstream from the YPP Lake.

The EFSFSR between Meadow Creek and Sugar Creek has been heavily impacted by legacy mining activities. In addition to the YPP Lake, a remnant of legacy mining activities, these impacts include waste rock dumps in and adjacent to the stream channel, tailings washed down from Meadow Creek valley, roads and infrastructure within and adjacent to the EFSFSR channel, dam construction across the EFSFSR main channel, and other legacy impacts (Midas Gold 2016). There are efforts currently underway by EPA to remove contaminated soils caused by historic mining on the EFSFSR, with one site just downstream from the YPP Lake, and two sites upstream of the YPP Lake. The uppermost site, which is located just downstream from the Meadow Creek confluence, was restored during the summer of 2023. Restoration included removal of contaminated tailings and mine waste located within channels and floodplain of the EFSFSR and its tributaries, and the diversion of surface water around mine wastes that were sources of metals to the stream, and improving both water quality and fish habitat complexity (NMFS No: WCRO-2022-03035).

Benthic macroinvertebrates (BMI) in the EFSFSR have been sampled for five years at five locations. All sample locations (one site downstream from Sugar Creek confluence, one site immediately upstream from Sugar Creek confluence, two sites below Meadow Creek, and one site upstream from Meadow Creek) are inhabited by a BMI community that is intolerant of organic pollution and generally poor water quality conditions (EcoAnalysts, Inc. and MWH Americas, Inc. 2017). Results also indicate there is little to no impact of metals on the macroinvertebrate community (i.e., relatively intolerant of metals contamination) at the sites. The macroinvertebrate community at the site below the YPP appears to be impacted by historic mining in the area, as the community composition at this site includes a larger proportion of filterers (e.g., blackfly larvae) and higher metals tolerant index (MTI) values. Other sites exhibiting potential decreases in water quality include an increase in MTI values in the EFSFSR below Sugar Creek (EcoAnalysts, Inc. and MWH Americas, Inc. 2017).

2.9.2.2.2. Yellow Pine Pit Lake

During mining activities during the 1930s through the 1950s, the nearly 5-acre YPP lake was created by open-pit mining while the EFSFSR was diverted through the Bradley Tunnel to Sugar

Creek (Hogen 2002). After mining ceased in 1952, the EFSFSR was allowed to flow through the abandoned mine pit. The pit currently has a maximum depth of approximately 36 ft. Diverting the EFSFSR back into the stream channel and pit created a long cascade with a high gradient cascade that precluded fish passage upstream into the upper watershed. Therefore, all streams upstream from the YPP Lake are inaccessible to anadromous Chinook salmon and steelhead without human intervention. The YPP Lake is used by both fish and mammals, including Chinook salmon, bull trout, and river otters. Mountain whitefish are abundant in the lake (Brown and Caldwell 2019; Brown and Caldwell 2020b).

The YPP Lake is the largest feature that affects flow rates in the EFSFSR; however, because of its small area, it affects low flows only slightly and does not affect high flows at all (Kuzis 1997). The lake also displays thermal stratification (i.e., order).

2.9.2.2.3. Meadow Creek

Meadow Creek, located within the upper EFSFSR subwatershed, is a major tributary to the EFSFSR that flows through a flat-bottomed valley surrounded by steep mountains. Elevations range from 3,937 ft. above sea level in the lower reach to over 7,546 ft. in the headwaters. Meadow Creek has been heavily impacted by legacy mining-related activities, including deposition of tailings and spent heap leach ore, ore processing facilities, heap leach pads, and other infrastructure, stream relocation into a straightened riprap channel, and construction of an airstrip (Midas Gold 2016). The downstream end of the valley shows remnant effects from early mining activities, along with a large outwash feature created by a dam failure in the EFMC. Portions of the creek have been modified over the years to improve conditions caused by past mine operations, including the regrading and revegetation of the 2 percent gradient lower reach of the creek in 2004 and 2005.

The middle reach of Meadow Creek is an engineered channel that was constructed to bypass the SODA. The channel was lined with riprap over geotextile fabric and is confined between reinforced/engineered slopes with a gradient of less than 2 percent. This reach has a short section with a 9 percent gradient, shallow depths, and few pools, which may be a partial fish migration barrier at low flows. The channel includes low-gradient riffles, glides, and runs. There is no side-channel development or potential LWD recruitment.

Upper Meadow Creek encompasses the headwaters downstream to the location of proposed TSF Buttress. Upper Meadow Creek is confined and high gradient at the most upstream extent and low gradient and unconfined immediately upstream from the SODA in lower Meadow Creek, transitioning from a gradient of 4 to 8 percent to 2 to 4 percent. Habitat is composed of riffles, step runs, and pools. The presence of side channels in some portions provide potential for lateral channel movement in the less confined sections. Immediately upstream from the SODA, Meadow Creek is unconfined, with a gradient less than 1 percent. The reach is composed of low-gradient riffle, step run, and pool habitat. The floodplain is active with oxbow cutoffs, side channels, and backwater features.
BMI in Meadow Creek have been sampled for five years at three locations. All sample locations (two sites downstream from EFMC and one site in the rock engineered reach upstream from EFMC) are inhabited by a BMI community that is generally intolerant of organic pollution and generally poor water quality conditions; however, the BMI at these locations may be slightly

more stressed than those in the EFSFSR. Results also indicate there is little to no impact of metals on the macroinvertebrate community at the sites.

2.9.2.2.4. EFSFSR - Headwaters

Upstream from the Meadow Creek confluence, the EFSFSR is characterized by narrower channels with moderate gradient (2 to 4 percent), transitioning to higher-gradient (4 to 8 percent) step-pool habitat farther upstream. Overall substrate size is generally smaller than downstream reaches, with sand, gravel, smaller cobble, and boulders. This reach of the EFSFSR has relatively abundant riparian vegetation and large amounts of LWD.

Kuzis (1997) found that the Headwaters EFSFSR displays evidence of a high sediment load, such as streambed aggradation (deposition of material), channel splitting, pool filling, and overbank deposits of fines. The combination of low-gradient, relatively wide valley, plentiful wood supply, and a high sediment supply have resulted in current channel conditions.

2.9.2.2.5. EFSFSR - between Sugar Creek and Profile Creek

The EFSFSR downstream from Sugar Creek is adjacent to the SGP mine site in the No Mans-EFSFSR subwatershed. Stibnite Road (CR 50-412) closely parallels the EFSFSR along its entire length of the action area. The EFSFSR ranges from low-gradient habitat with pools to high gradient habitat with cascades. Substrate throughout the reach is variable, and dependent on the gradient, with the lower-gradient sections dominated by gravel and cobble, while the higher-gradient units are dominated by large cobble and boulders. Avalanches in 2014 have resulted in high concentrations of LWD in the EFSFSR downstream from Sugar Creek (MWH 2017). In April 2019, a series of avalanches and related landslides caused extensive damage to Stibnite Road (CR 50-412), and pushed snow, timber, and other debris into the EFSFSR (Midas Gold 2019a). These events were naturally occurring in burn areas and were related to rain-on-snow events.

2.9.2.2.6. Sugar Creek

The Sugar Creek subwatershed is a priority ACS subwatershed. Sugar Creek flows into the EFSFSR downstream from the YPP. It is a relatively low-gradient stream. A gated maintenance USFS road closely parallels Sugar Creek for nearly 2 miles; however, this is a ML1 road, a road closed to public motorized use. Much of Sugar Creek has large aggregates of LWD. The dominant substrates are sand, gravel, and cobble. Sugar Creek has widened channels, and excessive medial and lateral bar formation in response to past sediment inputs. In the 1940s, approximately 1 million cubic yards of glacial overburden was removed from the EFSFSR channel and placed in both Sugar Creek and other parts of the EFSFSR (Kuzis 1997).

BMI in Sugar Creek have been sampled for five years at two locations. All sample locations (one site upstream from and one site downstream from West End Creek) are inhabited by a BMI community that is intolerant of organic pollution and generally poor water quality conditions. While data gathered by MWH (2017) suggests macroinvertebrate communities can be considered to be in good condition based on community composition metrics, Kraus et al. (2022)

reported decreased insect biodiversity in Sugar Creek as a result of upstream historic mining impacts and associated mercury loading to the stream network.

2.9.2.3. **Johnson Creek**

A portion of Johnson Creek flows through the Porcupine Creek-Johnson Creek subwatershed, which has been identified as an ACS priority subwatershed. Johnson Creek flows from its origin near Deadwood Summit approximately 32 miles to its confluence with the EFSFSR near the town of Yellow Pine. It is the largest tributary stream of the EFSFSR. The Johnson Creek watershed encompasses 213 miles. Major tributaries to Johnson Creek include Riordan, Trapper, Burntlog, Ditch, Halfway, Rustican, Sheep, Lunch, Landmark, Rock, and Boulder Creeks.

Roads are the foremost cause of soil erosion in the Johnson Creek drainage – much of Johnson Creek Road is next to Johnson Creek. Roads have contributed up to 90 percent of the management induced sediment. Landslides occur naturally, resulting in the addition of sediment, substrate, and LWD; however, the frequency and magnitude of landslide events have greatly increased due to the construction of roads (Rabe and Nelson 2010).

2.9.2.3.1. Burntlog Creek

Burntlog Creek flows through the Lower and Upper Burntlog Creek subwatersheds, which have been identified as ACS priority subwatersheds. Burntlog Creek, a tributary of Johnson Creek, is a moderate-gradient stream that parallels Johnson Creek in the lowest reaches and occupies a steep valley floor in the upper reaches of the drainage. It is approximately 14.1 miles long, with approximately 3.2 miles upstream from the Burnt Log Road crossing. Tributaries of Burntlog Creek that cross the Burnt Log Road include East Fork Burntlog Creek and Peanut Creek. Burntlog Creek is characterized by a granitic watershed geology. Substrate samples measured at two locations sampled for six years show relatively low cobble embeddedness levels (around 8 percent) and multi-year estimates of free matrix estimates ranging from 51 to 56 percent (Stantec 2020); both cobble embeddedness and free matrix are considered FA at these survey sites. The upper reaches have moderate amounts of LWD from extensively burned areas, and minimal overhead canopy. The dominant substrates are sand, gravel and cobble.

2.9.2.3.2. Trapper Creek

A portion of Trapper Creek flows through the Porcupine Creek-Johnson Creek subwatershed, which has been identified as an ACS priority subwatershed. Trapper Creek, a tributary of Johnson Creek, is approximately 9.2 miles long, with approximately 4.1 miles upstream from the existing Burnt Log Road crossing. Trapper Creek has a high gradient passage barrier approximately 0.75 miles upstream from its confluence with Johnson Creek. The downstream portion consists of large boulders and cascades. Trapper Creek is characterized by a granitic watershed geology. The lower reach of Trapper Creek has a low cobble embeddedness level (around 3 percent) and free matrix values are FA (Stantec 2020). The mid-section of Trapper Creek has an abundant LWD count (MWH 2017). The stream’s dominant substrates are gravel and cobble.

2.9.2.3.3. Riordan Creek

Riordan Creek, a tributary of Johnson Creek, is approximately 9.8 miles long with less than 0.12 miles upstream from the Burntlog Road crossing. Riordan Creek is a relatively low-gradient stream. Roughly halfway down the length of the stream is Riordan Lake. Downstream from the lake, Riordan Creek has a slightly higher gradient, particularly just before it enters Johnson Creek. A trail with bridges that are open to small off-road vehicles crosses the creek several times above and to the north side of the lake. The dominant substrates are sand and gravel.

2.9.2.4. **Watershed Condition Indicators**

Not all WCIs are equal in terms of evaluating the potential impacts of the SGP within the mine site. Some baseline WCIs are of historical interest, some will not be affected by the SGP. For these reasons, NMFS selected WCIs that have the greatest potential to accurately identify potential impacts of the SGP on the ability of the PBFs to support all anadromous salmonid life stages. The five WCIs selected for detailed analysis in this opinion include:

- Water Temperature;
- Sediment/Turbidity;
- Chemical Contaminants;
- Physical Barriers; and,
- Change in Peak/Base Flows.

The conditions of each of these WCIs will be discussed in more detail below. Baseline conditions for all WCIs are presented in Appendix C of the BA.

2.9.2.4.1. Water Temperature

Stream temperatures at the mine site are believed to be influenced by a combination of past mining activities, loss of shade from forest fires, as well as climate change (Baldwin and Etheridge 2019). Continuous temperature data has been collected since 2011 (Figure 26) (some gages have a longer period of record) at the following five USGS gages:

- Meadow Creek (upstream of historic mining impacts): USGS Gage 13310850
- EFSFSR (upstream of Meadow Creek): USGS Gage 13310800
- EFSFSR (downstream of Meadow Creek): USGS Gage 13311000
- EFSFSR (upstream of Sugar Creek): USGS Gage 13311250
- Sugar Creek (upstream of EFSFSR): USGS Gage 13311450

As shown in Figure 26, and based on data recently collected at the five gaging stations above, baseline water temperatures in the upper EFSFSR and Meadow Creek are fully supportive of spawning, rearing, and migration for Chinook salmon and steelhead. Water temperatures in the lower sites are generally supportive of juvenile rearing for Chinook salmon and steelhead. Stream temperatures in the EFSFSR below Meadow Creek typically don’t drop below 13°C until after early September. Temperatures are slightly cooler downstream in the EFSFSR, dropping below 13°C slightly sooner – in late August. Sugar Creek exhibits similar temperature patterns as the EFSFSR below the YPP.

Climate change is expected to impact stream temperatures into the future. The NorWeST summer stream temperature model, produced by the USFS Rocky Mountain Research Station (Isaak et al. 2016), provides a variety of scenario-based predictions for mean August stream temperatures. These are presented alongside average August temperatures obtained at the USGS gaging stations at the mine site to provide information regarding the possibility of changing climate conditions in the analysis area (Table 31). Under baseline conditions, August mean stream temperatures may warm by about 1.5°C.

Table 31. Comparison of Average August temperatures for gaging states at the mine site with NorWeST Model Stream Temperatures (Mean August Temperatures) for Multiple Time Periods.

Gage Station	Average August Temperatures (°C)	NorWeST Model Stream Temperature (°C)		
		1993 – 2011	2030-2059[1]	2070-2099[1]
13310800 EFSFSR above Meadow Cr.	8.3	9.95	11.2	12.01
13310850 Meadow Cr	9.4	9.49	10.73	11.53
13311000 EFSFSR at Stibnite	10.5	10.85	12.13	12.95
13311250 EFSFSR above Sugar Cr	12	11.57	12.86	13.70
13311450 Sugar Creek	10.1	9.97	11.22	12.03

Source: Isaak et al. 2016; USGS 2024
Key: °C = degrees Celsius;
[1]This is the A1B warming trajectory.

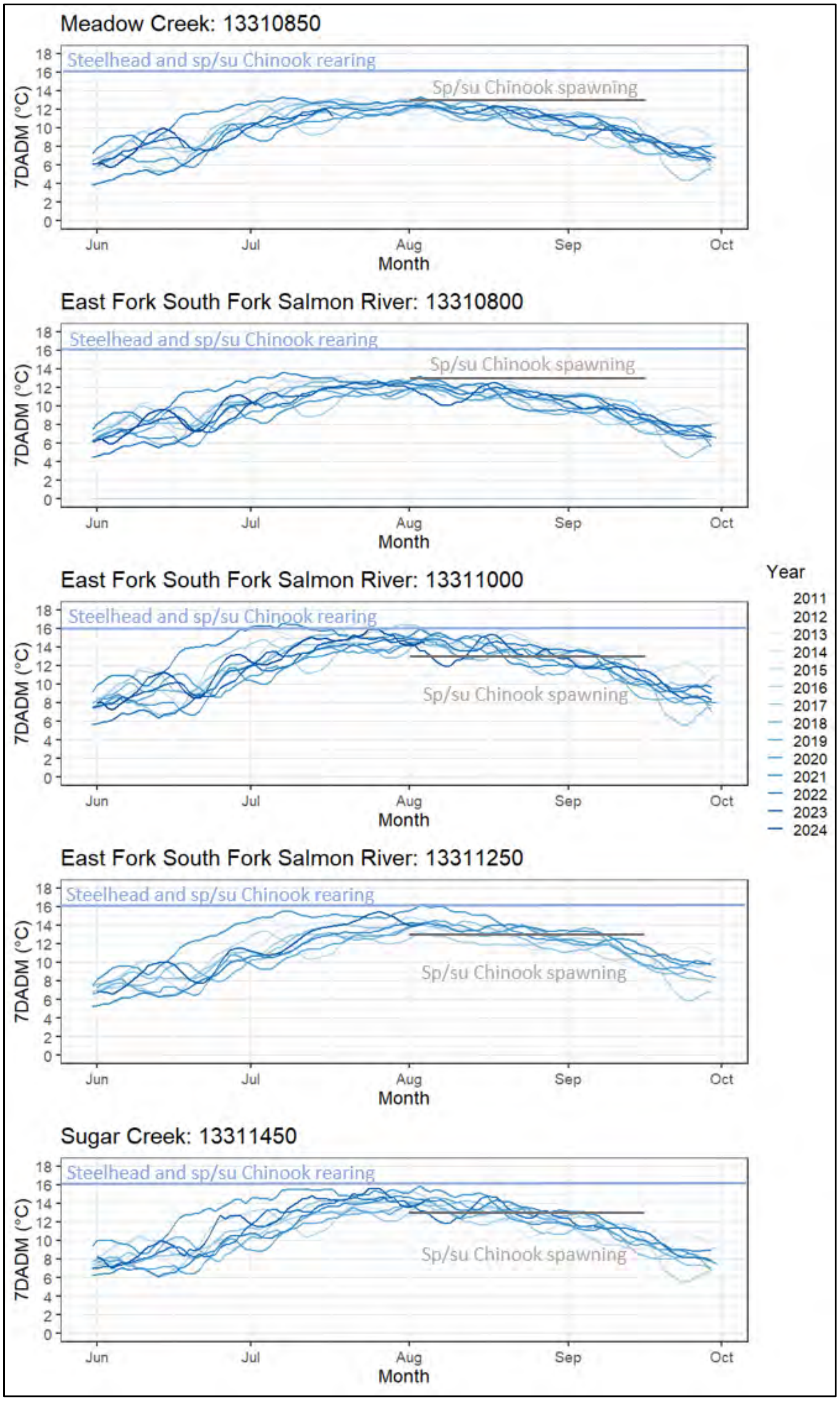


Figure 26. Seven Day Average Daily Maximum (7DADM) Temperatures in Degrees Celsius at Five USGS Gaging Stations at The Mine Site. Temperature Data Collected From 2011 Through 2024.

2.9.2.4.2. Sediment and Turbidity

Substrate monitoring has occurred since 2010, with sites spread out across the Stibnite Analysis Area (BA Figure 4.1-1). Stantec (2024) measured these sites annually, so the data are best interpreted as a measure of annual, watershed scale conditions and trends, rather than site-specific effects from point sources of sediment. Generally high embeddedness relative to reference conditions could indicate degraded conditions in a watershed, while low embeddedness indicate favorable conditions in a watershed.

Nelson and Burns (2005), Nelson et al. (2006), and Zurstadt et al. (2016), describe a method to rate the interstitial sediment deposition indicator. The rating system is used in this analysis to describe the current condition of the interstitial sediment deposition WCI in the analysis area. Background levels of sediment deposition are generally lower in areas dominated by non-granitic lithology (Nelson et al. 2006); however, the watershed geology within the analysis area is granitic.

The current existence, use, and maintenance of the Stibnite Road, Quartz Creek Road, and historical mining disturbance in the Stibnite area continue to be a source of existing and potential anthropogenic sediment to the EFSFSR. Because they occur in the same geology and have experienced similar weather and management activity, analysis area tributaries that lack data are expected to have embeddedness levels comparable with those measured in other tributaries.

The floods of 2008 and landslides in 2018 and 2019 deposited sediment into the EFSFSR and the sediment accumulations behind log jams and debris fans that were created are evident. However, it also may be that the influx of diverse particle sizes and LWD were more beneficial than deleterious because the system was deficient in LWD, and anadromous salmonid spawning sites were limited downstream of the town of Yellow Pine.

A variety of past disturbances at the SGP mine site affected streambank stability and erosion, and the proximity to existing roads have affected the sediment levels in the streams. However, substrate/sediment monitoring between 2012 and 2019 showed most monitoring locations within the mine site area at a FA level. Currently, following storm events, high levels of sediment are released from the EFMC, the largest single source of sediment in the watershed, resulting in increased turbidity.

2.9.2.4.3. Passage Barriers

Fish passage barriers were identified and described within the SGP mine site (BioAnalysts 2021). BioAnalysts (2021) identified fish passage barriers, with five artificial barriers and one natural barrier in fish-bearing streams (BA Figure 4.1-2) (Stantec 2024). The status of these barriers was identified as either complete, meaning no fish species can pass at any time of year, or partial, meaning some or all fish may pass at moderate or high flows, but not at low flows. Artificial barriers can be attributed to various actions, for example, construction of culverts and stream alteration (BioAnalysts 2021). Table 32 presents the amount of total potential habitat upstream from each barrier for Chinook salmon and steelhead; those that do not have potential habitat for these species upstream from the barrier are not included in the table.

BioAnalysts (2021) identified major barriers to fish movement in the SGP mine site area including: (1) the high gradient cascade in the EFSFSR upstream from the YPP Lake; (2) EFSFSR box culvert; and (3) the high gradient cascade in Meadow Creek upstream from the confluence with the EFMC (at the downstream end of the engineered channel). The high gradient cascade in the EFSFSR upstream from the YPP Lake is a complete barrier to natural fish passage. The other two major barriers, the EFSFSR box culvert and Meadow Creek barriers, are flow-dependent partial barriers that can block seasonal migration, and only hinder migration of fish that reside in or were stocked upstream from the YPP Lake cascade barrier (i.e., translocated Chinook salmon).

Table 32. Existing Fish Passage Barriers at the SGP and Potential Habitat Under Baseline Conditions.

Barriers	Status	Potential Habitat Upstream from Barrier (miles)[1]
Chinook Salmon		
EFSFSR above YPP (02) Artificial – Gradient	Complete	5.51[2] 16.08[3]
EFSFSR (203) Artificial – Box Culvert	Partial	3.91[2] 14.35[3]
Meadow Creek (05) Artificial – Gradient	Partial	0.63[3] 4.23[3]
Steelhead		
EFSFSR above YPP (02) Artificial – Gradient	Complete	5.42[2]
EFSFSR (203) Artificial – Box Culvert	Partial	4.28[2]
Meadow Creek (05) Artificial – Gradient	Partial	1.05[2]

Notes:
[1] Not all of the Total Habitat is considered usable/accessible habitat.
[2] Results based on accessible Intrinsic Potential Habitat for early life stages of Chinook salmon and steelhead.
[3] Results based on usable/accessible Critical habitat for all life stages modeled for Chinook salmon.
Key: EFSFSR = East Fork South Fork Salmon River; YPP = Yellow Pine Pit

2.9.2.4.4. Chemical Contaminants

Baseline water quality at the mine site is influenced by both natural mineralization and historical mining activity (Baldwin and Etheridge 2019). Locally, remnant features from historical mining include underground mine workings; multiple open pits; development rock dumps, piles, and tailings deposits; heap leach pads and spent heap leach ore piles; contaminated soils from the former mill and smelter sites; former surface water diversions, dams, townsites, and roads; and an abandoned water diversion tunnel (Midas Gold 2016). Detailed descriptions of existing chemical contaminant conditions in streams, sediments, and biota within the action area are available in Midas Gold (2019b), HDR (2017), and MWH (2017). This section summarizes baseline contaminant conditions in the water column, sediments, and biota. Because the toxicity of many contaminants is dependent upon other water chemistry conditions, we have included a brief summary of major ions, pH, and TDS.

Major Ions, pH, and TDS. The average baseline major ion chemistry for the surface water assessment nodes (refer to Figure 4.1-3 in the BA [Stantec 2024]) is summarized in Table 33. The EFSFSR and Sugar Creek sampling locations each exhibit a calcium-magnesium-bicarbonate water type, meaning that calcium and magnesium are the dominant cations in solution, and bicarbonate is the dominant anion. The samples from Meadow Creek had on average a higher relative proportion of calcium and are therefore classified as calcium-bicarbonate water.

Average TDS concentrations also were consistent in the Meadow Creek and EFSFSR sampling locations. The average TDS ranged from 56 to 57 mg/L in the Meadow Creek samples and appears to increase downstream in the EFSFSR from about 53 mg/L in the farthest upstream reach (YP-SR-10) to 67 mg/L in the downstream reaches. It appears that despite the higher TDS load in Sugar Creek (116 mg/L), the creek does not appreciably contribute to TDS concentrations in the EFSFSR, based on the similar average TDS concentrations obtained for the EFSFSR sampling points located just upstream (YP-SR-4) and downstream (YP-SR-2) of the Sugar Creek confluence.

Baseline samples from Fiddle Creek exhibited a slightly different water quality signature compared to the EFSFSR and Meadow Creek. Although Fiddle Creek is classified as a calcium-bicarbonate water, the creek has a lower proportion of magnesium and a higher proportion of sodium compared to the other monitoring locations. It also has a lower proportion of sulfate and higher proportion of bicarbonate. Some of these differences may be due to the relatively low average TDS concentration observed in Fiddle Creek during the baseline monitoring period (36 mg/L). The low sulfate and TDS concentrations also could point to a lack of mineralized deposits and historical mining-related impacts in the Fiddle Creek drainage, and different lithologies in the catchment area, specifically calcareous rock formations.

West End Creek stands out as having the most notably different major ion signature among the surface water assessment nodes (BA Figure 4.1-3) (Stantec 2024). During the baseline period, West End Creek surface water exhibited a calcium-magnesium-bicarbonate-sulfate water type. With the exception of chloride and sodium, the West End Creek samples also had the highest major ion constituent concentrations among the surface water assessment nodes considered, with baseline sulfate and TDS concentrations averaging 57 and 209 mg/L, respectively. West End Creek sample point YP-T-6 is located downstream of both the upper and lower historical West End waste rock dumps; it is therefore possible that the water chemistry at this location has been influenced by the waste material, especially where the creek flows directly through historical development rock piles. Mapped metamorphic bedrock in the West End valley (including marble, quartzite, and schist) in contrast to granitic batholith rocks in the EFSFSR drainage also may affect the stream chemistry, as these rock types locally tend to produce higher TDS and alkalinity (SRK 2021a).

Table 33. Average Major Ion Chemistry for Surface Water Assessment/Prediction Nodes (mg/L)

Node	Stream	# of Samples	pH	Hardness as $CaCO_3$	Bicarbonate as $CaCO_3$	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulfate	TDS	Water Type
YP-T-27	Meadow Creek	45	7.3	37.4	38.4	11.5	1.25	2.13	0.87	2.44	5.97	57	Calcium-bicarbonate
YP-T-22	Meadow Creek	45	7.4	37.5	39.5	11.3	1.00	2.18	0.84	2.42	5.16	56	Calcium-bicarbonate
YP-SR-10	EFSFSR	45	7.4	35.3	38.7	10.3	0.63	2.25	0.78	2.12	4.15	53	Calcium-magnesium bicarbonate
YP-SR-8	EFSFSR	45	7.5	39.1	42.2	11.4	0.73	2.55	0.83	2.36	6.77	60	Calcium-magnesium bicarbonate
YP-SR-6	EFSFSR	45	7.4	39.0	40.3	11.4	0.68	2.54	0.83	2.34	6.44	58	Calcium-magnesium bicarbonate
YP-SR-4	EFSFSR	45	7.5	43.8	42.5	12.7	0.63	2.89	0.88	2.30	8.86	65	Calcium-magnesium bicarbonate
YP-SR-2	EFSFSR	45	7.6	48.4	48.1	14.4	0.52	3.01	0.85	2.31	9.31	67	Calcium-magnesium bicarbonate
YP-T-6	West End Creek	45	8.4	179	120	43.1	<0.20	17.6	1.94	1.10	56.7	209	Calcium-magnesium bicarbonate-sulfate
YP-T-1	Sugar Creek	46	7.7	54.2	56.1	16.5	<0.20	3.09	0.76	2.24	9.00	116	Calcium-magnesium bicarbonate

Source: Data obtained from Midas Gold 2019b.
Note: Units are milligrams per liter except for pH, which is in standard units.
Values in the table represent the average of sample results collected between 2012 and 2018.
Average concentrations for calcium, magnesium, potassium, and sodium represent the dissolved fraction.
Key: $CaCO_3$ = Calcium Carbonate; EFSFSR = East Fork South Fork Salmon River; mg/L = milligrams per liter; TDS = total dissolved solids.

Field-measured pH values for the surface water assessment nodes were generally in the range of 7 to 8 standard units. The highest average pH (8.4) was observed at West End Creek sample location YP-T-6. Elevated baseline pH measurements at this location are likely another indicator of the geochemical influence exerted by legacy waste rock material, natural mineralization, and the predominance of carbonate bedrock in the West End Creek drainage. Overall, the neutral to alkaline pH values observed in streams near the mine site show that the geochemistry of the natural mineralized deposits and the legacy mine materials is not conducive to acidic drainage.

Contaminants of Concern. The Surface Water Quality Baseline Study (HDR 2017) showed that most metals analyzed in mine site streams occur at concentrations that are below the strictest potentially applicable surface water quality standard. We focus our review on four contaminants of concern: copper, antimony, arsenic, and mercury. These four contaminants were selected because existing and potential future concentrations may reduce individual fitness and the ability of the habitat to support successful spawning, rearing, and migration.

Naturally occurring mineralization and historical mining activity have resulted in surface water quality impairments for arsenic, antimony, and mercury (Baldwin and Etheridge 2019). As such, recent surface water baseline studies conducted by both Perpetua and USGS have attempted to characterize antimony, arsenic, and mercury concentrations in the Headwaters EFSFSR and Sugar Creek subwatersheds.

Table 34 provides the baseline conditions for the four contaminants of concern compared to the applicable screening levels. NMFS uses the phrase “screening level” to reduce potential confusion since not all levels are equivalent to existing aquatic life criteria. At the time of this opinion, only copper had aquatic life criteria that had undergone ESA consultation and were effective for CWA purposes. Antimony does not have aquatic life criteria. The screening levels for mercury and arsenic are equivalent to the reasonable and prudent alternatives identified by NMFS (2014). Additionally, the mercury screening levels are very similar to the recently proposed aquatic life water column criterion for mercury in Idaho (EPA 2024)

Water quality in the mine site area, particularly in the EFSFSR and in Sugar Creek have chemical constituents, particularly arsenic, antimony, copper, and mercury, that exceed screening levels (USFS 2023a). Copper exceeds the screening level in Sugar Creek but is well below the screening level in the other mine site area streams. Antimony and arsenic exceed screening levels in all streams that can support ESA-listed fish in the project area. Mercury exceeds the screening level in the EFSFSR and in Sugar Creek. Table 34 provides a summary of the measured concentrations of these chemical constituents. Figure 4.1-3 in the BA (Stantec 2024) provides the monitoring locations corresponding with the nodes shown in Table 34. These chemical constituents have the potential to affect the growth and survival of Chinook salmon and steelhead at their current concentrations.

Table 34. Average Measured Constituent Concentrations at Monitoring Locations in the Mine Area.

Contaminant of Concern		Copper[1]			Antimony[2]			Arsenic[3]			Mercury[4]		
Screening Levels		2.4 µg/L			5.6 µg/L			10 µg/L			2 ng/L		
Node	Stream	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
YP-T-27	Meadow Cr.	0.3	0.1	0.7	6.1	2.04	16.9	35	11.8	60.7	2.5	<1	11.8
YP-T-22	Meadow Cr.	0.3	0.1	1	8.1	2.4	35.8	34	13.6	56.8	15.6	1.3	404
YP-SR-10	EFSFSR	0.2	<0.1	0.5	12	3.9	47.1	25	8.6	41.4	6.1	2.0	31.5
YP-SR-8	EFSFSR	0.3	0.1	2.6	17	5.7	61.8	28	12.3	48.7	6	1.6	20.1
YP-SR-6	EFSFSR	0.2	0.1	0.5	19	6.4	46.9	31	12.6	41.4	5.6	1.9	24.7
YP-SR-4	EFSFSR	0.3	0.1	0.6	31	10.4	62	63	20.8	105	5.9	<0.5	32.7
YP-SR-2	EFSFSR	0.2	0.1	0.6	22	6.8	38.2	45	14.7	71.1	41.3	3.1	395
YP-T-1	Sugar Cr.	8.5[5]	0.1	342[5]	34	3.4	8.6	13	6.5	22.4	159	9.6	2,380

Source: Midas Gold 2019b; SRK 2021a; and USFS 2023a (Table 6-9a);
Key: Cr. = Creek; EFSFSR = East Fork South Fork Salmon River; µg/L = micrograms per liter; ng/L = nanograms per liter, Avg = Average; Min = Minimum; Max = Maximum.
Notes: Screening levels pertain to protection of fish species. Arsenic and mercury criteria are based on total concentrations while copper and antimony are based on dissolved concentrations.
[1]Copper screening level is based on the chronic criterion, which was derived using the Biotic Ligand Model per guidance contained in IDEQ (2017b). A conservative chronic copper standard was estimated by applying the lowest of the 10th percentile chronic criteria based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams. Per the SGP Water Quality Management Plan (Brown and Caldwell 2020a), preliminary calculations using the Biotic Ligand Model and site-specific data have produced similar values (i.e., 2.6 ug/L chronic and 4.2 ug/L acute criteria for the mine WTP outfall and 1.5 ug/L chronic and 2.5 ug/L acute criteria for the working housing treatment plant outfall) to the standard derived using these regional classifications (i.e., conservative guidance of 2.5 ug/L chronic and 4.0 ug/L acute criteria for third order streams and 2.4 ug/L chronic and 3.9 ug/L acute criteria for the Salmon River Basin).
[2]Antimony does not have a specified NMFS or USFWS criteria; the screening level is based on EPA's human health chronic criterion for consumption of water and organisms is 5.6 µg/L.
[3]Arsenic: NMFS (2014) directed EPA to promulgate or approve new aquatic life criterion. In the interim, NMFS directed EPA to ensure the 10 µg/L human health criterion applied in all National Pollutant Discharge Elimination System permits. NMFS utilized this interim threshold as the screening level for our analysis.
[4]Mercury: NMFS (2014) directed EPA to promulgate or approve a new criterion. In the interim, implement the fish tissue criterion that IDEQ adopted in 2005 (IDEQ 2005). Where fish tissue is not readily available, then NMFS specified application of a 2 ng/L threshold (as total mercury) in the interim. NMFS utilized this interim water column threshold as the screening level for our analysis.
[5]Of the 38 dissolved copper values reported for YP-T-1, only one value was higher than 2.6 µg/L; therefore, it is likely that this single anomalous value of 342 µg/L was the result of a sampling, analytical, or data management error as all other observations were less than 2.6 µg/L.

Ambient water quality criteria for the protection of aquatic life have not been established for antimony, so a screening threshold of 5.6 µg/L was selected. This screening threshold is the water quality criterion for protection of human health for the consumption of water and organisms. Average antimony concentrations currently exceed the screening threshold at every assessment node (Table 34). Monitoring by Baldwin and Etheridge (2019) found that antimony in mine site streams primarily occurs in the dissolved phase (primarily as Sb(V)) (Dovick et al. 2015). Lower antimony concentrations were recorded during high flow periods, suggesting a groundwater source.

Dissolved copper concentrations were almost always below the Biotic Ligand Model-based copper criteria, which was selected as the screening threshold, at all sites. The BA (Stantec 2024) reported that of the 38 samples for Sugar Creek at YP-T-1, only one value was higher than 2.6 micrograms per liter (µg/L). This value was reported as 342 µg/L, and is considered to be an anomaly resulting from a sampling, analytical, or data management error.

The screening threshold for arsenic is 10 µg/L, which was selected based upon the analysis in the Idaho Toxics opinion (NMFS 2014). Arsenic concentrations currently exceed the screening threshold at all assessment nodes (Table 34). Monitoring by Baldwin and Etheridge (2019) found that arsenic in mine site streams primarily occurs in the dissolved phase and was negatively correlated with streamflow, suggesting groundwater is the primary source of instream arsenic concentrations.

The screening threshold for mercury is 2 ng/L, which was selected based upon the analysis in the Idaho Toxics opinion (NMFS 2014). Mercury in the environment originates from both natural and anthropogenic (human-caused) sources. The most significant source of mercury in Idaho is air deposition; however, in the action area, mercury concentrations in Sugar Creek and the EFSFSR downstream of its confluence with Sugar Creek are significantly influenced by the Cinnabar Mine Site (Baldwin and Etheridge 2019; Eckley et al. 2021; Holloway et al. 2017). Mercury concentrations currently exceed the 2 ng/L screening threshold in the EFSFSR below Meadow Creek and Sugar Creek (Table 34). Mercury concentrations are also elevated in the upper reaches of West End Creek.

Sediment and Tissue Concentrations. Baseline sediment, macroinvertebrate, and fish tissue metals concentrations are described in the Aquatic Resources 2016 Baseline Study report MWH (2017) and summarized in tables 3.5-23 through 26 in the BA (Stantec 2024). Collectively, these data indicate the amount of metal contaminants entering the aquatic food web in the project area under baseline conditions. Results specific to mercury and arsenic concentrations in sediments and macroinvertebrate tissues are summarized in Table 35). Sediment concentrations, under current conditions, are elevated above selected screening levels. Arsenic concentrations in macroinvertebrate tissues are elevated in the EFSFSR downstream of Meadow Creek, and in Meadow Creek downstream of the SODA. Concentrations of arsenic in macroinvertebrates collected at sites upstream of historic mining influence in Sugar Creek, Meadow Creek, and the EFSFSR are below screening levels (Table 35). MWH (2017) provided a comparison table of macroinvertebrate tissue concentrations documented in 1995 through 1997 and 2016 (Table 36). Macroinvertebrate tissue concentrations for the lower Meadow Creek sites are substantially improved following restoration activities that occurred in the mid 1990s and early 2000s.

Table 35. Metals Concentrations in Sediments and Macroinvertebrate Tissues Compared to Screening Levels (data collected in 2016).

Stream	MWH Site ID	Analyte		Sediment (mg/kg dry weight) Antimony	Sediment (mg/kg dry weight) Arsenic	Sediment (mg/kg dry weight) Mercury	Macroinvertebrate Tissue (mg/kg dry weight) Antimony	Macroinvertebrate Tissue (mg/kg dry weight) Arsenic	Macroinvertebrate Tissue (mg/kg dry weight) Mercury	Macroinvertebrate Tissue (mg/kg dry weight) Mercury[1]
		Screening levels (mg/kg)		2	9.8	0.18		>14		>0.2
EFSFSR (below Rabbit Cr)	013			6.9	44.6	4.45	0.58	9.39	0.25	0.04
EFSFSR (below Meadow Cr.	012			743	200	11.6	13.3	38.2	0.23	0.04
EFSFSR (below Garnet Cr.)	011			222	246	0.305	6.33	57.8	0.19	0.03
EFSFSR (YPP alluvial fan)	074			138	184	0.962	6.67	29.1	0.23	0.02
EFSFSR (YPP outlet)	073			164	611	0.46				
EFSFSR (downstream of YPP)	030			241	1640	0.64	21.3	572	0.19	0.13
EFSFSR (above Sugar Cr.)	007			152	1090	1.4	27.2	331	0.18	0.03
EFSFSR (below Sugar Cr.)	009			48	219	62.6	8.06	100	0.43	0.03
Meadow (background)	016			2.9	11.1	0.037	0.24	6.49	0.212	0.02
Meadow (above EFMC)	075			186	307	0.447	1	55.5	0.18	0.03
Meadow (below EFMC)	014			19.8	52.8	0.153	1.84	71.9	0.20	0.03
Sugar (near West End Cr.)	069			19.3	81.2	70.2	1.11	24	2.56	0.46
Sugar (below West End Cr.)	029			19	80	61.8	0.39	9.35	2.06	0.34

Key: EFSFSR = East Fork South Fork Salmon River; YPP = Yellow Pine Pit; mg/kg = milligrams per kilogram; PQL = Practical Quantitation Limit; YPP = Yellow Pine pit

Note: Shaded cells are higher than the applicable screening level.

[1]Mercury data in mg/kg wet weight

[2]Screening levels for sediment were obtained from EPA website on November 15, 2017, Freshwater Sediment Screening Benchmarks developed for Region 3, at https://www.epa.gov/risk/freshwater-sediment-screening-benchmarks.*Several samples had higher mercury PQL due to required dilutions.

Table 36. Comparison of Macroinvertebrate Tissue Metal Concentrations (mg/kg dry weight).

Stream	Site	Antimony				Arsenic				Mercury		
		1995	1996	1997	2016	1995	1996	1997	2016	1995	1997	2016
EFSFSR	009	4.58	11.2	2.48	8.06	43.8	1117	17.9	100	0.8	0.24	0.43
	007	21	43.7	16.9	27.2	320	333	79.4	331	-	<0.25	0.18
	011	14.4	27	12	6.33	49.7	74.9	23	57.8	0.4	<0.25	0.19
	012	57.4	14.9	12.8	13.3	130	75.9	44.5	38.2	-	<0.25	0.23
Meadow Creek	014	36.8	76.8	13.9	1.84	209	147	63.5	71.9	0.59	<0.25	0.20
	075	11	23.3	12	0.99	105	291	45	55.5	0.44	<0.33	0.18
Sugar Creek	029	1.59	-	<0.5	0.39	47.1	-	10.9	9.35	1.09	0.6	2.06
	069	0.7	9.24	<0.5	1.11	5.97	1.54	5.52	24	1.05	1.64	2.56

Source: URS Corporation 2000 for 1995-1997 data
Note: Concentrations are milligrams per kilogram dry weight.
Key: '- '= Not sampled or not analyzed

Results specific to fish tissue concentrations are summarized in Table 37. Arsenic and antimony concentrations were highest in fish collected from the EFSFSR. Mercury was highest in fish collected from Sugar Creek.

Available information indicates that methylation is occurring within the vicinity of the SGP. Current fish tissue concentrations in resident fish in Meadow Creek and the EFSFSR are below levels that are thought to be associated with adverse effects (Table 37) (MWH 2017). Total mercury concentrations in fish in Sugar Creek are at levels that could elicit adverse effects (Kraus et al. 2022; Eckley et al. 2021; MHW 2017). Bull trout whole body tissue concentrations were collected by the USGS (Rutherford et al. 2020) from Sugar, Cinnabar, and Cane Creeks. Whole body total mercury concentrations in bull trout collected from habitats upstream of mining influence were generally below 0.1 mg/kg wet weight (ww); whereas whole body samples from habitats influenced by mercury contamination from the Cinnabar Mine ranged from 0.1 to 0.314 mg/kg ww (Figure 27). The data did not show any apparent relationship between fish size and mercury tissue burdens.

Table 37. Fish Tissue Metals Concentrations (samples collected in 2015).

Stream	Site ID	Sample ID	Species	Analyte (mg/kg wet weight)[1]	Mercury	Antimony	Arsenic
				EPA 2015	0.5	9.0	2.0
				NMFS 2014	0.2 – 0.3		2.0 - 5.0
EFMC	MWH-027	1G	WCT		0.04	0.05	0.09
	MWH-027	2G	WCT		0.04	0.03	0.14
	MWH-027	3G	WCT		0.02	0.04	0.21
EFSFSR	EFSFSR01	5G	WCT		0.02	0.06	0.27
	EFSFSR02	6G	WCT		0.03	0.06	0.49
	EFSFSR03	1H	WCT		0.02	0.06	0.36
	EFSFSR04	2H	WCT		0.02	0.04	0.14
	EFSFSR05	4G	WCT		0.02	0.05	0.09
	Glory Hole	1A	WCT		0.02	0.12	0.07
	Glory Hole	2A	WCT		0.06	0.24	0.31
	Glory Hole	3A	WCT		0.03	0.15	0.15
	MWH-011	1F	WCT		0.03	0.16	0.11
	MWH-011	2F	WCT		0.03	0.07	0.10
	MWH-011	3F	WCT		0.03	0.11	0.18
	MWH-026	4A	WCT		0.02	0.34	0.09
	MWH-026	5A	WCT		0.05	0.09	0.04
	MWH-026	4B	WCT		0.07	0.06	0.13
	MWH-026	5B	WCT		0.05	0.06	0.05
Meadow Creek	MWH-014	3E	WCT		0.05	0.05	0.19
	MWH-014	4E	WCT		0.03	0.05	0.23
	MWH-014	5E	WCT		0.04	0.04	0.12
	MWH-016	1C	WCT		0.02	0.07	0.01
	MWH-016	2C	WCT		0.02	0.06	0.03
	MWH-016	3C	WCT		0.02	0.05	0.02
Sugar Creek	MWH-018	1D	Sculpin		0.20	0.06	0.05
	MWH-018	1E	WCT		0.07	0.05	0.06
	MWH-018	2E	Sculpin		0.09	0.04	0.05

Note: Effects thresholds obtained from literature derived values in EPA 2015 and NMFS 2014. Effects thresholds are mg/kg wet weight.
Shaded cells are higher than the applicable threshold. Bold text cells are the maximum concentrations for each metal.
[1] Laboratory values were in mg/kg dry weight but were converted to mg/kg wet weight for comparison with the effect's thresholds, which are typically in mg/kg wet weight. Values were converted using the equation: wet weigh =dry weight x [1-(percent moisture/100)]. Percent moisture used in the equation was 77.54, which is the value reported for muscle in EPA 2016. Concentrations below the MDL were not converted to wet weight and the MDLs are as noted below:
a Below MDL of 0.7 b Below MDL of 0.046 c Below MDL of 0.11 d Below MDL of 0.039 e Below MDL of 0.15 f Below MDL of 0.035 g Below MDL of 0.055
Key: EFMC = East Fork Meadow Creek EFSFSR = East Fork of the South Fork of the Salmon River; mg/kg = milligrams per kilogram; WCT = Westslope cutthroat trout

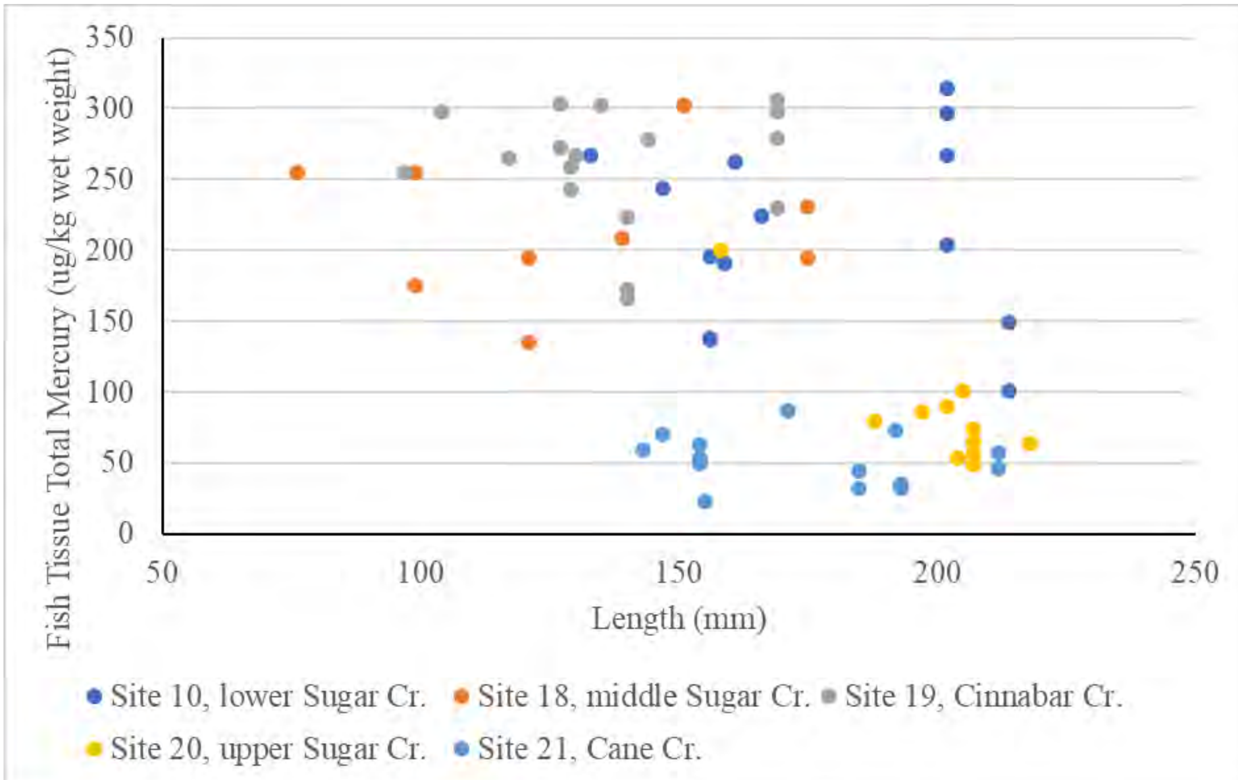


Figure 27. Total mercury concentrations in whole body bull trout samples collected from the Sugar Creek watershed. Upper Sugar Creek and Cane Creek represent "background" concentrations, and the remaining sites are influenced by mercury contamination at the Cinnabar Mine site.

2.9.2.4.5. Change in Peak/Base Flows

The SGP is located in mountainous terrain with typically narrow valleys and steep slopes. Elevations range from 6,000 to 6,600 ft. amsl along valley floors, rising to elevations exceeding 8,500 ft. amsl in the surrounding mountains (HydroGeo 2012a). Climate in the analysis area is characterized by wide annual, seasonal, and diurnal variations in temperature and humidity. The area typically has cold wet winters and hot dry summers, with most precipitation falling in October through May, and long periods of little or no precipitation common from mid-June through mid-September. During winter, storms typically move through the region resulting in seasonal snowfall accumulations of six feet or more. Cloudy and unsettled weather is common during the winter with measurable precipitation occurring on about one-third of the days (Brown and Caldwell 2017; Stantec and Trinity Consultants 2017).

The main EFSFSR valley floor is around 6,400 ft. in elevation and the tributary valleys—which are at higher elevations like Meadow, Fiddle, Hennessy, and Sugar Creeks—all show a strong and pronounced asymmetry with steeper south-facing slopes (Midas Gold 2017). South-facing slopes are more open to sunlight and warm winds and are thus generally warmer and dryer because of the higher levels of evapotranspiration compared to steep north-facing slopes.

A long-term climatological record is not available for the SGP. Therefore, Parameter-elevation Regressions on Independent Slope Model (PRISM) data compared with the National Weather Service and SNOTEL (snow telemetry) Secesh Summit site is used to develop average precipitation and temperature estimates (Table 38). The Secesh Summit site is located 35 miles northwest of the SGP, at a comparable elevation (Brown and Caldwell 2017).

Table 38. Estimated Average Monthly Precipitation and Temperature for the Analysis.

Month	Average Precipitation (inches)	Average Temperature (°F)	Minimum Temperature (°F)	Maximum Temperature (°F)
January	4.11	20.10	10.67	29.52
February	3.32	21.75	9.84	33.66
March	3.53	27.68	15.33	40.03
April	2.98	32.89	20.50	45.27
May	2.58	40.69	27.73	53.65
June	2.14	48.73	33.85	63.61
July	0.95	58.05	41.31	74.79
August	0.91	56.47	39.18	73.76
September	1.81	48.70	32.76	64.63
October	2.10	39.18	25.97	52.39
November	3.71	26.34	17.02	35.63
December	3.99	18.82	9.28	28.36
Annual	32.19	36.61	23.61	49.60

Source: 800-meter PRISM data, Brown and Caldwell 2017.

Because the action area includes the SFSR downstream from the EFSFSR, and flows in that reach are influenced by water use throughout the SFSR drainage, the analysis in this opinion considers water usage throughout the SFSR drainage. There is no large-scale agriculture in the SFSR drainage. The largest irrigated acreages include pastures and/or hay production for pack and saddle stock, and turf maintenance at the Johnson Creek Airport. Other water uses include domestic use at summer homes and support of residences and businesses in the Yellow Pine community; support of summer homes and businesses in the Warm Lake area; and operation of small (off grid) hydropower operations. Small amounts of water are also periodically diverted to facilitate USFS dust abatement and for fire-fighting operations, and are occasionally diverted to facilitate minerals exploration. Overall, water use in the SFSR drainage appears to be very light, based on the number and size (i.e., allowable diversion rates) of water rights and the lack of water rights on the vast majority of tributaries, and flow in most stream reaches is essentially unimpaired by water diversion/use. Based on water use, the action area is likely FA for peak/baseflow changes. However, base flows are relatively low, compared to the rest of the hydrograph, suggesting that base flows may be naturally more limiting of salmonid production than in other portions of the Salmon River drainage (e.g., the Upper Salmon).

There are three instream flow water rights with quantification reaches in the action area. These are 77-14196 on Sugar Creek, 77-14190 on the EFSFSR, and 77-14174 on the SFSR. The purposes of these instream flows are to preserve fish and wildlife, scenic values, and recreational values. The volume of these instream flows is equivalent to the unimpaired monthly 40 percent exceedance flows. As such, the establishment these instream flow water rights recognize the importance of greater than median flows for protection of aquatic resources. However, these water rights are be subordinate to all domestic, commercial, municipal, and industrial water rights, and therefore will not protect instream flows from the proposed action.

Streams. The SGP is in the Headwaters EFSFSR and Sugar Creek subwatersheds. The primary surface water features at the SGP include the EFSFSR and its tributaries, as well as intermittent drainages, ephemeral drainages, seeps, springs, wetlands, and ponds. These features include 10 named surface water channels: the EFSFSR, EFMC, Rabbit, Meadow, Garnet, Fiddle, Midnight, Hennessy, West End, and Sugar Creeks. Most of these streams occur in the Headwaters of the EFSFSR subwatershed except for Sugar and West End Creeks, which are in the Sugar Creek subwatershed. Brief descriptions of each stream are provided below, and specific drainage and channel characteristics are summarized in Table 39.

The EFSFSR is a perennial stream that flows from southeast to northwest through the SGP and has a drainage basin of 25 square miles upstream of its confluence with Sugar Creek. It is the principal stream draining the SGP and receives flow either directly or indirectly from all other drainages listed in Table 40. At ordinary high water, the EFSFSR is approximately 2 to 3 ft. deep and 25 to 30 ft. wide (Brown and Caldwell 2017).

Table 39. Summary of Stream Characteristics in the SGP Area.

Drainage	Approximate Drainage Area (square miles)	Channel Length (miles)	Elevation Change (feet)	Average Gradient (%)
EFSFSR (upstream of Sugar Creek)	25.0	7.04	2,129	5.7
Meadow Creek	7.7	4.78	1,570	6.2
EFMC	2.4	2.66	1,491	10.6
Rabbit Creek	0.6	1.19	1,506	24.0
Garnet Creek	0.5	1.24	1,558	23.8
Fiddle Creek	2.0	2.47	1,444	11.1
Midnight Creek	0.9	1.83	2,205	22.8
Hennessy Creek	0.7	1.16	1,499	24.5
West End Creek	0.6	1.55	2,234	27.3
Sugar Creek	17.4	7.14	2,356	6.2

Source: Brown and Caldwell 2017; HydroGeo 2012b

Historical mining activities have affected the course of the EFSFSR in the central portion of the SGP where it flows through the YPP Lake. The river enters the pit on the south side and exits from the north. The flow velocity of the EFSFSR slows as it passes through the YYP Lake, causing the river to drop much of its sediment load. The original YPP was excavated to a depth of 125 ft. below the current pit lake level, but sediment deposited through time has reduced the lake depth to only 35 ft. The lake has a surface area of approximately 4.75 acres and is estimated to contain approximately 92 acre-feet of water (Brown and Caldwell 2017). An artificial drop into the pit creates a steep whitewater cascade on the EFSFSR where it enters the pit and blocks upstream fish passage above the pit lake.

Meadow Creek originates southwest of the SGP, flows east into the EFSFSR, and drains an area of approximately 7.7 square miles. The Meadow Creek headwaters occur in an alpine lake, and the drainage contains multiple wetland complexes. At ordinary high water, Meadow Creek is approximately 2 to 4 ft. deep and 20 to 25 ft. wide at the bottom of the drainage (Brown and Caldwell 2017).

EFMC is a tributary to Meadow Creek that drains an area of 2.4 square miles in the southern end of the SGP. The creek previously supplied water to a reservoir that provided hydroelectric power and process water to the historical mill and smelter. EFMC is locally referred to as Blowout Creek because the dam forming the reservoir breached in 1965, causing large-scale scouring of the steep channel downstream, and deposition of an alluvial fan. From its headwaters, EFMC meanders through a former wetland area that dried up due to stream incision and declining groundwater levels related to the dam failure.

Rabbit and Garnet Creeks are small tributaries of the EFSFSR that drain 0.6 and 0.5 square miles, respectively. Rabbit Creek is in a steep drainage that has steep side slopes, with numerous seeps and springs occurring throughout its headwaters. Garnet Creek is formed from seeps and springs located in the eastern portion of the SGP. The current shop, camp facilities, and the historical Garnet Pit are in the Garnet Creek drainage. Historical waterworks from the 1940s and 1950s, as well as a 1990s diversion, are present below the former open pit.

Fiddle Creek occurs in a well-defined glacial cirque, drains an area of two square miles, and flows into the EFSFSR from the west. The drainage area for Fiddle Creek includes forested and open scree slopes. The middle reach of Fiddle Creek also contains a former reservoir and dam, and a former townsite occurs in the lower reach above and below the County Road. In addition, the creek itself was diverted from its natural outfall site to the north under the County Road through a culvert in the 1980s.

Midnight Creek is a small tributary that drains an area of 0.9 square miles and flows into the EFSFSR from the east, just above the YPP Lake. Several miles of current and historical exploration and haul roads exist in the Midnight Creek drainage.

Hennessy Creek is a small tributary that drains an area of 0.7 square miles and flows into the EFSFSR from the west. The upper end of the drainage is heavily forested, and the lower portion of the drainage has been modified by current access roads and historical mine workings. Hennessy Creek also has a historical water diversion just above the county road that included a large pipe system. The creek flows in the direction of, and then adjacent to, Stibnite Road (CR 50-412) in a channel around the Bradley Northwest mine dump complex, through a diversion installed in 2022 under the Stibnite ASAOC to avoid historical mine development rock piles, and through two culverts before entering the EFSFSR.

West End Creek flows into Sugar Creek from the south and has a drainage area of 0.6 square miles. The drainage basin of West End Creek was modified extensively and diverted into a now failed French drain system during construction of the large waste rock dump in the middle reach. The current creek flow disappears and reemerges among historical waste rock piles. Several miles of current and historical exploration roads are present in the West End Creek drainage.

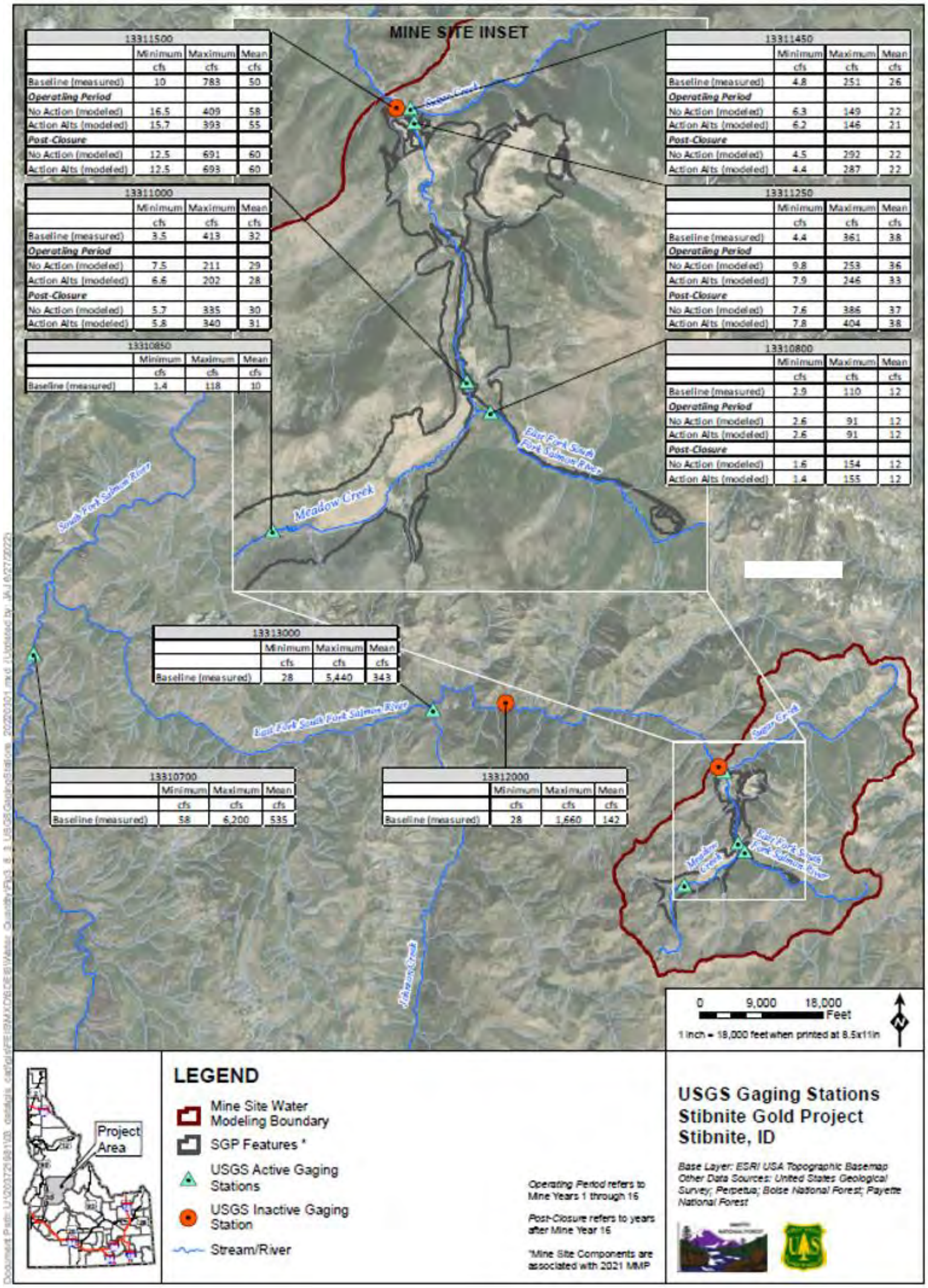
Sugar Creek drains an area of approximately 17.4 square miles and flows into the EFSFSR downstream of the YPP. A portion of the upper Sugar Creek valley has been impacted by past mercury mining activities at the former Cinnabar Mine, located in the upper Cinnabar Creek drainage which is a tributary to Sugar Creek. These activities included underground mine development and operations, development rock disposal, ore processing, deposition of tailings in the valley, construction and use of buildings and housing (several of which still exist), and road construction.

Nine USGS streamflow gages (Figure 27) in and near the analysis area provide data to characterize the existing environment. Table 40 provides streamflow statistics for these gaging stations, and Figure 27 presents average monthly discharge hydrographs for the six gaging stations in the project area. The hydrographs illustrate the snowmelt-dominated streamflow pattern observed in the area with flows beginning to rise in March and April and peaking in May or June, before receding to base flow conditions in late summer/fall and remaining low through the winter.

Baseflow and groundwater recharge estimates were derived using data from two of the USGS gaging stations in the analysis area (Brown and Caldwell 2017). Groundwater recharge over the Sugar Creek and EFSFSR drainage areas was calculated to 8.1 inches per year over the alluvial valley bottom areas and 6.2 inches per year in the bedrock dominated mountainous areas. These values represent about 20 percent of the estimated annual precipitation for the SGP analysis area, which is equal to 32.19 inches (Perpetua 2021d).

USGS data also were used to derive peak flow statistics for the seven major drainages in the analysis area. Results from the peak flow analysis were summarized in the baseline study (HydroGeo 2012b) and Table 41. Peak flows were calculated for the bottom of each drainage using the USGS StreamStats program (https://streamstats.usgs.gov/ss/).

In addition to the USGS data, streamflow data were collected in conjunction with surface water quality baseline sampling on a monthly or quarterly basis at 32 non-USGS monitoring stations (Figure 27). The monitoring points were selected at upstream and downstream locations to bracket historical and potential future mining activities in the analysis area (Brown and Caldwell 2017). Table 42 provides streamflow statistics derived from baseline measurements collected between 2012 and early 2016. The mean flows calculated from this dataset for the EFSFSR ranged from 4.47 cfs at the farthest upstream monitoring location YP-SR-14, to 31.31 cfs at the most downstream location YP-SR-2. Note that the baseline monitoring sites are at different locations than the USGS gaging stations, thus providing additional site-specific data proximal to historical and proposed facilities.



13311500	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	10	783	50
Operating Period			
No Action (modeled)	16.5	409	58
Action Alts (modeled)	15.7	393	55
Post-Closure			
No Action (modeled)	12.5	691	60
Action Alts (modeled)	12.5	693	60

13311000	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	3.5	413	32
Operating Period			
No Action (modeled)	7.5	211	29
Action Alts (modeled)	6.6	202	28
Post-Closure			
No Action (modeled)	5.7	335	30
Action Alts (modeled)	5.8	340	31

13310850	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	1.4	118	10

13311450	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	4.8	251	26
Operating Period			
No Action (modeled)	6.3	149	22
Action Alts (modeled)	6.2	146	21
Post-Closure			
No Action (modeled)	4.5	292	22
Action Alts (modeled)	4.4	287	22

13311250	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	4.4	361	38
Operating Period			
No Action (modeled)	9.8	253	36
Action Alts (modeled)	7.9	246	33
Post-Closure			
No Action (modeled)	7.6	386	37
Action Alts (modeled)	7.8	404	38

13310800	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	2.9	110	12
Operating Period			
No Action (modeled)	2.6	91	12
Action Alts (modeled)	2.6	91	12
Post-Closure			
No Action (modeled)	1.6	154	12
Action Alts (modeled)	1.4	155	12

13313000	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	28	5,440	343

13310700	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	58	6,200	535

13312000	Minimum cfs	Maximum cfs	Mean cfs
Baseline (measured)	28	1,660	142

Figure 28. USGS Gaging Stations, Stibnite Gold Project.

Table 40. USGS Gaging Station Drainage Area and Flow Statistics.

Gage Number	Gage Name	Drainage Area (mi^2)	Min (cfs)	Max (cfs)	Mean (cfs)	Period of Record (# years monitored)
13310850	Meadow Creek near Stibnite, Idaho	5.6	1.37	129	11.0	09/2011–02/2022 (10 years)
13310800	EFSFSR above Meadow Creek near Stibnite, Idaho	9.0	2.20	159	11.8	09/2011–02/2022 (10 years)
13311000	EFSFSR at Stibnite, Idaho	19.3	3.50	413	31.5	1928–1943 1982–1997 2010–2022 (41 years)
13311450	Sugar Creek near Stibnite, Idaho	18.0	4.00	252	22.9	09/2011–02/2022 (10 years)
13311250	EFSFSR above Sugar Creek near Stibnite, Idaho	25.0	4.39	366	36.9	09/2011–02/2022 (10 years)
13311500	EFSFSR near Stibnite, Idaho[1]	43.0	10	783	50.4	06/1928–09/1941 (13 years)
13312000	EFSFSR near Yellow Pine, Idaho[1]	107.0	28	1,660	142.4	08/1928–07/1943 (13 years)
13313000	Johnson Creek at Yellow Pine, Idaho	218.0	28	5,440	342.5	09/1928–02/2022 (93 years)
13310700	SFSR near Krassel Ranger Station, Idaho	330.0	35	6,200	536.6	10/1966–02/2022 (55 years)

Source: Brown and Caldwell 2017 – Table 7-9; Flow data from 2017-2022 updated from waterdata.usgs.gov.
[1] Inactive

Table 41. Peak Stream Flow Statistics for Drainages in the Analysis Area.

Drainage	1.5-year event	2-year event	2.33-year event	5-year event	10-year event	25-year event	50-year event	100-year event
	PK1.5 (cfs)	PK2 (cfs)	PK2.33 (cfs)	PK5 (cfs)	PK10 (cfs)	PK25 (cfs)	PK50 (cfs)	PK100 (cfs)
Meadow Creek (13310850)	83 (76-91)	98 (90-107)	105 (97-114)	132 (122-144)	152 (140-168)	175 (159-200)	191 (170-223)	205 (179-247)
EFSFSR above Meadow Creek (13310800)	83 (75-90)	97 (89-105)	104 (96-112)	130 (120-141)	149 (138-165)	171 (156-195)	186 (167-218)	200 (176-241)
EFSFSR below Meadow Creek (13311000)	174 (154-195)	215 (193-240)	235 (211-261)	316 (285-353)	379 (341-432)	454 (401-539)	507 (438-623)	557 (469-710)
EFSFSR above Sugar Creek (13311250)	229 (205-254)	279 (252-307)	301 (273-331)	395 (359-437)	466 (423-525)	550 (491-643)	608 (532-733)	662 (566-826)
EFSFSR below Sugar Creek (13311500)	372 (327-418)	465 (415-520)	508 (454-567)	693 (622-777)	837 (749-959)	1010 (888-1207)	1133 (973-1403)	1249 (1044-1606)
Sugar Creek (13311450)	143 (124-162)	181 (160-204)	199 (177-224)	278 (247-314)	340 (301-393)	415 (361-502)	469 (398-589)	520 (429-680)
Johnson Creek (13313000)	2,497 (2,268-2,727)	2,962 (2,713-3,230)	3,175 (2,911-3,563)	4,079 (3,737-4,491)	4,789 (4,356-5,375)	5,652 (5,058-6,592)	6,273 (5,521-7,574)	6,877 (5,936-8,617)

Source: Rio ASE 2021, Appendix C.

cfs = cubic feet per second; peak flow volume statistic reported followed by its 95 percent confidence interval in parentheses.

Table 42. Baseline Monitoring Surface Water Flow Statistics.

Monitoring Site	Stream	Min (cfs)	Max (cfs)	Mean (cfs)
YP-SR-2	EFSFSR	8.97	74.56	31.31
YP-SR-4		7.67	37.84	16.92
YP-SR-6		8.00	50.76	20.38
YP-SR-8		5.88	61.08	19.33
YP-SR-10		6.23	106.21	23.97
YP-SR-11		3.32	40.67	10.41
YP-SR-13		2.05	54.92	11.56
YP-SR-14		0.48	22.25	4.47
YP-T-1	Sugar Creek	5.71	78.06	21.24
YP-T-6	West End Creek	0.16	1.68	0.51
YP-T-37		0.003	0.12	0.03
YP-T-49		0.37	1.37	0.71
YP-T-7	Sugar Creek	5.25	34.12	12.51
YP-T-8A		4.61	77.36	19.27
YP-T-10	Midnight Creek	0.15	2.62	0.67
YP-T-42		0.12	3.59	0.99
YP-T-11	Fiddle Creek	0.22	20.57	3.30
YP-T-12		0.15	17.87	3.59
YP-T-15	Scout Creek	0.04	0.62	0.15
YP-T-21	Rabbit Creek	0.22	3.47	0.95
YP-T-22	Meadow Creek	3.91	86.61	17.94
YP-T-27		2.78	76.45	14.86
YP-T-33		1.96	41.13	9.22
YP-T-43		1.97	49.00	13.48
YP-T-29	EFMC	0.78	24.45	4.69
YP-T-35	Garnet Creek	0.01	1.16	0.19
YP-T-40	Salt Creek	0.80	13.38	2.80
YP-T-41	Hennessy Creek	0.15	7.37	1.25
YP-T-48		0.09	5.09	1.00
YP-T-44	Fern Creek	0.06	2.65	0.54
YP-T-45	North Fork Meadow Creek	0.24	19.01	3.92
YP-T-46	South Fork Meadow Creek	0.28	9.67	3.04

Source: Brown and Caldwell 2017.

USFS 2023b, Sections 6.2.4 and 6.2.5 provide a detailed description of the stream flows associated with the Stibnite portion of the action area, a summary of which is provided here.

USGS data were used to derive peak flow statistics for the ten major drainages in the analysis area (BA Figures 4.1-4 and 4.1-5) (Stantec 2024). Results from the peak flow analysis were summarized in the baseline study (HydroGeo 2012a) and are presented in the SGP Water Quantity Specialist Report (USFS 2023a). Peak flows were calculated for the bottom of each drainage using the USGS StreamStats program. Predicted peak flows for a 1.5-year event ranged from 1.84 cfs for West End Creek to 237 cfs for the upper EFSFSR, and for a 500-year event they ranged from 13.4 cfs to 931 cfs, respectively.

Base stream flow data were collected in conjunction with surface water quality sampling on a monthly or quarterly basis at 32 non-USGS monitoring stations (USFS 2023b; Brown and Caldwell 2017). The monitoring points were selected at upstream and downstream locations to bracket historical and potential future mining activities in the analysis area (Brown and Caldwell 2017). The mean flows calculated from this dataset for the EFSFSR ranged from 4.47 cfs at the farthest upstream monitoring location to 31.31 cfs at the most downstream location. Table 43 shows average monthly stream flows during the August to March low flow period at five gaging stations and location in lower Meadow Creek in the SGP mine site streams for the years 1929 to 2017.

Table 43. Average Monthly Stream Flow Year-Round and During the Low Flow Period for 1929 to 2017 at USGS Gaging Stations and One Meadow Creek Location.

Month	EFSFSR above Meadow Ck.: 13310800 (cfs)	EFSFSR at Stibnite: 13311000 (cfs)	EFSFSR above Sugar Ck.: 13311250 (cfs)	Sugar Creek above EFSFSR: 13311450 (cfs)	Meadow Ck.: 13310850 (cfs)	Meadow Ck.: MC-6 (cfs)
January	3.5	8.0	9.9	6.5	2.3	4.2
February	3.3	7.7	9.5	6.4	1.9	3.8
March	3.4	8.7	10.5	7.3	2.2	4.3
April	6.5	19.8	24.3	15.8	6.7	11.0
May	40.7	82.8	116.4	66.2	37.5	52.2
June	48.2	116.8	138.9	80.6	48.8	70.9
July	14.8	38.7	42.6	29.9	13.9	22.0
August	7.3	15.4	17.3	12.5	4.1	7.7
September	5.7	11.9	13.1	9.0	3.0	5.9
October	5.3	11.5	12.6	8.3	3.1	5.8
November	4.6	10.8	12.8	8.3	3.4	5.8
December	3.7	9.0	11.0	7.2	2.8	4.8
Average	4.6	10.4	12.1	8.2	2.9	5.3

Note: the low-flow period is August to March.
Key: cfs = cubic feet per second; Ck = Creek; EFSFSR = East Fork South Fork Salmon River; USGS = U.S. Geological Survey.

Climate change conditions resulting in increasing air temperatures will potentially transition snow to rain resulting in diminished snowpack and earlier season streamflow along with changes in groundwater recharge to aquifers that discharge to streams. Mean annual streamflow projections suggest a slight increase, but summer low flows are expected to decline (Halofsky et al. 2018).

A review of IDWR water right records indicates that there are no downstream consumptive-use water rights on the EFSFSR until after the river merges with Johnson Creek (HDR 2017). The IWRB maintains minimum streamflow rights on various rivers and creeks in the state, including a location near the end of the EFSFSR below the confluence with Johnson Creek, which is covered under water right 77-14190. The purpose of these minimum flows is to preserve fish and wildlife, scenic, and recreational values and to protect and enhance water quality. The minimum flow protected by water right 77-14190 varies throughout the calendar year (Table 44), with a base flow minimum of 173 cfs between October 1 and October 31 as measured on the EFSFSR at the confluence of the EFSFSR with the SFSR. Water right 77-14190 is subordinate to future domestic, commercial, municipal, and industrial uses and future non-domestic, commercial, municipal, and industrial development up to 8.2 cfs.

Table 44. State of Idaho, IDWR Water Right No. 77-14190 Minimum Stream Flow EFSFSR at the SFSR.

Usage Period	Discharge Rate (cfs)
8/1 to 8/31	223
9/1 to 9/30	179
10/1 to 10/31	173
11/1 to 11/30	214
12/1 to 12/31	222
1/1 to 1/31	254
2/1 to 2/28	232
3/1 to 3/31	291
4/1 to 4/30	625
5/1 to 5/31	1,829
6/1 to 6/30	2,269
7/1 to 7/31	590
Total Diversion	2,269

Source: HDR 2017
cfs = cubic feet per second.

The IWRB also holds a minimum streamflow water right downstream (approximately 26.4 miles from the SGP and approximately nine miles from the EFSFSR confluence) on the SFSR (77-14174). Water right 77-14174 is also subordinate to all future domestic, commercial, municipal, and industrial uses and future non- domestic, commercial, municipal, and industrial development up to 20.6 cfs.

Next, the IWRB holds a minimum streamflow water right on Sugar Creek above its confluence with the EFSFSR (77-14193). Water right 77-14193 is subordinate to all future domestic, commercial, municipal, and industrial uses and future non- domestic, commercial, municipal, and industrial development up to 0.3 cfs.

Riparian Conservation Areas. The width of the RCA is dependent on the stream type: (1) Perennial streams have an RCA width of 300 ft. on each side of the stream channel as measured from the bankfull width; (2) intermittent and ephemeral streams have an RCA width of 150 ft. on each side of the stream's bankfull edge; and (3) special aquatic features such as wetlands have RCA widths between 50 ft. to 300 ft. Under baseline conditions, RCAs were observed to be 62 percent intact for the upper EFSFSR (Kuzis 1997), while the lower EFSFSR tributaries have relatively intact drainages and are likely to have more than 80 percent intact RCAs. Riparian vegetation in the BNF is considered below the desired conditions due to severe and widespread historical fires.

Road density within the headwaters EFSFSR subwatershed is approximately 1.8 miles per square mile (mi./mi.^{2}), with 15.2 miles of road in RCAs. In the BNF, road densities range between less than 0.7 mi./mi.^{2} (for 47 percent of the subwatersheds) to 1.7 mi./mi.^{2} (for 12 percent of the total subwatersheds).

The disturbance within the watershed for an acceptable condition is less than 15 percent equivalent clearcut area (ECA); however, within the upper EFSFSR, the ECA is roughly 25 percent due to extensive wildfire in 2007 (Armstrong and Nelson 2011), with disturbance concentrated in RCAs. However, according to Nelson et al. (2004), there is no discernable proof that the high ECA has any observable effect on salmonid habitat. The ECA in the BNF is greater than 15 percent for the entire watershed.

2.9.2.5. **Lemhi River**

2.9.2.5.1. Watershed Condition Indicators

Water Temperature. The Lemhi River water temperature is often too high to be considered suitable for Chinook salmon spawning (Idaho Transportation Department 2017). Water temperatures in the Lemhi River are affected by the loss of riparian vegetation, flows reduced by irrigation diversions, and channelization. Total Maximum Daily Loads (TMDLs) for shade have been identified for multiple segments of the Lemhi River and its tributaries. The USGS gage (13304050) in Big Creek, just upstream from the town of Leodore, started recording water temperature in June 2022. Temperatures recorded during this period dropped to near zero between early November and mid-April. However, summer temperatures rapidly increased, with daily maximum temperatures ranging between around 13°C and nearly 20°C.

Sediment and Turbidity. The headwater streams of the Lemhi River are considered sediment supply zones, affected by weathering and erosion of the bordering slopes. Sediment has accumulated in the alluvial fan, creating terraces along the valley margins. As a result, the Lemhi River exhibits a pronounced deposition zone. Sediment input from land use practices in the Lemhi River basin continue to affect the mainstem Lemhi River. Several segments of the Lemhi subbasin have TMDLs approved for sediment targets in the Lemhi tributaries, though the Lemhi River TMDL is for fecal coliform bacteria and not sediment (Idaho Department of Health and Welfare 1999).

Fish Passage. There are no structural fish passage barriers in the Lemhi portion of the action area. Upper Lemhi River rehabilitation activities have included irrigation diversion consolidation screening and improvements for fish passage barrier removals for habitat access and tributary flow reconnection. Inadequate flows have resulted in passage barriers to salmonids.

Chemical Contaminants. The Lemhi River is categorized as a Category 4 water, which is defined as those impaired for one or more standards for one or more beneficial uses. The Lemhi River is primarily impaired by bacteria (*Escherichia coli*) for primary recreation based on the 1999 Lemhi River Watershed TMDL (Idaho Department of Health and Welfare 1999). Pathogens are likely a result of agricultural runoff where livestock occur. Other potential contaminants include roadway runoff, agricultural runoff containing pesticides and fertilizers, and household or commercial cleaning or other waste products.

Peak/Base Stream Flow. The upper Lemhi River has a complex hydrology, with interactions of snowmelt surface flows, groundwater gains and losses, and an extensive network of irrigation diversions and returns. Peak flows occur from snowmelt runoff, typically in May and June (Rio ASE and Biomark 2021). Groundwater discharge and recharge is an important factor affecting the year-round water budget, caused by an extensive alluvial aquifer. Irrigation diversions combined have legal rights totaling 205 cfs, with most diversions made between late April and early October (Rio ASE and Biomark 2021).

Water management improvements have been made for several decades, including improving flow conditions in tributary streams. Despite these improvements, the upper Lemhi River still requires a more normative hydrologic regime to promote habitat formation and improve access, particularly in light of future climate change effects. Since June 2022, flows have been recorded at USGS gage stations at Big Timber Creek near Leodore (USGS gage 13304050) and in the Lemhi River near McFarland (USGS gage 1330470), just downstream from the restoration site. Flows in Big Timber Creek had short-term peak flows just over 200 cfs in June 2022, and peak flows around 130 cfs in June 2023. Flows rapidly drop from the peak flows in early July. Flows begin to increase in March.

Flows in the Lemhi River at the USGS gage at McFarland show that, between August 10, 2022, and July 24, 2023, low flows occurred in August and September (between 45 and 60 cfs). Peak flows were as high as 298 cfs in April and 249 cfs in June. The average flow for the 11 months of available data is 122 cfs.

2.10. Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action but that are not part of the action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (50 CFR 402.17).

The BA provides a detailed analysis of the effects of the proposed action on SR Basin steelhead and SR spring/summer Chinook salmon. The BA uses the Southwest Idaho Matrix WCIs to evaluate elements of the proposed action that have the potential to affect the ESA-listed fish or PBFs of their critical habitat. The potential effects of the proposed action on ESA-listed salmon and steelhead and their critical habitat can be broadly categorized into the following bullets:

- Effects to water quality, including chemical contamination and accidental spill or discharge of toxic substances, during and after mine operation;
- Changes to surface water quantity resulting from water withdrawal from action area streams;
- Effects to fish passage and habitat conditions during and after mine operation;
- Effects to riparian vegetation in the project area; and,
- Fish handling and sampling of ESA-listed fish associated with ongoing mining and restoration efforts.

The potential for mine-related adverse effects on ESA-listed salmon, steelhead, and their critical habitat, varies depending upon a variety of factors. The potential for effects varies based on site-specific features such as: (1) topography; (2) location of the mining; (3) the mining method; (4) toxicity of chemicals and minerals used or generated during mining; (5) mine management and engineering (including water management); (6) haul road location and design; (7) control and disposal of mine wastes; (8) reclamation methods; (9) monitoring and adaptive management effectiveness; (10) proximity to critical habitat; and (11) life stages of fish that may be affected. Effects will also vary through time, and Table 45 describes the anticipated timeline for major activities affecting action area stream habitats.

Effects from the BRGI portion of the proposed action are expected to be either minor or unlikely to occur, as described in NMFS' concurrence letter on March 14, 2022 (NMFS No: WCRO-2022-00428). Because these activities will proceed as originally described by the BNF in their BA (BNF 2022), and they will occur during the pre-construction phase of the SGP, effects of the action remain unchanged from those previously analyzed in our concurrence letter. This analysis summarizes effects and conclusions as described in our concurrence letter, referring the reader to our concurrence letter for more detailed analysis. Potential effects associated with the BRGI portion of the SGP are incorporated into this analysis and considered into our overall conclusions regarding the SGP.

Table 45. Annual Timeline of Major Changes to Physical Stream Habitats.

Period and Mine Years	Activity
Pre-Production/Construction (-3 to -1)	
-3	Conduct Burntlog Geophysical Investigation
-3 to -1	Construct Burntlog Route
	Transmission Line Construction.
	Existing Garnet Creek diversion extended around plant site; restored downstream from plant site (design reach GC2).
	Begin construction of EFSFSR fish tunnel around YPP (up to approximately 2 years to build).
	Divert Meadow Creek and tributaries around TSF and TSF buttress area including low-flow pipes to moderate temperature.
	Lemhi River Restoration
-1	Fiddle Creek piped beneath growth media stockpile.
	Midnight Creek diverted into EFSFSR upstream from the tunnel, and Hennessy Creek diverted into Fiddle Creek.
	EFSFSR tunnel and associated fishway completed; EFSFSR diverted into tunnel and YPP Lake dewatering begins.
	Upper Midnight Creek placed in pipe under the West End haul road.
	West End Creek diverted around West End Pit (design reach WE2).
	Enhancement in EFSFSR (excluding YPP) and the lower portion of Meadow Creek (design reaches MC6, EF2A, EF2B, and EF2C).
	Sediment control and rock drain constructed on EFMC (design reach BC2).
Mine Operations (1 to 15)	
1	Upper EFMC meadow, groundwater table, and associated wetlands restored.
3	Divert Meadow Creek into a constructed channel around Hangar Flats Pit footprint and downstream approximately 1,000 feet (design reaches MC4B, MC5, and MC6).
	Restore the lower section of EFMC (394 ft. downstream from the rock drain) to its new confluence with Meadow Creek (design reach BC3).
5	YPP backfill begins.
6-7	Hangar Flats pit backfilled (design reach HF1).
8	Midnight pit backfilled.
10	YPP backfill completed.
	YPP backfill surface preparation for stream liner and placement of floodplain material and growth media.
	Construct West End Pit Lake overflow channel.
11	YPP stream restoration including EFSFSR, Hennessy Creek, and Midnight Creek (design reaches EF3, MNC2, and HC1&2).
	Flow restored to EFSFSR and Hennessy Creek over the YPP backfill.
	EFSFSR diversion tunnel inactive with option to divert extreme high flows through tunnel to protect riparian vegetation development.
	Stibnite lake fills and spills.
12	Pipe removed from upper Midnight Creek haul roads and stream segment restored (design reach MNC1).
13	Flow restored to lower Midnight Creek including restored stream over YPP backfill.

Period and Mine Years	Activity
	Remaining road crossings removed and remaining portions of Midnight Creek restored (upstream from YPP, design reach MNC2).
	Removal of diversion around West End Pit.
	West End Pit Lake begins to fill; not expected to spill except possibly in extreme runoff.
15	Final tailings deposited into TSF; TSF allowed to consolidate before placing stream liner and growth media.
	EFSFSR diversion tunnel deactivated.
	Plant site and ancillary facilities decommissioning/reclamation begins.
Closure and Post-Closure (16 to 112)	
17	Non-perennial streams restored on TSF buttress.
	Stockpiles used up from Hangar Flats stockpile area; non-perennial streams and wetlands restored over the backfilled pit.
18	Meadow Creek restored from toe of TSF buttress to previously restored channel around Hangar Flats footprint (design reaches MC3 and MC4A).
19 to 23	Meadow Creek surface preparation for stream liner; placement of floodplain material and growth media atop TSF and TSF buttress.
	TSF contact water collection basins installed outside of Meadow Creek floodplain corridor; treated contact water discharged to non-perennial streams on TSF buttress draining to restored wetland on backfilled Hangar Flats Pit.
23	Plant site decommissioning completed.
	Garnet Creek and associated wetland restored through decommissioned plant site (design reach GC2).
	Meadow Creek stream restoration at TSF and TSF buttress completed; restore perennial flow into new Meadow Creek channel and deactivate low flow pipes in Meadow Creek diversions (design reaches MC1A, MC1B, MC1C, MC1D, MC1E, and MC2).
	Maintain former Meadow Creek diversions for non-perennial hillslope runoff to reduce volume of TSF contact water.
24	Fiddle Creek restored after growth media stockpile removed (design reach FC2).
40	End water treatment.
41	TSF contact water collection basins deactivated and Meadow Creek non-perennial diversions fully decommissioned, and non-perennial streams restored on TSF.
	Water treatment plant decommissioned, and water treatment plant site reclaimed.

Note: Figures 6-2 through 6-4 in Brown and Caldwell (2021b) (Stibnite Gold Water Management Plan) depict operations period water management changes.
Key: EFSFSR = East Fork South Fork Salmon River; TSF = Tailings storage facility

The BA also describes the Lemhi Restoration part of the Project as compensatory mitigation for wetland impacts of the SGP, with the intent of improving habitat conditions in the Lemhi River basin. This restoration effort is scheduled to occur in MY-2 (Table 45). The project will enhance habitat conditions across approximately 7,000 ft. of the Lemhi River channel, increasing habitat quality and complexity, reducing channel W:D, enhancing floodplain connectivity, improving instream structure and velocity, increasing pool quantity and complexity, facilitating surface/groundwater interchange for temperature moderation, providing instream cover for fish, and establishing a riparian corridor for shade, cover, and bank stability. The potential effects of this portion of the proposed action on ESA-listed salmon and steelhead and their critical habitat can be broadly categorized into effects from fish salvage, and temporary habitat-related effects to water quality (i.e., turbidity, chemical contamination) and habitat (i.e., sedimentation of spawning gravels). In the long-term, reconnecting the Lemhi River to its floodplain is expected to improve habitat complexity and will improve habitat conditions across the reach.

Effects described below for the Stibnite mine portion of the project will affect the SFSR SR Spring/summer Chinook salmon MPG, specifically the SFSR and EFSFSR populations. Although the effects of the Lemhi Restoration portion of the project will affect the same ESU, it will affect a different MPG (i.e., Upper Salmon) and different population (i.e., Lemhi River). For SR Basin steelhead, the mine will affect the Salmon River MPG, specifically the SFSR population; while effects of the Lemhi Restoration portion of the project will affect the same MPG, but the Lemhi River population.

This analysis includes the effects of the SGP and the consequences of mine activities on non-Federal lands; therefore, in addition to the activities being permitted by the USFS and the USACE, the effects of activities on salmon and steelhead occurring on private and/or patented lands were also considered.

2.10.1. Effects to Critical Habitat – SFSR

The action area contains DCH for SR spring/summer Chinook salmon and SR Basin steelhead. Critical habitat within the action area has an associated combination of PBFs essential for supporting freshwater rearing, migration, and spawning for steelhead and Chinook salmon. Individual PBFs present in the action area (Table 28), and their condition were described in Section 2.9.2. Effects from the BRGI portion of the proposed action are expected to be either minor or unlikely to occur. Adverse effects to DCH are likely to occur as a result of the USFS approving and the USACE permitting the SGP. Adverse effects will be primarily related to potential changes in water quality (contaminants or temperature) and quantity, impacts to riparian vegetation, effects to natural cover/space, reduced forage (due to chemical contaminants and water quantity effects), potential increased sediment deposition, fish passage, and floodplain connectivity. Modification of these PBFs may affect freshwater spawning, rearing or migration in the action area. Proper function of these PBFs is necessary to support successful adult and juvenile migration, adult holding, spawning, incubation, rearing, and the growth and development of juvenile fish. The following sections discuss the action and any effects on critical habitat as organized by PBF and WCI effect pathway.

2.10.1.1. **Water Quality**

The water quality PBF is essential to steelhead and Chinook salmon spawning, rearing, and migration. Potential effects to the water quality PBF were described as potential effects to the Water Quality Pathway in the Matrix, specifically for the Chemical Contamination, Temperature, and Intragravel Quality WCIs. Effects to the water quality PBF will be described in detail below for chemical contamination, water temperature, and suspended sediment.

Water quality could be affected through chemical contamination, which could occur: (1) should a spill occur onsite or in the transportation corridor; (2) when construction equipment is working within or adjacent to the stream channel; (3) as a result of weed treatment; (4) as a result of effluent discharge; or (5) through groundwater contamination.

2.10.1.1.1. Accidental Spill of Toxic Substances During Transport

Toxic spills have the potential to enter streams in the action area either through a spill occurring during transport, or through an on-site spill and subsequent discharge into nearby waterbodies. An accidental spill of fuels or toxic chemicals being transported to or on-site at the SGP could affect ESA-listed salmon and steelhead if the spill reached any of the action area streams. The potential for, magnitude of, and severity of those effects would be dependent upon a number of variables, such as: (1) proximity to streams; (2) whether the spill reached a stream; (3) accident severity; (4) amount of material spilled; (5) volume and attributes of receiving waters at the time of the spill; (6) type of chemical; (7) form of chemical (dry or liquid); (8) transportation container; (9) weather; (10) spill response time; (11) effectiveness of spill containment; and (12) salmonid life stage(s) present and exposed.

Annually, the SGP will transport substantial quantities of fuels and other materials to the mine site (Table 19). The SGP will also ship large quantities of antimony concentrate. Many of these substances are toxic to salmonids or their food base if released to surface waters. Table 19 describes the quantity and types of chemicals that will be annually transported to/from the mine. Spills of toxic materials could occur along access roads as materials are trucked to and from the SGP during construction of access roads and mine facilities, as well as during operations and closure activities. If a spill were to occur at a stream crossing or near a stream, surface water could be impacted. Although not all waterbodies crossed via culverts are fish-bearing, spills into any waterway could travel downstream to fish-bearing waters.

As described in the BA, mine transport begins on Warm Lake Road (CR 10-579) where the risk of spills will be lower, as it is paved, maintained by Valley County, and has overall gentler grades. At the intersection of Warm Lake Road and Johnson Creek Road (CR 10-413) the two mine access routes begin, with the Johnson Creek Route north along Johnson Creek Road (CR 10-413) and the Burntlog Route east onto Burntlog Road (FR 447). The location of the spill risk will change as the SGP progresses under the proposed action. Johnson Creek and the portion of the EFSFSR between Yellow Pine and the Operations Area Boundary will be at risk of spills of hazardous materials during the first one to two years of the SGP when the Johnson Creek Route is used as the access route during the Burntlog Route construction. For the remainder of the mine life, the waterbodies along the Burntlog Route will be at risk for spills of hazardous materials.

Close proximity of access roads to surface water resources increases the potential for spilled material on the roadways to enter water, thus increasing the potential consequences of a spill. The Johnson Creek Route crosses 43 different streams and includes 27 miles of road that are within 0.5 mile of surface water resources, including several miles that parallel the fish-bearing EFSFSR and Johnson Creek waterways. The Burntlog Route crosses 37 streams, but only includes 9 miles of road that are within 0.5 mile of surface water resources. Though the Burntlog Route includes a greater number of actual stream crossings, the Johnson Creek Route includes significantly greater proximity to water resources occupied by spawning, migrating, and rearing ESA-listed salmonids. Because the majority of the Johnson Creek Route is immediately adjacent to Johnson Creek and the EFSFSR, the potential consequences from trucking spills will thus be greater along the Johnson Creek Route that will be utilized for transport while the Burntlog Route is being constructed.

As suggested in the BA, the most probable release scenario associated with truck transport on the access routes to the SGP will be relatively small amounts (less than 5 gallons) of fuel spilled from vehicles. Under this scenario, immediate cleanup actions to contain, recover, and remove the contaminated soils is anticipated. Because trucks and pilot cars will be equipped with spill response kits, fuel spilled to soils/roadbed should be readily contained and recovered, although fuel which enters waterways via roadside drainages may be difficult or impossible to fully recover and there will be potential for spread and downstream effects beyond the immediate spill area. The risk from spills of this magnitude should be minimal, as spill response materials on the vehicles are pre-positioned along the access routes, and SGP response vehicles will contain materials to not only clean up the site but also to contain and recover floating oil.

A more serious release of liquid petroleum or hazardous material from a bulk truckload could potentially occur assuming the puncture of the bulk tanker in an accident. Under this scenario, spilled material will be released to the immediate roadbed area, and potentially impact physical resources and ecological receptors (e.g., vegetation) and nearby surface water depending on the topography and location.

Table 19 identifies the materials, supplies, and reagents that will be delivered to the SGP. As bulk liquids, diesel, lubricants, gasoline, antifreeze, propane, solvents, Aerophine 3418A, AP 3477, methyl isobutyl carbonyl, sulfuric acid, magnesium chloride, and carbon dioxide present the highest risk of release should an accident occur. Of all the substances to be transported, fuel may pose the highest risk to fish and fish habitat with delivery of 5.8 million gallons of diesel and 0.5 million gallons of gasoline expected annually via tanker truck. This is because large quantities of fuel are transported in each load, numerous trips are made each year, and the substance is a liquid that rapidly flows down gradient toward nearby streams in the event of a spill.

Many of the streams with segments in proximity to access roads support Chinook salmon and/or steelhead. The intensity of the impact of a hazardous materials spill on fish and fish habitat could be high; as a large diesel spill could result in the mortality of 100 percent of the Chinook salmon and steelhead juveniles, adults, alevins, and eggs for a considerable distance (several miles) downstream from the accident (NMFS 1995). In terms of toxicity to water-column organisms, diesel is one of the most acutely toxic oil types. Fish, invertebrates, and aquatic vegetation that come in direct contact with a diesel spill may die (NOAA 2023). The severity of the impact will depend on the timing, size, and location of the spill. Small spills in deep open waters are expected to rapidly dilute; however, fish mortality has been reported for small spills in confined, shallow water (NOAA 2023).

As displayed in Table 19, diesel will be the substance hauled to the SGP most frequently (estimated 5.8 million gallons/year, 580 deliveries per year, 22% of all deliveries), while gasoline (500,000 gallons/year) and propane (2.02 million gallons/year) represent an additional 13% of the expected deliveries to the SGP. $MgCl_2$ will also be delivered in large quantities, estimated at 250,000 gallons/year, 56 deliveries per year, and as liquids, each will be hauled in large volume aluminum tanks that are readily punctured, and hauled in relatively close proximity to action area streams. These factors result in fuel spills during transport being the most likely type of accidental chemical contamination from the proposed action and the most likely substance that ESA-listed salmon, steelhead, and their habitat may be exposed to from accidental spills within the action area. The potential effects from an accidental release of any of these liquids is described in more detail below.

Diesel. Of the substances being transported, diesel has been identified as posing the highest risk of a spill affecting ESA-listed salmonids and critical habitat. This is because diesel is delivered in large quantities (10,000 gallons), will be hauled to the mine site about 580 times per year, containers are aluminum and easily ruptured, and the substance is a liquid that can rapidly flow down gradient into nearby streams.

The 96-hour LC_{50}[8] for diesel and rainbow trout has a range of 18 to 25 mg/L (Conoco 2022). The wide range of toxicity for diesel reflects variations in the petroleum compounds which occur for each source of crude, where it was refined, and the time of year the petroleum was produced. Petroleum products which are refined for use during the summer have different toxicity than products refined during the winter because the additives used to maintain the desired viscosity are applied in different proportions.

Diesel and gasoline contain petroleum aromatic hydrocarbons (PAHs), which have been linked to severe developmental abnormalities at incredibly low concentrations (µg/liter) (NWFSC 2022). Severe PAH toxicity is characterized by complete heart failure, with ensuing extra-cardiac defects (secondary to loss of circulation) and mortality at or soon after hatching. More moderate forms of PAH toxicity, such as might be expected for untreated/unfiltered roadway runoff, include acute and latent alterations in subtle aspects of cardiac structure, reduced cardiorespiratory performance and latent mortality in surviving larvae and juveniles. Total PAH levels in the range of 5-20 µg/L resulted in cohorts of pink salmon (*O. gorbuscha*) that survived the exposure and appeared outwardly normal, but nevertheless displayed reduced growth and reduced survival to reproductivity maturity. Follow-up studies at the Northwest Fisheries Science Center have linked this poor survival to reduced individual fitness manifested by reduced swimming performance and subtle changes in cardiac structure. In essence, embryonic exposure to petroleum mixtures leads to juvenile fish that show signs of pathological hypertrophy of the heart (Incardona et al. 2015, 2021; Gardner et al. 2019).

In smaller streams, like those along the Burntlog Route, a relatively small spill, if not contained, could cause toxicity. In larger streams, like Johnson Creek or the EFSFSR, a spill of as little as 10 gallons could be toxic. Diesel spills have the potential to affect listed salmon, steelhead, and their habitat. Diesel spills have not been uncommon in Idaho, and have included but not necessarily limited to: (1) Little Salmon River (1993, 900 gallons diesel + 900 gallons gasoline), 133 dead rainbow trout and brook trout; (2) Lochsa River (2003, 6,300 gallons diesel), no documented fish kill; and the (3) Middle Fork Clearwater River (2002; 10,000 gallons diesel), no documented fish kill.

[8] LCx (Lethal Concentration): The estimated concentration where a specified percentage of the test organisms die. The LCx is estimated using a statistical distribution or regression model of the dose-response relationship based on toxicity testing. The most common test statistic used in acute studies is the LC_{50} (the lethal concentration where 50% of the organisms die).

Two additional spills in the Salmon River basin warrant further discussion, representing local examples of diesel spills standing out as having negatively affected critical habitat and aquatic life. On August 19, 1983, the IDFG reported a diesel fuel spill of 2,800 gallons into the Little Salmon River. The IDFG calculated that approximately 30,000 fish total (all species) died in the kill and also reported aquatic insect mortality. Another spill occurred on September 6, 1989, occurring on Johnson Creek and resulting in 400 gallons of diesel reaching Johnson Creek. The precise effects of this spill and the emergency response to it were not well documented. However, given the toxicity of PAHs previously described, PAHs retained in the sediments may have led to development abnormalities. Also, depressed populations of aquatic insects were reported for 3.5 miles downstream, and diesel odor was evident in stream substrates a year after the spill. The IDFG notes do indicate seeing Chinook salmon and steelhead showing obvious signs of stress. Given the SGP will on average have approximately 15,000 gallons of diesel delivered per day, spilling even a portion of one delivery truck's diesel load into surface water source could have substantial adverse effects to water quality.

A large diesel spill of 10,000 gallons in Johnson Creek or the EFSFSR would impact water quality to the point that it will kill Chinook salmon and steelhead juveniles, adults, alevins, and eggs for miles downstream of the accident, depending on the time of year. Spills along the Burntlog Route would be more likely to affect rearing Chinook or steelhead, but could also affect staging or spawning adults or their redds should diesel transmit downstream to spawning areas.

Any diesel spilled into action area streams would tend to travel downstream in a slug and dissipate slowly. Diesel from a spill could mix with spawning gravels and sand and be retained in the stream substrate for a year or more, and thereby negatively affect salmon and steelhead eggs, alevins, and juveniles for several years. Large amounts of petroleum products can suffocate aquatic organisms by coating their gills. Diesel fuel, like most petroleum products, contains toxic organic compounds that adversely affect water appearance and odor.

Gasoline. CITGO (2023) reported that various grades of gasoline exhibited a range of lethal toxicity (LC_{100}) from 40 mg/L to 100 mg/L in ambient stream water for rainbow trout. Chevron identifies a 96-hour LC_{50} for rainbow trout and unleaded gasoline at 2.7 mg/L (Chevron 2023).

Transported as a bulk liquid in 5,000-gallon containers, gasoline poses both a high risk of accident and a high risk of delivery to streams should an accident occur. Approximately 500,000 gallons will be delivered in 100 trips per year to the SGP. As with diesel, containers will be aluminum and easily ruptured, and, and as a liquid, it will be able to rapidly flow down gradient into nearby streams.

The bulk of the available literature on gasoline relates to the environmental impact of monoaromatic (benzene, toluene, ethylbenzene, xylenes: BTEX) and diaromatic (naphthalene, methylnaphthalenes) constituents. In general, non-oxygenated gasoline exhibits some short-term toxicity to freshwater and marine organisms, especially under closed vessel or flow-through exposure conditions in the laboratory. The components which are the most prominent in the water-soluble fraction and cause aquatic toxicity, are also highly volatile and can be readily biodegraded by microorganisms. This material is expected to be readily biodegradable following a spill (USDA Forest Service 2007; Chevron 2023).

The effects of even a 30-gallon gasoline spill into occupied streams would be extreme and would likely result in mortality of all life stages of ESA-listed salmon or steelhead present immediately downstream from the spill. As with diesel, the magnitude and extent of effect would vary dependent upon the amount of water in the receiving waterbody and the amount of material spilled. As with diesel, effects would be most likely to occur to fish of all life stages exposed in Johnson Creek and the EFSFSR during the first couple of years while the Burntlog Route is being constructed, and to rearing fish exposed in tributaries of Johnson Creek and the upper EFSFSR once the Burntlog Route is in use.

Propane. The safety data sheet for liquid propane (Global 2024) identifies a 96-hour LC_{50} for rainbow trout at 1.38 mg/L, for fathead minnow (*Pimephales promelas*) at 3.20 mg/L, and water fleas (*Daphnia magna*) at 0.09 mg/L. Bioaccumulation is not expected based on the volatile nature of propane.

Transported as a bulk liquid in 6,000- and 11,000-gallon containers, propane poses a high risk of accident as approximately 2.02 million gallons will be delivered in 226 trips per year to the SGP. As with diesel, containers could be easily ruptured in the event of an accident. However, unlike diesel or gasoline, the effects of a propane spill would be less likely to contaminate local steams, as spilled propane liquid turns to vapor, dissolving in the air and not polluting soil and water resources (Foster Fuels 2024).

Magnesium Chloride. Magnesium is a naturally occurring mineral, found in both terrestrial soils and aquatic sediment, posing very little threat to the environment (Vincoli 1997). As described by El-Mowafi and Maage (1998), magnesium is an essential element for fish, where deficiency has been found to result in retarded growth, anorexia, sluggishness, high mortality, reduced ash content, and reduced concentrations of magnesium and calcium in the whole body and vertebrae. Magnesium is nearly insoluble (0.01%) and highly persistent in water, with a half-life >200 days. Anthropogenic sources of magnesium include discharges and spills from industrial and municipal waste treatment plants (Vincoli 1997).

Magnesium and its salts have slight acute toxicity to aquatic life, and little information exists regarding its short-term toxicity to plants, birds, or terrestrial animals. The EPA does not currently consider magnesium a hazardous substance (Vincoli 1997). Mount et al. (1997) reported 24-, 48-, and 96-hour LC_{50}s of 3,520, 2,840, and 2,120 mg/L $MgCl_2$ for fathead minnows, and 24-, and 48-hour LC_{50}s of 1,560 and 3,330 mg/L $MgCl_2$ for *D. magna*. For rainbow trout eggs exposed to $MgCl_2$, the Pesticide Action Network's PAN Pesticides Database (2008) reported a mean 28-day LC_{50} of 1,355 mg/L, ranging from a low of 119.9 mg/L to a maximum of 1,507 mg/L. After 14 days, Shearer and Åsgård (1992) noted elevated whole body concentrations of magnesium in fish exposed to 150 mg/L and 1,000 mg/L, further noting that fish exposed to the higher concentration were significantly smaller than fish exposed to lesser concentrations. Mortalities began to occur in rainbow trout after 2 days of exposure to the 1,000 µg/L concentration, increasing to 48% total mortality at the end of the experiment (14 days). In the absence of dietary magnesium, the authors concluded that rainbow trout are able to meet their magnesium requirement at waterborne concentrations of 46 mg/L.

$MgCl_2$ will be transported to the site in 4,500-gallon truckloads, delivered up to 56 times per year. Spilling even a portion of one delivery truck's load into surface water source could have adverse effects to water quality. Spills of large quantities of $MgCl_2$ into action area streams could impact water quality to the point that it is likely to kill aquatic invertebrates, Chinook salmon and steelhead juveniles, adults, alevins, and eggs downstream of the accident, depending on the time of year. Spills along the Burntlog Route would be more likely to affect rearing Chinook or steelhead, but could also affect staging or spawning adults or their redds should the spill transmit downstream to spawning areas.

Solid Materials. A release of large quantities of solid hazardous materials such as cyanide or antimony concentrate could also occur during transport. Breaches of the shipping containers for these materials in the case of an accident could release the solid materials to the ground where it will reside until response actions are taken to mechanically clean it up, along with any contaminated soil. Migration of these solid materials from the immediate release site will be less likely than for liquid materials, but could be possible in wet weather conditions.

Cyanide toxicity to fish in the project area is associated with catastrophic spill risk and acute toxicity including mass mortality. Free cyanide (CN-) kills fish by disrupting oxygen uptake at the cellular level leading to suffocation, hepatocyte necrosis, or other tissue damage (Davis et al. 2017; David and Kartheek 2015). Mass mortality of salmonids would occur at CN- concentrations approaching 45 µg/L, the median lethal concentration for rainbow trout (Barber et al. 2003). Antimony is far less toxic than cyanide, with acute toxicity not being observed in 24-hour exposures to 11,400 µg/L (Brook et al. 1986).

A large spill could potentially cause the mortality of a substantial number of adult Chinook salmon and steelhead depending on various factors (NMFS 1995). A spill in the fall months could result in the mortality of all the 1-year-old juveniles and zero age eggs/alevins, thus eliminating 2 years of Chinook salmon progeny.

A release of large quantities of solid hazardous materials such as cyanide or antimony concentrate during transport will be unlikely. Transportation of cyanide and antimony concentrate will represent less than one percent of the site truck trips. The overall incident rate involving hazardous materials is very low. Transportation of cyanide and antimony concentrate will represent less than one percent of the site truck trips. Shipment of these materials will occur in packaging and containments designed to prevent release to the environment even in the event of a traffic incident. Quick spill response and recovery measures will help to limit impacts.

Overall Transportation Spill Risk. It is expected the risk associated with a transportation spill large enough to negatively affect fish or aquatic habitat will generally be low but possible. An exception may be when materials are transported during inclement weather conditions, this could increase the risk to moderate. Spills during the winter will be easier to contain because spilled material will not penetrate frozen ground as readily as unfrozen ground, and snow could absorb the spilled material, in addition the visual contrast between snow and fuel could aid in cleanup. However, areas that are harder to access (e.g., remote or in a canyon) may increase the time it takes to access and cleanup a spill, creating the potential for fish or fish habitat to be in contact with a hazardous material longer and could impact more fish or fish habitat.

The available information supports the BA's determination that a large spill is unlikely to occur as a result of the proposed action. The BA described the likelihood of a spill occurring as being relatively small, stating that accident rates with release of hazardous materials range between 1 every 522 million miles to 1 every 714 million miles. There will be estimated 240,000 truck trips to the site, with not all trips associated with the transport of hazardous materials. Applying the round-trip distance from Cascade (approximately 150 miles) to that number of trips will be a travel distance of 36 million miles. This considered, the BA suggests zero to one accident involving a release of hazardous materials over the life of the SGP. This considered, the probability that a spill will occur and it will be delivered to action area streams is low.

A SPCC Plan will be developed prior to construction to establish procedures for responding to accidental spills and releases of petroleum products. In addition, a Hazardous Materials Handling and Emergency Response Plan will be developed prior to construction to address procedures for responding to accidental spills or releases of hazardous materials to minimize health risks and environmental effects. Although not specifically identified in the BA as documents that will be reviewed by the IARB, NMFS expects that both the SPCC Plan and the Hazardous Materials Handling and Emergency Response Plan will be provided for review by the IARB as finalized to ensure they both adequate and likely to be effective.

NMFS expects that the risk of a hazardous material spill should be effectively minimized by proven, proposed transport EDFs. For example, pilot vehicles will accompany all transports of fuel or hazardous materials between the SGLF and the Operations Area Boundary, and will carry spill response tools and materials, communications equipment, and all drivers trained in spill responses. Thus, response to a small-to-moderate spill of fuel or hazardous material during transit over the SGP access roads will essentially be immediate. Spill response and recovery measures such as containment, deployment of absorbent materials, removal of impacted roadbed material and vegetation, and deployment of water-based spill recovery materials and equipment will also be quickly applied to help to limit impacts.

2.10.1.1.2. Onsite Spills

Aboveground storage tanks at the SGP will be used for fuels and other fluids, including gasoline, diesel fuel, $MgCl_2$, lubricants, coolants, hydraulic fluids, and propane. Approximately 200,000 gallons of diesel fuel, 10,000 gallons of gasoline, 20,000 gallons of $MgCl_2$, and 30,000 gallons of propane will be stored at the SGP in addition to a variety of materials, supplies, and reagents (Table 19). The storage tank facility for gasoline, diesel fuel, and propane will be located near the maintenance workshop with additional propane storage at the ore processing facility area, the underground portal area, and the worker housing facility. The aboveground storage tanks will be installed on containments sized to contain 110 percent of the capacity of the tank. Refueling will occur on concrete-paved areas designed to contain refueling spills (i.e., berms around their perimeters). There will be no below ground fuel storage or piping used for refueling. Storage management will be outlined in the SPCC Plan required by the CWA, which NMFS expects will be provided for review by the IARB for adequacy and effectiveness.

Should a spill occur onsite, spawning, rearing, and migratory habitat could all be affected in the EFSFSR. However, the combination of the proposed monitoring, planning, and EDFs for storage and handling of fuels and hazardous materials will effectively minimize the risk of accidental releases during the storage, management, and use of hazardous materials. While the likelihood of a spill is low given the measures described above, if there is a spill, water quality impacts could be catastrophic to individuals exposed to harmful concentrations of hazardous materials depending on the type of material releases, the location of the spill, and the presence of Chinook salmon, steelhead, and critical habitat for each species in the affected area.

2.10.1.1.3. TSF Buttress, Process Water Pipeline, and Containment Ponds

Design criteria for the TSF were established based on the facility size and risk using applicable dam safety and water quality regulations and industry best practices for the TSF embankment on a stand-alone basis; the addition of the buttress substantially increases the safety factor for the design to about double the minimum requirements. The upstream face of the TSF embankment and the Meadow Creek valley where the TSF impoundment will be located will be fully lined to minimize leakage (Stantec 2024). The final designs for the TSF will be brought to the IARB for review and verification. Compliance with IDWR's Dam Safety Division safety regulations (IDAPA 37.03.05 and IDAPA 37.03.06) (Table 2) requires an acceptable monitoring plan be in place to assure the TSF buttress and various containment ponds functions within the acceptable safety factors. Containment ponds are designed to contain the contents of process water pipelines and runoff from the pond and lined pipeline corridor from a 100-year, 24-hour storm event plus snowmelt. Given IARB review, and compliance with dam safety regulations, catastrophic failure of the TSF or the containment ponds is unlikely, and the effects of a catastrophic failure on DCH in the action area are not further considered.

2.10.1.1.4. Herbicide Application

Noxious weed and invasive species plant control will be conducted according to methods described in the PNF's 2020 Programmatic Activities Biological BA (PNF 2020) and NMFS opinion (NMFS 2020) on that programmatic Weed treatments typically occur between April and November, depending on elevation. During this period, water quality could be affected at a time when all life stages of Chinook salmon and steelhead could potentially be exposed to herbicides, overlapping incubating eggs, rearing juveniles, or migrating/holding adults. The potential effects of weed treatment when applied as proposed have been described in detail in Section 2.5.4.1 of NMFS' opinion (NMFS 2020), incorporated here by reference and summarized below.

Application of herbicides may lead to contamination of surface water, which could then harm individual fish. Herbicides proposed for use could potentially drift to waterways or leach into soils, contaminate groundwater, and eventually show up in streams where listed fish spawn and rear. This risk depends on a number of variables, including but not limited to the rate of application, concurrent precipitation, herbicide degradation, solubility, and distance to water. An accidental spill of herbicides directly to waterways could also result in water quality conditions toxic to salmonid fish species and result in harm/death of ESA-listed fish.

Herbicides (and adjuvants) applied as proposed cannot be kept entirely out of the water. However, herbicides applied by the applicant are not expected to reach streams in concentrations that kill fish; although concentrations may be of sufficient magnitude to elicit short-term sublethal effects. The PNF's weed treatment program has been in place for over two decades, and implementation of weed control project design features (PDFs) developed over that long timeframe are expected to effectively reduce the risk of chemical contamination associated with weed treatment activities.

Although direct lethal effects are not expected, the types of chemicals used are ones that can be capable of causing harmful sublethal effects. It is possible that water quality will be impacted so that individual or smaller groups of fish could be exposed to and experience sublethal effects. Herbicide applications will not occur over large contiguous areas, and most of the action area will not be subjected to spraying in any given year. Considering the low level of effects that may occur coupled with the very small impact area, we do not expect widespread or long lasting effects to the water quality PBF from herbicide application.

2.10.1.1.5. Surface and Groundwater Quality Analysis.

The SGP will address some of the historical nonpoint sources of contamination in the action area and will create new point and nonpoint sources of contamination during construction, operations, and closure. Once in surface waters, the fate and transport of contaminants is dictated by biogeochemical processes (Alpers et al. 2000a, 2000b; Bricker 1999; Chadwick et al. 2004; Johnson et al. 2005). Contaminants may remain suspended in the water column, settle onto stream substrates, diffuse into interstitial pore spaces, or be taken up by benthic organisms, plankton, fish, or other species. Kraus et al. (2022) documented mercury movement from aquatic ecosystems to terrestrial ecosystems when aquatic invertebrates emerged as adults and were preyed upon by riparian spiders. Ultimately, the risk of toxicity from contaminant exposures is greatest within the mine site and is generally expected to decrease with downstream distance. Mercury is an exception to this general rule of thumb, because methylation is expected to continue to occur downstream.

A SWWC model was developed to evaluate potential impacts of the SGP on surface and groundwater quality. The model and its sensitivity analysis are fully described in the SWWC report (SRK 2021a), SWWC sensitivity analysis (SRK 2021b), and Water Quality Specialist Report (Section 7 in USFS 2023a). A summary of the modeling performed, including notable assumptions underlying the modeling is provided in Appendix E of this opinion.

As previously described (Section 2.9.2.1), baseline water quality conditions within the upper EFSFSR watershed have been, and continue to be, impacted by past mining activities. The proposed action involves removal and reprocessing of Bradley tailings (described in Section 1.7.6) and removal of SODA and Hecla Heap leach materials in the Meadow Creek valley, and closure of the Bradley tunnel in the Sugar Creek watershed. While these existing sources of contamination will be eliminated, the proposed action also involves handling and storing new sources of mineralized materials that are expected to leach major ions (e.g., calcium, magnesium, potassium, sulfate, etc.), TDS, and/or metals. These new nonpoint sources of contamination are expected to impact surface and groundwater quality during mine operations and closure. Potential nonpoint sources of chemical contaminants include: (1) ore stockpiles; (2) TSF buttress and embankment; (4) backfill in the YPP, HFP, and Midnight Pit; (5) pit walls newly exposed to oxygen and water; (5) groundwater outflow from the WEP lake; and (6) the TSF.

In addition to the nonpoint sources of contaminants, surface water quality will be impacted by wastewater treatment plant discharges. As stated in Section 1.7.10 of this opinion, the types of wastewater treated include sanitary wastewater discharged in the EFSFSR upstream of its confluence with Meadow Creek and mine contact water[9] discharged into either the EFSFSR below Meadow Creek or into Meadow Creek. Discharge into Meadow Creek will occur during operation if needed to augment streamflow. Discharge of treated water into Meadow Creek will occur during early closure. The SWWC model accounted for discharge from the mine contact water treatment plant to Meadow Creek and the EFSFSR during different time periods (Appendix E). The assumed effluent quality used in the SWWC model is summarized in Table 15. This assumed effluent quality means that mixing zones will not be authorized for the contaminants in the discharge and that the discharges will be required – in the relevant IPDES discharge permits – to meet applicable water quality criteria at the point of discharge, i.e. end of pipe.

The SWWC model made water quality predictions for assessment nodes in Meadow Creek, West End Creek, Sugar Creek, and the EFSFSR. The assessment nodes are downgradient of mine facilities (Figure 28). Predictions were made for existing conditions, operations period, early-closure period, and late-closure period. The operations period extends from MY -2 through MY 12. During operations, mine contact water (including pit dewatering water) that is collected and is in excess of water needed for ore processing will be treated and then discharged to surface water. The operations period includes the last two years of construction (i.e., MYs -2 and -1) because mine contact water will be generated and collected. The early-closure period includes MYs 13 through 40. This period begins when open pit mining is complete and it includes two years of continued processing of the stored ore stockpiles (MYs 13 and 14) as well as the early-closure years where consolidation water from the TSF continues to be collected, treated, and subsequently discharged. The late-closure period occurs after the TSF has completed its consolidation and all mine facilities have been fully reclaimed. During this period, water is no longer collected and treated. The tabulated predictions for each assessment node are presented in Appendix E (refer to Tables E-2 through E-10). Figures 28 through 32 graphically display the average and maximum water quality predictions for arsenic, antimony, copper, and mercury.

[9] Examples of mine contact water include: snowmelt or stormwater runoff from development rock storage facilities, ore stockpiles, or other disturbed mining areas; toe seepage from the TSF buttress or ore stockpiles; pit dewatering; and underdrain seepage.

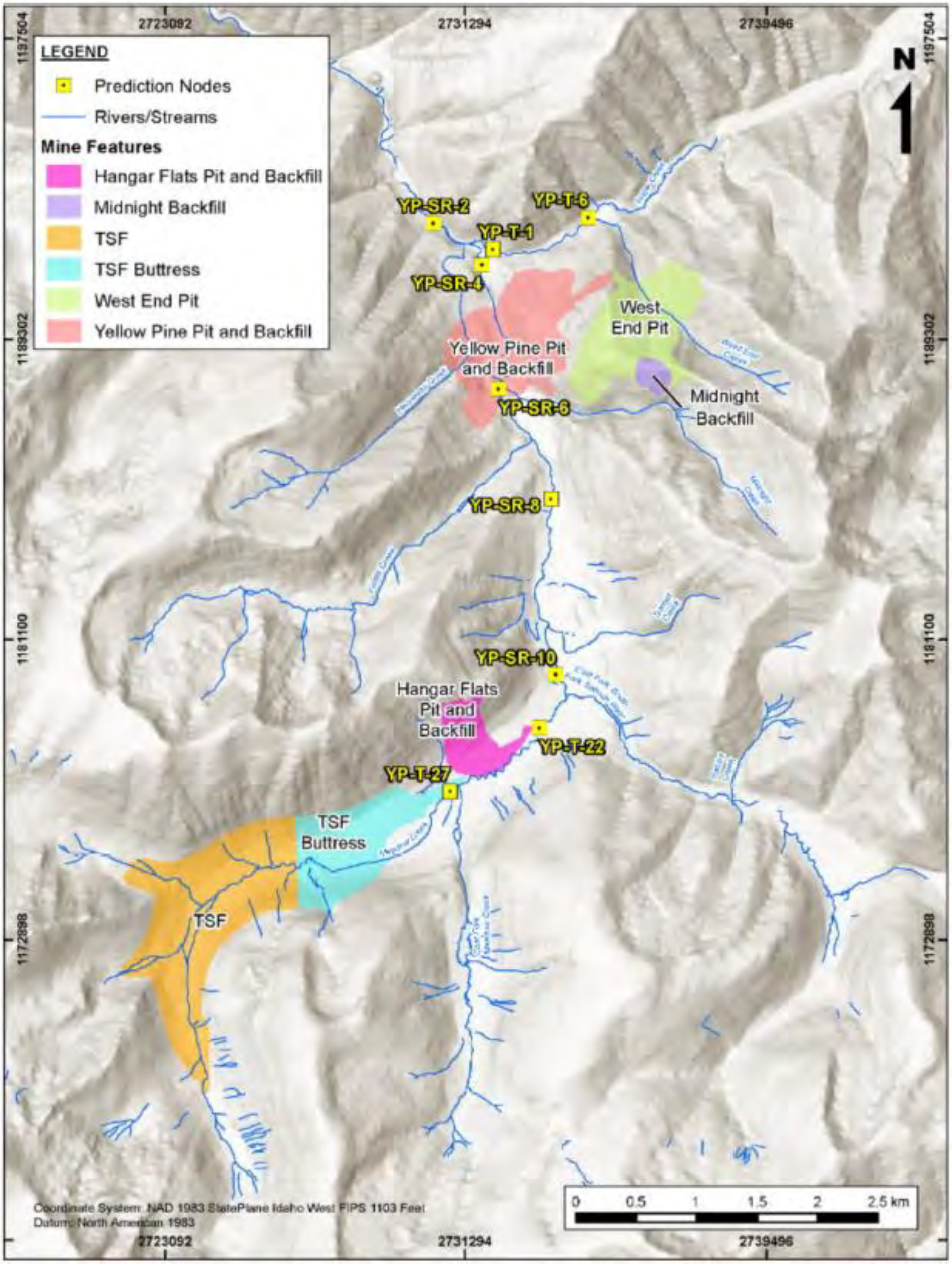


Figure 29. Surface Water Quality Prediction Nodes (SRK 2021a).

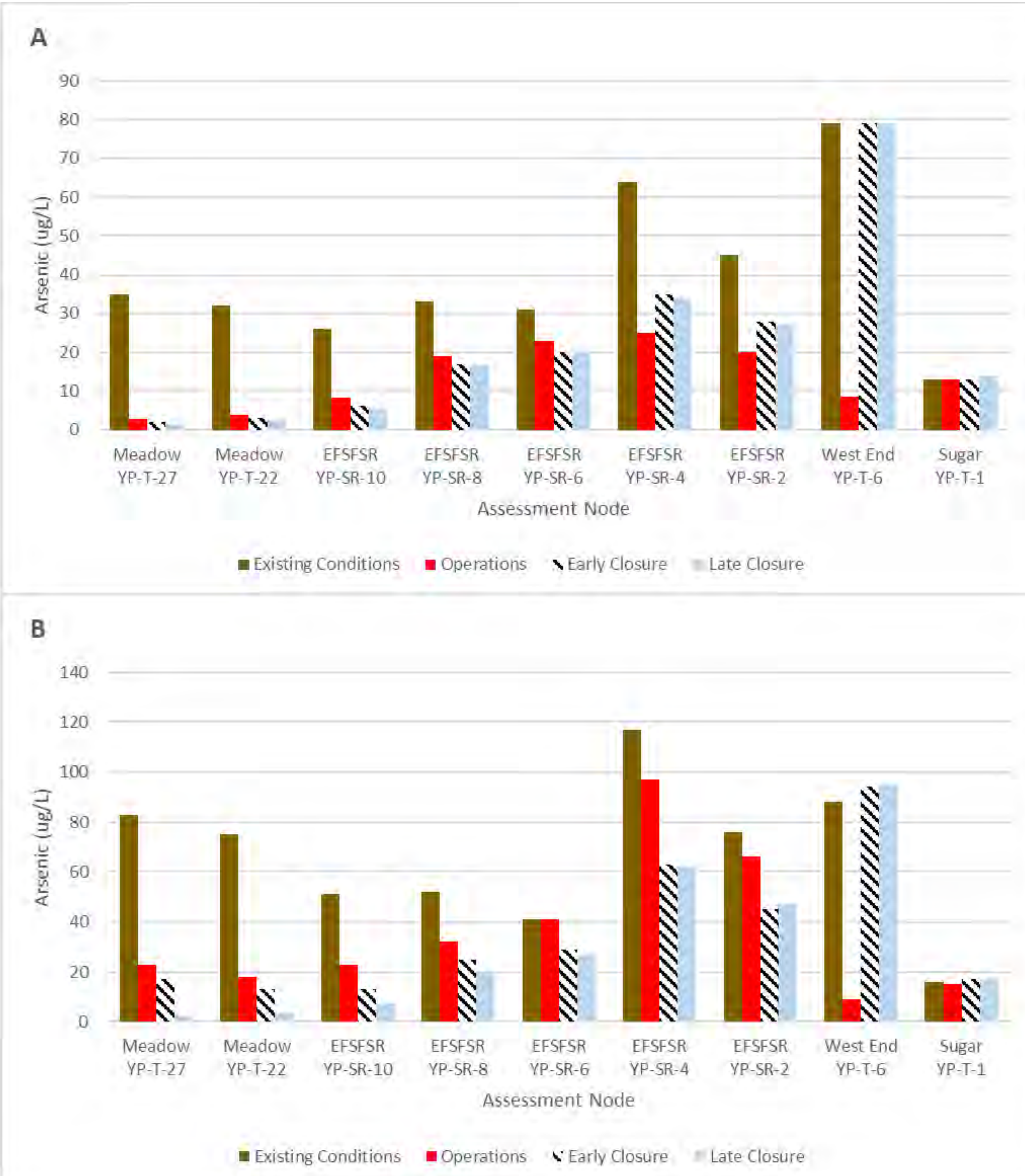


Figure 30. Modeled average (A) and maximum (B) arsenic concentrations for existing conditions, operations, early closure, and late closure periods at assessment nodes within the project area.

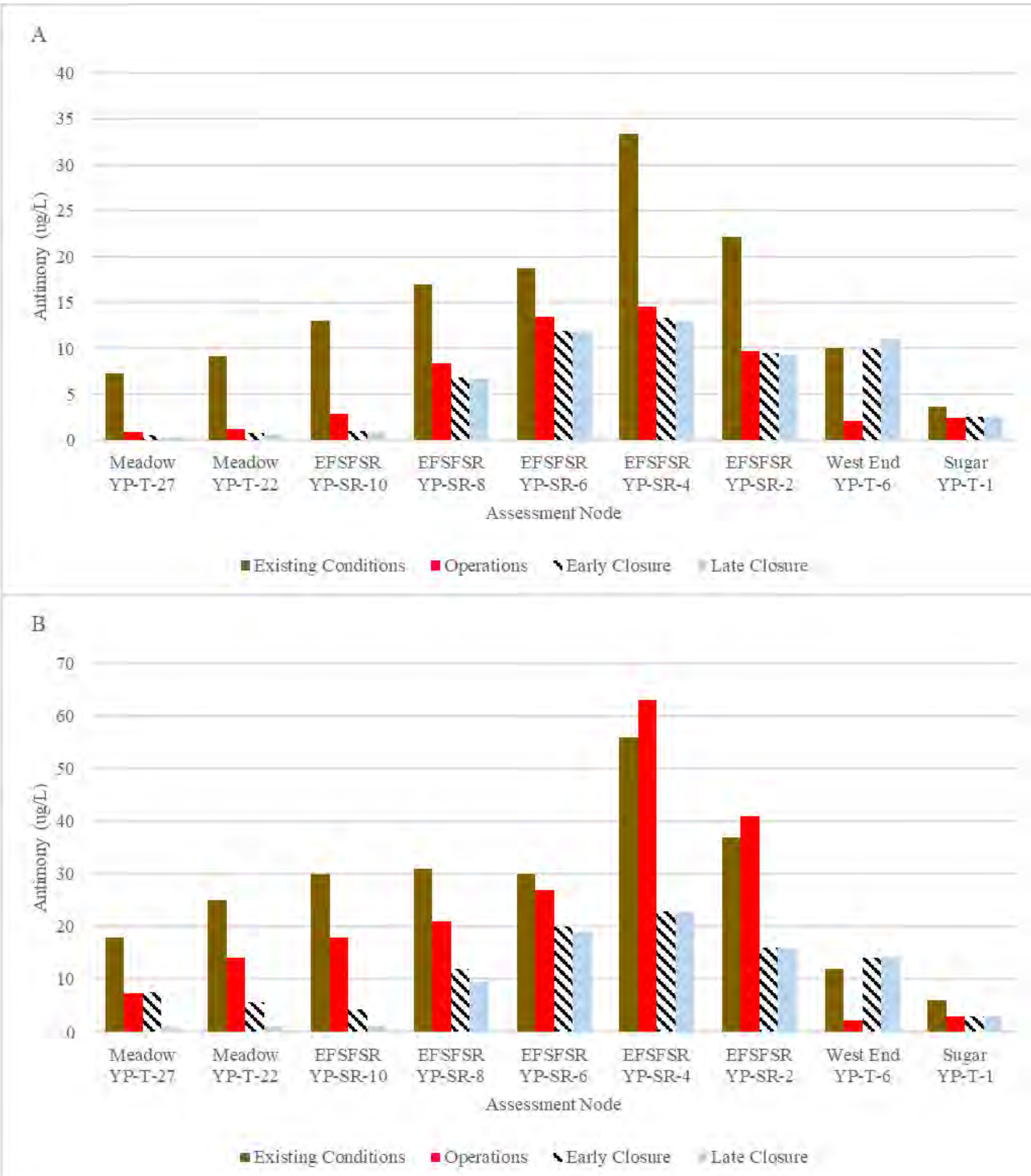


Figure 31. **Modeled average (A) and maximum (B) antimony concentrations for existing conditions, operations, early closure, and late closure periods at assessment nodes within the project area.**

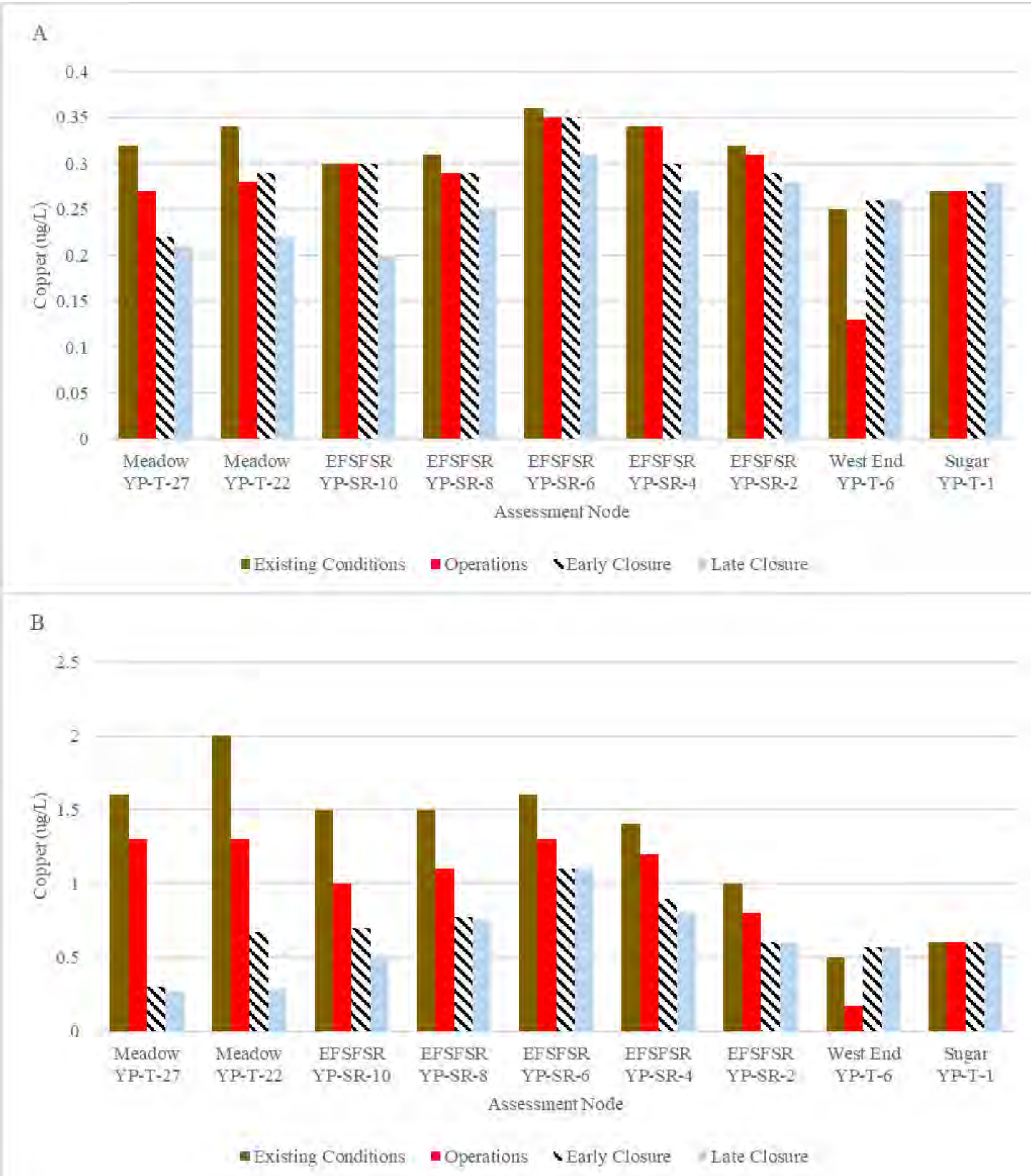


Figure 32. **Modeled average (A) and maximum (B) copper concentrations for existing conditions, operations, early closure, and late closure periods at assessment nodes within the project area.**

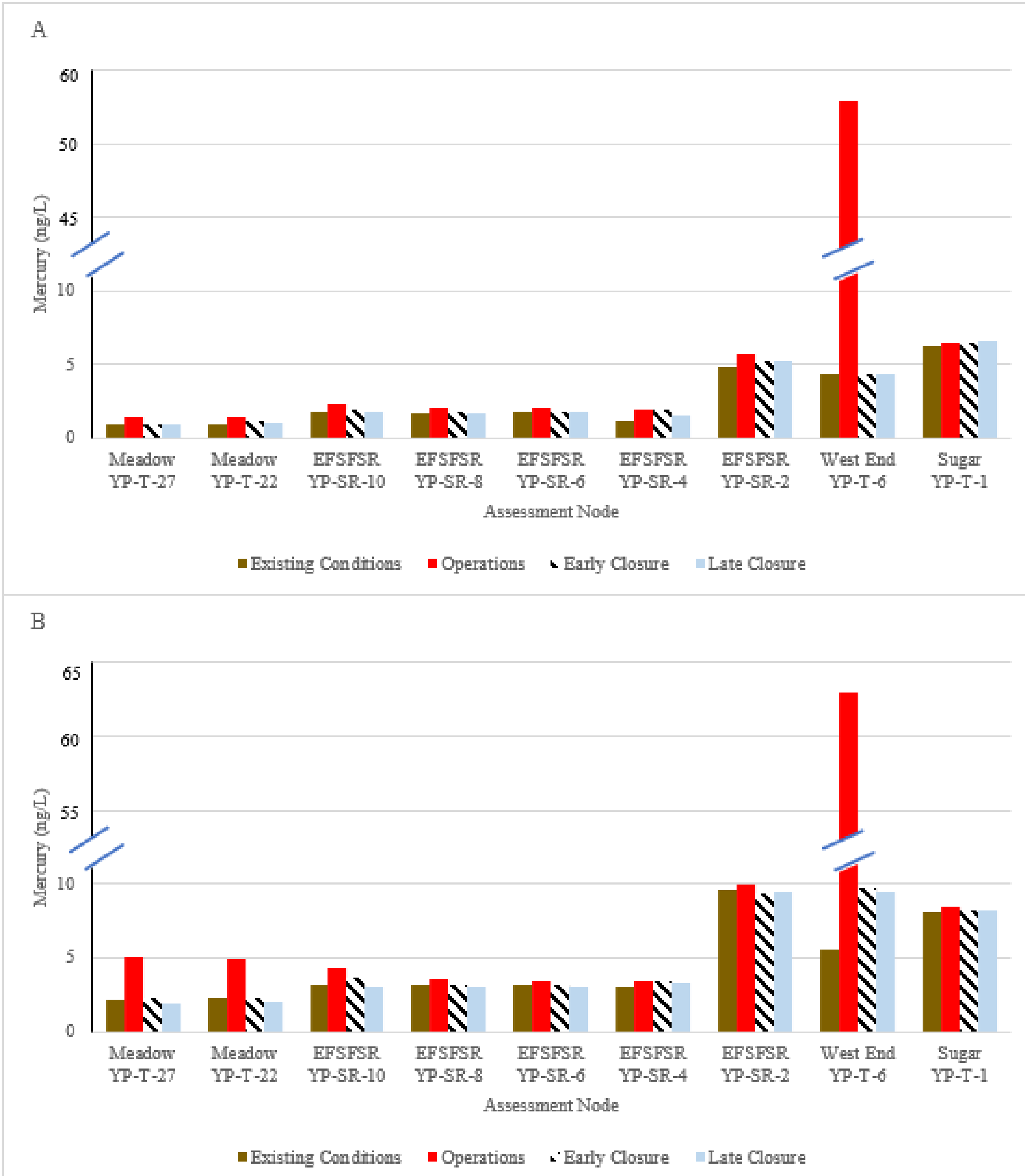


Figure 33. **Modeled average (A) and maximum (B) mercury concentrations for existing conditions, operations, early closure, and late closure periods at assessment nodes within the project area. Note the y-axis scale break.**

Considering the toxicity of contaminants is of paramount importance when assessing the ability of the water quality PBF to support spawning, rearing, and migration. To evaluate the risk of adverse effects from contaminant exposures, NMFS calculated a risk quotient by dividing the predicted instream concentrations by a selected toxicity threshold. The risk of adverse effects from contaminant exposure was then initially characterized as low (risk quotient < 0.5), moderate (risk quotient 0.5 – 0.99) or high (risk quotient ≥ 1.0). Tables 46 and 47 summarize the results. Our review focused on those constituents with a moderate or high risk of causing adverse effects either directly (through waterborne exposures) or indirectly (through dietborne exposures). Table 48 identifies these contaminants for each stream and mine phase. Our assessment of mixture toxicity considered all contaminants and was not limited to just those receiving a more detailed review.

Cyanide is also considered a contaminant of concern given its toxicity and presence in the TSF. Even after accounting for liner leakages, cyanide was not included in the SWWC model because it is not expected to persist at detectable concentrations because geochemical conditions that favor rapid breakdown of the cyanide molecule exist at the site (G. Fennemore, personal communication, July 2, 2024). Cyanide will be present in the wastewater treatment plant effluent; however, cyanide is expected to rapidly breakdown in the receiving stream given sunlight exposure and circumneutral pH. The assumed permit limit of 3.9 µg/L or less of WAD cyanide is below concentrations that would limit the ability of the water quality PBF to support spawning, incubating, rearing, and migrating life stages of fish. The greatest risk relative to cyanide is associated with accidental spills or any upset condition that releases process solution. Risks associated with these unlikely events were described previously.

Predicted concentrations for remaining metals not included in Table 47 (refer to Tables E-2 through E-10 in Appendix E) were well below their respective lowest effect evaluation thresholds; therefore, sublethal or lethal effects from exposures to those contaminants are considered extremely unlikely. As such, a detailed analysis of these constituents has not been conducted, because the predicted water quality concentrations of these metals are expected to continue to support the spawning, rearing, and migratory life stages of anadromous fish. Similarly, impacts on stream pH levels are expected to be minimal through all periods. Predicted pH levels range from 6.1 to 7.6, with an average of 7.0 to 7.3. These pH levels are expected to continue to support the spawning, rearing, and migratory life stages of anadromous fish within the action area.

Table 46. Predicted average and maximum monthly concentrations and calculated risk quotients for antimony and arsenic for specific stream reaches in the project area.

	Antimony						Arsenic					
	30 ug/L						10 ug/L					
	Operations		Early Closure		Late Closure		Operations		Early Closure		Late Closure	
	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient
Meadow Creek[1]												
Average	1.2	0.04	0.74	0.02	0.55	0.02	3.8	0.38	3	0.3	2.5	0.25
Maximum	14	0.47	7.6	0.25	1.02	0.03	23	2.30	17	1.70	3.7	0.37
EFSFSR upstream YPP[2]												
Average	8.4	0.28	6.9	0.23	6.7	0.22	19	1.90	17	1.70	17	1.70
Maximum	21	0.70	12	0.40	9	0.30	32	3.20	25	2.50	20	2.00
EFSFSR (Sugar Creek to YPP)[3]												
Average	14.5	0.48	13.3	0.44	13	0.43	25	2.50	35	3.50	34	3.40
Maximum	63	2.10	23	0.77	23	0.77	97	9.70	63	6.30	62	6.20
EFSFSR below Sugar Creek												
Average	9.7	0.32	9.5	0.32	9.3	0.31	20	2.00	28	2.80	27	2.70
Maximum	41	1.37	16	0.53	16	0.53	66	6.60	45	4.50	47	4.70
Sugar Creek												
Average	2.4	0.08	2.5	0.08	2.5	0.08	13	1.3	13	1.3	14	1.4
Maximum	3	0.10	3	0.10	3	0.10	15	1.50	17	1.70	17	1.70

Key: Pred. Conc. = Predicted Concentration; µg/L = microgram per liter

Note: Low risk quotients have no shading, Moderate risk quotients are shaded yellow, and high-risk quotients are shaded red.

[1]Highest concentrations among sample locations YP-T-27 and YP-T-22

[2]Highest concentrations among sample locations YP-SR-10 and YP-SR-8

[3]Highest concentrations among sample locations YP-SR-6 and YP-SR-4

Table 47. Predicted average and maximum concentrations and calculated risk quotients for copper and mercury for specific stream reaches in the project area.

	Copper 2 ug/L						Mercury 2 ng/L					
	Operations		Early Closure		Late Closure		Operations		Early Closure		Late Closure	
	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient	Pred. Conc.	Risk Quotient
Meadow Creek[1]												
Average	0.28	0.14	0.29	0.15	0.22	0.11	1.5	0.75	1.2	0.60	1.1	0.55
Maximum	1.3	0.65	0.67	0.34	0.29	0.15	5.1	2.55	2.3	1.15	2	1.00
EFSFSR upstream YPP[2]												
Average	0.3	0.15	0.3	0.15	0.25	0.13	2.3	1.15	1.9	0.95	1.8	0.90
Maximum	1.1	0.55	0.8	0.40	0.8	0.40	4.3	2.15	3.7	1.85	3	1.50
EFSFSR (Sugar Creek to YPP)[3]												
Average	0.35	0.18	0.35	0.18	0.31	0.16	2.1	1.05	1.9	0.95	1.8	0.90
Maximum	1.3	0.65	1.1	0.55	1.1	0.55	3.4	1.70	3.4	1.70	3.3	1.65
EFSFSR below Sugar Creek												
Average	0.31	0.16	0.29	0.15	0.28	0.14	5.7	2.85	5.2	2.60	5.2	2.60
Maximum	0.8	0.40	0.6	0.30	0.6	0.30	10	5.00	9.3	4.65	9.4	4.70
Sugar Creek												
Average	0.27	0.14	0.27	0.14	0.28	0.14	6.5	3.25	6.5	3.25	6.6	3.30
Maximum	0.6	0.30	0.6	0.30	0.6	0.30	8.5	4.25	8.2	4.10	8.2	4.10

Key: Pred. Conc. = Predicted Concentration; µg/L = microgram per liter; ng/L = nanogram per liter
Note: Low risk quotients have no shading, Moderate risk quotients are shaded yellow, and high risk quotients are shaded red.
[1]Highest concentrations among sample locations YP-T-27 and YP-T-22
[2]Highest concentrations among sample locations YP-SR-10 and YP-SR-8
[3]Highest concentrations among sample locations YP-SR-6 and YP-SR-4

Table 48. Contaminants of particular concern identified with the site-wide water chemistry model for the SGP.

Stream	Operation Period	Early-Closure Period	Late-Closure Period
Meadow Creek	Arsenic Copper Mercury Antimony	Arsenic Mercury Antimony	Arsenic Copper, Mercury Antimony
EFSFSR (above YPP)	Arsenic Mercury Antimony Total Dissolved Solids (TDS)	Arsenic Mercury Antimony TDS	Arsenic Mercury Antimony
EFSFSR (from YPP to above Sugar Creek)	Arsenic Copper Mercury Antimony TDS	Arsenic Copper Mercury Antimony TDS	Arsenic Mercury Antimony
Sugar Creek	Arsenic Mercury Antimony	Arsenic Mercury Antimony	Arsenic Mercury Antimony
EFSFSR (below Sugar Cr)	Arsenic Mercury Antimony	Arsenic Mercury Antimony TDS	Arsenic Mercury Antimony

Information regarding the toxicity of arsenic, antimony, copper, mercury, and TDS is provided in Appendix F, and briefly summarized below. We discuss the effects in terms of toxicity to salmonids because this provides direct insight into the degree to which the water quality PBF can support spawning, incubating, rearing, and migrating life stages of fish.

Antimony. Predicted antimony concentrations are summarized in Table 46. Antimony is not expected to bioaccumulate in salmonids, nor is it expected to cause acute mortality at predicted concentrations. Adverse sublethal effects that may arise from chronic exposure to antimony range from changes in growth, developmental abnormalities, and normal physiological function (e.g., locomotor behavior, swimming, development, and respiratory activities) (Xia et al. 2021; Brooke et al. 1986). The preponderance of studies documented toxicities to fish at concentrations orders of magnitude higher than those predicted to occur during any phase of the project. However, one study documented low levels of mortality at concentrations similar to those predicted for the proposed action. In that study (Birge et al. 1978), the LC_{50} and LC_1 values for rainbow trout exposed to antimony from fertilization through 4 days post-hatch were reported to be 580 µg/L and 28.6 µg/L, respectively. The 95 percent confidence intervals around the LC_1 were quite large, ranging from a lower limit of ~5 µg/L to an upper limit of ~72 µg/L. Table 49 summarizes how the predicted antimony concentrations could impact the ability of the water quality PBF to support salmon and steelhead over the life of the project in various stream reaches.

Table 49. Biological response that will occur as a result of exposure to predicted antimony concentrations.

Stream	Operations (MY-2 – 12)	Early Closure (MY13 to 40)	Late Closure (MY41+)
Meadow Creek[1]			
Biological Response	None expected	None expected	None expected
EFSFSR above YPP[1]			
Biological Response	None expected	None expected	None expected
EFSFSR below YPP[1,2]			
Biological Response	Risk of mortality if redds are chronically exposed to maximum predicted concentrations.	None expected	None expected
Sugar Creek[1,2]			
Biological Response	None expected	None expected	None expected

[1]Snake River spring/summer Chinook salmon designated critical habitat.
[2]Snake River Basin steelhead designated critical habitat.

Arsenic. Predicted arsenic concentrations are summarized in Table 46. Arsenic (As) speciation is an important consideration when evaluating arsenic toxicity, with arsenite (As^{III}) being more toxic than arsenate (As^{V}). Acute toxicity of arsenic occurs at very high concentrations (i.e., much greater than 1,000 µg/L). Chronic toxicity may occur from longer term exposures to much lower waterborne concentrations; coho salmon experienced delayed mortality following a 6-month exposure to 33 µg/L (Nichols et al. 1984). Rainbow trout embryos were similarly sensitive, with reported LC_1 and LC_{10} values of 42 and 134 µg/L, respectively, following a 28-day exposure to arsenic (Birge et al. 1980). While these concentrations are low, dietborne exposure to arsenic is believed to be a greater threat to salmonid health than waterborne exposure. Dietborne exposures have been linked to liver and gall bladder damage, growth reduction, and reduced reproduction in fishes. These sublethal effects are thought to occur when arsenic concentrations in prey are approximately 20 mg/kg dry weight (dw) or greater, which can accumulate when water levels are about 10 µg/L. More recent literature further complicates the toxicity assessment by demonstrating arsenic speciation may be an important factor in toxicity. Erickson et al. (2019) found that dimethylarsinate and monomethylarsonate were far less toxic than inorganic arsenic. The authors present a compelling case for obtaining a better understanding of arsenic speciation in water and macroinvertebrates in order to better assess the risk of growth reductions and other sublethal effects in juvenile fish. One limitation of their study was utilizing older fish that may be more tolerant of arsenic-laden food relative to younger fry that have just begun exogenous feeding.

Dovick et al. (2016) found that As^{V} was the dominant form of arsenic in surface water collected in the project area in 2010; although As^{III} accounted for up to 30 to 37 percent of the total arsenic in the lower reaches of Meadow Creek. Even if the waterborne concentration is comprised mostly of the less toxic form of arsenic, biota at the bottom of the food chain may contain a higher proportion of the more toxic form, which Erickson et al. (2019) attributed to the “reducing environment in the organism.”

Average arsenic concentrations are predicted to decrease ten-fold compared to baseline conditions during operations due to removal of historic contamination in the valley. Yet, predicted maximum concentrations will exceed the 10 µg/L threshold identified in NMFS (2014) occasionally (i.e., for some years at the start of operations and during early closure); however, average concentrations are expected to be below the 10 µg/L. Table 50 summarizes how the predicted arsenic concentrations could impact the ability of the water quality PBF to support salmon and steelhead over the life of the project in various stream reaches.

Table 50. Biological response that will occur as a result of exposure to predicted arsenic concentrations.

Stream	Operations (MY-2 – 12)	Early Closure (MY13 to 40)	Late Closure (MY41+)
Meadow Creek[1]			
Biological Response	None expected from waterborne exposure. Juvenile fish may experience sublethal effects as a result of dietary exposures in years with prolonged maximum predicted arsenic concentrations.	None expected from waterborne exposure. Juvenile fish may experience sublethal effects as a result of dietary exposures in years with prolonged maximum predicted arsenic concentrations.	None expected from waterborne or dietary exposures.
EFSFSR above YPP[1]			
Biological Response	Low risk of mortality if redds or juvenile fish are chronically exposed to maximum predicted concentrations Juvenile fish may experience sublethal effects as a result of dietary exposures.	Juvenile fish may experience sublethal effects as a result of dietary exposures.	Juvenile fish may experience sublethal effects as a result of dietary exposures.
EFSFSR below YPP[1,2]			
Biological Response	Risk of mortality if redds are chronically exposed to maximum predicted concentrations. Juvenile fish may experience sublethal effects as a result of dietary exposures.	Risk of mortality if redds are chronically exposed to maximum predicted concentrations. Juvenile fish may experience sublethal effects as a result of dietary exposures.	Risk of mortality if redds are chronically exposed to maximum predicted concentrations. Juvenile fish may experience sublethal effects as a result of dietary exposures.
Sugar Creek[1,2]			
Biological Response	Juvenile fish may experience sublethal effects as a result of dietary exposures.	Juvenile fish may experience sublethal effects as a result of dietary exposures.	Juvenile fish may experience sublethal effects as a result of dietary exposures.

[1]Snake River spring/summer Chinook salmon designated critical habitat.
[2]Snake River Basin steelhead designated critical habitat.

Copper. Predicted copper concentrations are summarized in Table 47. Copper is highly toxic to aquatic life. Toxicity to fish includes, but is not limited to, direct mortality, reduced growth, and reduced olfactory function. The estimated 96-hour LC_{50} for Chinook salmon is 7.4 µg/L in test water at a pH of 7.7 and a hardness of 35 mg/L. Sandahl et al. (2007) reported reduced olfaction function after short-term (i.e., 3 hours) exposures to copper concentrations as low as increases in copper concentrations by as little as 0.18 µg/L over background (where background was identified as 3 µg/L). Hansen et al. (1999a) documented avoidance responses in juvenile Chinook salmon and rainbow trout at concentrations as low as 0.75 ug/L in soft water. Morris et al. (2019) documented a 20 percent reduction in alarm cue response after being exposed to copper concentrations of 2.7 and 2.5 µg/L for 24 or 96 hours, respectively. Reported EC_{10} values for reduced growth in Chinook salmon (Chapman 1982) and rainbow trout (Marr et al. 1996) chronically exposed (i.e., 120 days) to elevated levels of copper were 1.9 µg /L and 2.8 µg /L, respectively. Mebane and Arthaud (2010) employed regression models describing the relation between juvenile Chinook salmon growth and copper concentrations. Based on their models, the corresponding length reductions associated with exposure to 2.1 µg/L copper ranged from zero to 4.5 percent.

It is evident that sublethal effects, such as reduced growth, avoidance, and reduced olfactory function can occur at very low copper concentrations, with the later response occurring after short exposure durations. Copper concentrations are generally expected to be less than 1 µg/L and are not expected to result in reduced growth; however, maximum predicted concentrations are at levels that could impart some low level of effects (e.g., reduced olfactory function, avoidance) to rearing juvenile salmonids or migrating adults. Inhibition of olfaction has been shown to reduce juvenile salmonids' ability to evade predation, so it is possible that juveniles could die as a result of copper concentrations at the site. Table 51 summarizes how the predicted copper concentrations could impact the ability of the water quality PBF to support salmon and steelhead over the life of the project in various stream reaches.

Table 51. Biological response that will occur as a result of exposure to predicted copper concentrations.

Stream	Operations (MY-2 – 12)	Early Closure (MY13 to 40)	Late Closure (MY41+)
Meadow Creek[1]			
Biological Response	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations	There may be some sublethal effects such as reduced olfaction at maximum predicted concentrations	None expected
EFSFSR above YPP[1]			
Biological Response	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations
EFSFSR below YPP[1,2]			
Biological Response	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations	There may be some sublethal effects such as reduced olfaction or avoidance at maximum predicted concentrations
Sugar Creek[1,2]			
Biological Response	There may be some sublethal effects such as reduced olfaction at maximum predicted concentrations.	There may be some sublethal effects such as reduced olfaction at maximum predicted concentrations.	There may be some sublethal effects such as reduced olfaction at maximum predicted concentrations.

[1]Snake River spring/summer Chinook salmon designated critical habitat.
[2]Snake River Basin steelhead designated critical habitat.

Mercury. Predicted mercury concentrations are summarized in Table 47. Mercury is a potent neurotoxin that causes neurological damage, which in turn can lead to sublethal effects that can impair growth and reproduction. Predicted mercury concentrations are not expected to cause sublethal or lethal effects via waterborne exposures; however, predicted mercury concentrations may lead to sublethal effects as a result of dietary exposures. Substantial work has been done to relate water column concentrations to elevated fish tissue concentrations, and deserves attention here (effects through dietborne exposures are also addressed in Section 2.10.1.3 for effects to the prey PBF).

The proposed action will contribute additional mercury to the stream network through groundwater, overland flow, wastewater treatment plant discharge, and atmospheric deposition. The greatest increases will occur primarily during the operating and early post-closure periods. The degree to which these increases will translate to increased bioaccumulation is influenced by a myriad of site-specific factors as described in Appendix F. Those factors include the amount of bioavailable inorganic mercury, presence of suitable methylation conditions (e.g., pH, organic carbon, bacterial communities and activity, dissolved oxygen, wetland abundance), growth rate efficiencies, and trophic position in the food web.

NMFS (2014) established a linear relationship between total mercury concentrations in the water column and total mercury concentrations in fish tissue using paired data reported by Essig (2010). Applying this linear regression equation to average and maximum predicted total mercury concentrations yields potential fish tissue concentrations ranging from 0.172 to 0.528 mg/kg ww and 0.231 to 0.759 mg/kg ww, respectively. Available water column and fish tissue information suggests that these predictions may overestimate future realized tissue burdens. While we were not able to access readily available paired water column and fish tissue information for the action area, the range of water column concentrations collected as part baseline monitoring from 2012 through 2016 in Meadow Creek, the EFSFSR, and Sugar Creek are shown in Table 52. Also shown are estimated fish tissue concentrations based on the average and maximum water column values.

Table 52. Baseline water quality concentrations of total dissolved mercury and estimated whole body fish tissue concentrations of total mercury using the water column-tissue linear regression from NMFS (2014).

Stream	Site	Total Dissolved Mercury (ng/L)[1]			Estimated Fish Tissue Concentration (mg/kg ww)	
		Min	Max	Mean	Max	Mean
Meadow Creek	YP-T-27	<0.6	3.8	1.5	0.449	0.297
Meadow Creek	YP-T-22	<0.7	4	1.7	0.442	0.290
EFSFSR	YP-SR-10	<1	4.9	2.4	0.495	0.330
EFSFSR	YP-SR-8	<1	5	2.5	0.581	0.416
EFSFSR	YP-SR-6	1.4	4.6	2.3	0.528	0.376
EFSFSR	YP-SR-4	1.3	4.5	2.3	0.515	0.370
EFSFSR	YP-SR-2	1.7	29.5	5.6	2.2	0.607
Sugar Creek	YP-T-1	1.6	14.2	7.6	1.2	0.726

Ng/L = nanograms per liter; mg/kg ww = milligrams per kilogram wet weight; min = minimum; max = maximum; EFSFSR = East Fork South Fork Salmon River

[1]MWH 2017

Documented Westslope cutthroat trout (*O. clarkia lewisi*) whole body fish tissue concentrations in Meadow Creek, EFSFSR, and Sugar Creek range from 0.02 to 0.05 mg/kg ww, 0.02 to 0.07 mg/kg ww, and 0.07 to 0.09 mg/kg ww, respectively. Fish tissue samples were collected in 2015 (MWH 2017). These fish tissue burdens are well below levels that have been linked to sublethal effects. Documented whole body mercury concentrations in bull trout collected from the lowermost Sugar Creek site in 2016 ranged from 0.101 to 0.314 mg/kg ww (Rutherford et al. 2020). Documented westslope cutthroat trout fish tissue concentrations are generally about an order of magnitude less than what is predicted from the linear regression. The difference between predicted and actual fish tissue concentrations is likely due to the aquatic systems' net methylation potential and food web composition.

The proposed action is expected to cause incremental increases in total mercury in the water column of streams inhabited by salmon and steelhead. These increases could lead to greater bioaccumulation of mercury in fish tissues. Additionally, an incremental increase in organic carbon content in the EFSFSR due to sanitary wastewater effluent could increase in methylation potential in the EFSFSR, contributing to increased bioaccumulation. For these reasons, the ability of the water quality PBF to support rearing juvenile salmon and steelhead will be further reduced as a result of the proposed action.

Total Dissolved Solids. Increased concentrations of TDS are a potential effect associated with mining projects. Increased TDS concentrations typically result from sulfide oxidation and acid-neutralization reactions that make constituents such as sulfate, calcium, and metals available for dissolution in surface water and groundwater. The SGP has limited sulfide mineralization present in its non-ore materials; therefore, the potential to leach major ions that contribute to TDS from these materials is limited. Ore material is capable of generating higher TDS concentrations, particularly as it is processed. The process solutions will be treated to reduce TDS concentrations prior to discharge (treatment target of 500 mg/L). The low TDS generating potential of the non-ore materials and treatment of process water result in little change in predicted surface water TDS concentrations.

Predicted TDS concentrations in all streams during all phases of the mine are well below than concentrations that have been associated with adverse effects to salmon and steelhead. As such, predicted changes in TDS will not reduce the ability of the water quality PBF to support spawning, rearing, and migration.

Contaminant Mixtures. In addition to the effects described for the individual metals, mixtures of metals can also have interactive effects leading to toxicity at lower or higher levels than from a single metal alone (Finlayson and Verrue 1982). Predicting whether the complex mixture of contaminants will have synergistic, antagonistic, additive, or independent interactions is difficult. In some studies, mixtures of metals have shown both additive toxicity (with adverse effects observed at mixture concentrations of one-half to one-third the approximate toxicity threshold of metals in isolation (NMFS 2014). However, in other studies of metal mixtures, metal combinations have been less toxic than their single-metal toxicities (Finlayson and Verrue 1982; NMFS 2014). There is considerable uncertainty about the toxicity of the predicted future chemical mixtures in the EFSFSR, Meadow Creek, and Sugar Creek. It is not possible to rule out the potential for any adverse effects to the water quality PBF due to chemical mixtures with any reasonable certainty.

Given the complexities of predicting the toxicity of metal mixtures, an integrated approach to water quality management is often taken by measuring and controlling toxics using a combination of numeric criteria, whole effluent toxicity (WET) testing, and biological monitoring of streams that receive point or nonpoint discharges. Only with ongoing chemical and biological monitoring can we continue to evaluate the potential for mixture toxicity, detect potential issues, and subsequently trigger adaptive management to ameliorate the situation

Contaminant toxicity is often exacerbated by increased temperatures because elevated temperatures accelerate metabolic processes and thus the penetration and harmful action of toxicants. Changes in stream temperatures within the Stibnite project area due to project implementation are not expected to be substantial enough to enhance toxicity. Climate change is expected to exacerbate the impacts of the proposed action, making it more difficult (though not impossible) to achieve the performance objectives for temperature. Adherence to the performance objectives relevant to stream temperatures will adequately minimize the risk of enhanced toxicity due to climate change.

SWWC Model Exclusions. The SWWC model excluded stormwater runoff from haul roads, access roads, maintenance facilities, and the residential camp. Constituent leaching from haul roads and access roads by meteoric and snowmelt runoff was evaluated using the site-wide water balance to estimate flows and humidity cell data to estimate runoff water chemistry. Leachate chemistry from road surface materials is predicted to have circumneutral pH with analyte concentrations below surface water quality criteria (SRK 2021a). Use of chemical additives for dust control on roadways is not expected to add constituents to surface water for the following reasons. Dust control products, such as $MgCl_2$, $CaCl_2$, lignin sulfonate, or other appropriate and environmentally-acceptable products, to further enhance dust control at the site will be used. The USFS will require that where haul roads pass within 25 feet (slope distance) of surface water, dust abatement will only be applied to a 10-foot swath down the centerline of the road. The rate and quantity of application will be regulated to ensure the chemical is absorbed before leaving the road surface. Therefore, effects of dust abatement chemicals in stormwater runoff from haul roads and access roads were not incorporated into the water chemistry modeling, but were incorporated into the analysis of sediments and hazardous materials.

Construction and operation of the Burntlog Maintenance Facility and worker housing facility will have the potential for increased runoff, erosion, sedimentation (as a result of vegetation removal and excavation of soil, rock, and sediment) and fuel and/or material discharge to nearby waterbodies during operations (if not properly stored or contained) and early closure. Implementation of EDFs proposed by Perpetua, regulatory and Forest Plan requirements required by the USFS, and permit stipulations from state and federal agencies (including BMPs, sanitary wastewater, and SPCC Plan) is expected to minimize runoff, erosion, sedimentation, and the potential for discharges. For these reasons, effects associated with stormwater runoff from the Burntlog Maintenance Facility were not quantified using the SWWC model.
Although not modeled, stormwater discharges are reasonably certain to occur and will affect surface water quality. Stormwater that is not mine contact water will be generated from the

maintenance facilities, worker housing facility, haul roads and other roadways. Sources of pollution in this stormwater includes vehicle-related contaminants that accumulate on paved roads and parking lot surfaces due to increased vehicular use (McIntyre et al. 2015; Peter et al. 2018; Spromberg et al. 2016), as well as contaminants that accumulate on the building rooftops (WDOE 2014). This stormwater will be managed through application of EDFs aimed at capturing runoff and directing it to stormwater basins where sediment can collect and water can evaporate, infiltrate into the ground, or be discharged to nearby surface water. Even with application of EDFs, discharges into surface water are expected to contain an array of contaminants, most notably PAHs, tire wear particles, and some metals. The toxicity of PAHs was previously described, and best available information regarding the toxicity of tire wear particles is below.

Tire wear particles contain 6PPD [N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine], which can transform to 6PPD-quinone (6PPD-q) in the presence of ozone. 6PPD-q was identified by Tian et al. (2021) and has been linked to mortality of salmon and steelhead following acute exposures to extremely low concentrations. Available science suggests variation in species sensitivities with coho salmon being most sensitive followed by steelhead and then Chinook salmon (Brinkman et al. 2022; Chow et al. 2019; French et al. 2022; Lo et al. 2023; McIntyre et al. 2018; and McIntyre et al. 2021). Lo et al. (2023) reported LC_{50} values of 41 ng/L and ~67 µg/L for newly feeding (~3 weeks post swim-up) coho and Chinook salmon, respectively, following a 24-hour exposure to 6PPD-q. Acute mortality from exposures to this compound can be prevented by infiltrating road runoff through soil media containing organic matter, which removes 6PPD-q and other contaminants (Fardel et al. 2020; Spromberg et al. 2016; McIntyre et al. 2015). No information exists regarding the sublethal toxicity of 6PPD-q; however, the overall field of 6PPD-q toxicity is rapidly evolving.

While stormwater runoff from non-mine contact water was not included in the SWWC model, it is reasonable to conclude that pollutants from stormwater generated from increased vehicular use on haul roads and other roadways, new parking areas, and new facilities will contain pollutants that can exert toxic effects. Feist et al. (2017) found that road density and traffic intensity was positively related to coho salmon mortality. At its peak, during construction, the proposed action will contribute 65 annual average daily trips to the project area. The increased traffic is expected to release additional vehicle-related contaminants onto the road surface, which will be captured during runoff events. The vast majority of runoff from Warm Lake Highway is directed to a vegetated right of way where it infiltrates into the ground. Some stormwater runoff is expected to enter streams, particularly in locations where the road crosses the stream channel. Untreated stormwater has the potential to reduce the water quality PBF in localized areas immediately following rain events. However, considering the traffic intensity associated with the proposed action, it is unlikely that water quality would be reduced to a degree that would reduce its ability to support spawning, incubating, rearing, and migrating life stages of salmon and steelhead.

The SWWC model also excluded sanitary wastewater treatment plant discharge into the EFSFSR upstream of Meadow Creek. The discharge volume from the wastewater treatment plant will vary between the mine construction, operation, and closure and reclamation periods, depending on the number of workers present at the SGP. Influent flows during construction and operations are estimated to be approximately 0.10 and 0.05 cfs, respectively (Brown and Caldwell 2020a).

We assume influent flows are representative of effluent flows. Sewage effluent systems will have waste containment and runoff control structures to prevent escape of untreated waste to the EFSFSR. The effluent is expected to contain phosphorus, nitrogen, caffeine, pharmaceuticals, personal care products, plasticizers, food additives, flame retardants, microparticles, and per and polyflouryl alkyl substances (PFAS) (Bothfeld 2021). The toxicity of these emerging contaminants of concern are poorly understood, but a number of authors have reported a variety of adverse sublethal effects (e.g., vitellogenesis, decreased whole body lipid content, reduced brain sodium-potassium ATPase activity, liver damage, and reductions in plasma glucose) in fish exposed to diluted wastewater treatment plant effluent (Ball et al. 2024; Meador et al. 2018; Popovic et al. 2023). These types of sublethal effects can impact individual fitness by altering behaviors and reducing survival (unable to evade predators, unable to successfully compete for food, etc.). The discharge will represent a very small proportion of the EFSFSR streamflow (~1 to 3 percent); however, dilution alone is not able to fully ameliorate the potential for adverse effects (Ball et al. 2024). It is possible that rearing juvenile salmonids in the EFSFSR in the vicinity of the discharge could experience adverse sublethal effects from continuous exposure to constituents in the effluent.

Uncertainty. When evaluating the impacts to the water quality PBF, we have assumed no untreated contact water at the ground surface (e.g., pond overflow or failures in contact water collection) will be discharged directly into surface waters and the SWWC model outputs represent the best available information regarding SGP impacts.

We recognize there is a substantial amount of uncertainty in whether the predicted instream concentrations represent actual conditions that will exist during operations and closure. Predicting future instream concentrations is incredibly difficult and there is uncertainty surrounding the validity of the assumptions employed. A variety of factors can impact the ability to accurately predict water quality changes including: inadequate geochemical characterization; inadequate hydrologic characterization (e.g., overestimating dilution, underestimating volume of contact water, underestimating storm size); and ineffective implementation of mitigation measures (e.g., liner leaks more than anticipated, underdrain system unable to capture all tailings leakage, ineffective segregation of rock material, etc.) (Kuipers et al. 2006). Some of the assumptions used in the various modeling efforts are conservative (e.g., no attenuation of solutes) while others may be less conservative (e.g., proportion of material effectively contacted by meteoric waters). Employing model outputs from one model as inputs to a different model results in additional uncertainty in predicting future water quality conditions during project implementation and following closure. For purposes of our opinion, we have assumed that the uncertainty associated with these factors have been appropriately minimized and the modeling represents the best scientific and commercial information available.

In addition to modeling uncertainty, the SWWC model does not account for contribution of contaminants from aerial deposition, sanitary wastewater treatment plant discharge, or stormwater runoff (beyond that which is collected and treated). As previously described, we have assumed that implementation of appropriate stormwater erosion control BMPs will minimize contributions of contaminants from this pathway. Air emissions from the SGP have the potential to contribute metals to the ground surface via wet and dry deposition which will subsequently have the potential to affect surface water chemistry. Actual local mercury deposition rates from

SGP emissions depend on the fractions of particulate versus gaseous mercury emissions. Particulate emissions generally deposit on the ground surface nearer to their source while gaseous emissions tend to deposit farther from the source or potentially become part of global atmospheric mercury burden. Most of the SGP contributions will be in the form of particulate matter, but a portion of the local aerial deposition of mercury may also occur in elemental form. Total mercury emissions from the SGP are predicted to be approximately 13.6 pounds of mercury per year. Mercury deposition rates from the air quality analysis of SGP emissions are predicted to be 0.056 g/km^2/year compared to baseline deposition rates estimated to be between 12.7 and 13.9 g/km^2/year (Air Sciences 2021). This suggests there would be a fractional increase (<0.5 percent) in the amount of mercury deposited in the area.

Ratios of stream mercury loads to atmospheric mercury deposition rates have been reported in watersheds affected by gold and silver mining (Domagalski et al. 2016). The effects of aerial mercury deposition on stream loads are variable based on watershed area, mineralization present, land development, rainfall, and soil adsorption characteristics. In smaller watersheds hosting precious metal mining, total mercury stream loads are higher relative to the mass associated with aerial deposition. This is because erodible sediments contribute relatively more to the stream load. Contributions from aerial deposition appear in stream loads over time as deposited mercury retained in soils is re-mobilized by local precipitation. Because the ratios reported in Domagalski et al. (2016) are variable and dependent on site-specific characteristics, they were not quantitatively applied for the analysis of the SGP watershed.

Ensuring a rigorous effectiveness monitoring and adaptive management program is essential in light of these uncertainties. Perpetua has incorporated an environmental monitoring and adaptive management program into the SGP (refer to Sections 1.10 and 1.11) and committed to finalizing that program following issuance of federal and state permitting and regulatory decisions (Brown and Caldwell 2021d). Furthermore, NMFS expects that the monitoring and mitigation plans under the EMMP (including the adaptive management) will be provided for review by the IARB to ensure the programs will be adequate and effective. Implementation of a thorough and robust monitoring program will enable Perpetua and the USFS to identify contaminant concentrations that are exceeding predictions relied upon in this analysis. The ongoing monitoring and adaptive management processes as described in the EMMP (Brown and Caldwell 2021d) and its component plans are key to ensuring effects do not rise to levels greater than predicted and analyzed. Ongoing monitoring, evaluation, and discussions with the IARB are expected to increase the probability of identifying issues early. In addition, the requirement to identify and implement appropriate responses to address issues not foreseen and adaptively manage the project and requiring adaptive management should reduce the magnitude and duration of unanticipated water quality impacts.

2.10.1.1.6. Water Temperature.

In order to support adult migration and spawning, incubation, and juvenile rearing, 7DADM water temperatures should be below 18, 13, and 16°C, respectively (EPA 2003). As previously mentioned, DCH for Chinook salmon occurs throughout the action area; whereas DCH for steelhead is more limited in the action area and excludes habitat upstream of the YPP.
The Water Quality Specialist Report (Section 7 in USFS 2023a) provides details and references regarding the predicted surface water temperatures during the construction, operations, and

closure/post-closure periods. Water temperatures at the mine site will be impacted as a result of channel relocation and reconstruction, EFSFSR diversion tunnel construction, riparian vegetation removal, and point source discharges. Table 45 identifies the mine years where major changes to physical stream habitats are expected to occur and is incorporated by reference here.

Potential temperature impacts in watersheds along the transportation and transmission line corridors are expected to be minor because these activities involve little riparian disturbances. The transmission line ROW overlaps with 132.4 acres of RCAs (including non-anadromous RCAs) (Stantec 2024), of which 14.8 acres will be new disturbance associated with the new powerline ROW. The utility poles are not directly along creeks or within RCAs, so clearing of construction pads for footings will not reduce riparian vegetation. However, some vegetation removal may occur if trees exceeds the maximum height specified for the wire and border zones in the RCA. Because lower-growing vegetation will be maintained along the ROW, stream temperatures are not expected to be measurably altered. Construction of new access roads (including the Burntlog Route) will involve multiple stream crossings, but the new routes will generally not closely parallel or constrict streams. Most of the constructed and retrofitted stream crossings will occur high in tributary headwaters. Although removal of trees will be avoided where possible, there will be localized area where vegetation will be removed and stream shading will be reduced. Given the location in the watersheds where this will occur, and given the limited area of impact, any realized temperature increases will be minor.

The greatest temperature impacts are expected to occur within the mine site area, and are the focus of this evaluation. Under the SGP, there will be limited mining activity in the Sugar Creek watershed, with the majority of temperature-related effects being associated with diverting the West End Creek around the WEP. West End Creek is not fish bearing and contributes relatively minor flow volumes to Sugar Creek (i.e., West End Creek inflow [mean flow of 0.51 cfs] is approximately 2 percent of Sugar Creek flow [21.2 cfs]). Predicted increases in stream temperature will be between 0.1 and 0.3°C, with predicted maximum summer temperatures ranging from 15.5°C to 15.7°C compared to a baseline temperature condition of 15.4°C. Predicted maximum fall temperatures will range from 12.2°C to 12.3°C, compared to a baseline temperature condition of 12.2°C (Brown and Caldwell 2021a). Resultant temperature changes in Sugar Creek are not expected to reduce the ability of temperature conditions to support spawning, incubation, rearing, and migration.

In order to quantitatively evaluate the potential effects of the SGP, a Stream and Pit Lake Network Temperature (SPLNT) model was developed by Brown and Caldwell (2021a). The SPLNT model was used to first simulate existing conditions, expressed as a maximum weekly maximum temperature (MWMT[10]). The existing conditions model was developed and calibrated primarily using extensive site-specific meteorological, hydrologic, and stream data collected at the mine site (Brown and Caldwell 2021a, Appendix A). The model uses widely accepted numerical modeling approaches that consists of stream temperature and shading models (QUAL2K) and the General Lake Model for simulating pit lake temperatures. Results of the SPLNT model describing existing conditions (maximum weekly summer [July] and fall [September] temperatures) are shown in Table 53.

[10] The MWMT is the highest recorded 7DADM in a given season or period of interest.

Table 53. SPLNT Modeled Baseline Maximum Weekly Summer and Fall Stream Temperatures for Specific Stream Reaches.

SPLNT Model Stream Reaches	Baseline Summer[1] Maximum Weekly Temperature (°C)	Baseline Fall[2] Maximum Weekly Temperature (°C)
Upper EFSFSR (upstream from Meadow Creek confluence)	13.4	11.0
Meadow Creek upstream from EFMC confluence	14.0	12.0
Meadow Creek downstream from EFMC confluence	19.4	15.9
Middle EFSFSR (between Meadow Creek and YPP)	17.3	13.9
Lower EFSFSR (between YPP barrier and Sugar Creek)	14.1	11.2
EFSFSR downstream from Sugar Creek confluence	14.9	11.9

Key: C = degrees Celsius; EFSFSR = East Fork South Fork Salmon River; EFMC= East Fork Meadow Creek; SPLNT = Stream and Pit Lake Network Temperature; YPP = Yellow Pine Pit
[1]Summer temperatures are represented by July daily maximum temperatures
[2]Fall temperatures are represented by September weekly maximum temperatures.

After the existing conditions SPLNT model was calibrated, it was used to generate future temperature predictions in Meadow Creek, West End Creek, Sugar Creek, and the EFSFSR resulting from SGP implementation. A post closure timeline also was simulated to represent how the site will function after the mine facilities and permitted discharges have been removed, dewatering and mining have been discontinued, and the channels and vegetation have been fully reclaimed.

The following years were selected for simulation in the SPLNT modeling: MYs 6, 12, 18, 22, 27, 32, 52, and 112. Mine year 6 was selected to represent the construction and operations periods because it is considered to represent the warmest conditions associated with the SGP prior to the YPP reclamation activities in MY 12. According to the USFS (Stantec 2024), characteristics that make MY 6 the warmest year for the construction and operations periods are:

- Largest project disturbance footprint and removal of riparian shading effects;
- Riparian plantings associated with early time restoration and reclamation activities will not have time to provide stream channel shading;
- Peak dewatering operations will result in the lowest groundwater elevations and lowest groundwater recharge to streams; and,
- Treated water discharges of excess dewatering water will be highest with the greatest volume contribution of warmer treated water to streams.

Simulation of MY 6 also includes the effects of the Meadow Creek diversion channel and low flow pipelines around the TSF area that will be installed at the start of construction and remain in use until closure of the TSF and restoration of the Meadow Creek channel on top of the reclaimed TSF. This is expected to result in stream cooling, which will be consistently present starting in MY -3 until completion of the TSF reclamation, channel restoration, and associated mitigation measures as necessary (anticipated in MY 27).

MY 12 represents the discontinuation of the use of the fish tunnel and the restoration of surface water flow across the restored stream channel across the YPP and through the Stibnite Lake feature but prior to the reestablishment of riparian vegetation along that restored channel segment. MY 18 represents the conditions at the end of mining operations. MY 22 represents the conditions following completion of most closure activities with the notable exception of the TSF closure and restoration of the Meadow Creek channel on the reclaimed TSF surface. Restoration of Meadow Creek on the reclaimed TSF will take longer to complete due to the need to dry the TSF surface tailings so equipment can access the TSF surface to install the reclamation cover. MY 27 represents the conditions following completion of the TSF closure and restoration of the Meadow Creek channel on its reclaimed surface but prior to the reestablishment of riparian vegetation. This includes discontinuation of the use of the Meadow Creek diversion around the TSF (i.e., via a constructed channel and low flow pipelines) and resumption of surface flow in the restored Meadow Creek channel. MYs 32, 52, and 112, represent interim and final conditions associated with the reestablishment of riparian vegetation associated with restored stream segments.

A summary of water temperatures predicted to occur as a result of SGP implementation are presented in Table 54. A key assumption of the SPLNT model is that revegetation success will be achieved as identified in the Reclamation Closure Plan and Stream Restoration Design (refer to Section 1.10.2.1).

Table 54. Predicted maximum weekly maximum temperatures during summer (July) and fall (September) for modeled mine years.

Stream (Life Stages)	Season	Baseline (°C)	Mine Year								Change from Baseline			
			6 (°C)	12 (°C)	18 (°C)	22 (°C)	27 (°C)	32 (°C)	52 (°C)	112 (°C)	to 6 (°C)	to 27 (°C)	to 52 (°C)	to 112 (°C)
EFSFSR upstream from Meadow Cr. (spawning, rearing, migration)	Summer	13.4	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	-0.01	-0.01	-0.01	-0.01
	Fall	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	-0.01	-0.01	-0.01	-0.01
Meadow Cr. upstream from EFMC (spawning, rearing, migration)[3]	Summer[1]	14.0	12.4	12.3	12.4	12.4	**20.8**	**18.6**	17.1	15.1	-1.6	6.8	3.1	1.1
	Fall[1]	12.0	10.5	10.5	10.5	10.5	16	13.8	12.7	11.3	-1.5	4.0	0.7	-0.7
	Summer[2]	16.8	13.5	13.0	13.1	13.1	**21.7**	**20.2**	**18.5**	16.0	-3.3	4.9	1.7	-0.8
	Fall[2]	14.2	11.2	11.0	11.1	11.0	15.9	14.4	13.1	11.5	-3.0	1.7	-1.1	-2.7
Meadow Cr. downstream from EFMC (spawning, rearing, migration)	Summer	19.4	17.6	16.5	16.3	16.1	**18.5**	17.9	16.6	15.2	-1.8	-1.4	-2.8	-4.2
	Fall	15.9	15.5	13.6	13.2	13.0	13.9	13.3	12.4	11.6	-0.4	-2.0	-3.5	-4.3
EFMC (rearing)	Summer	14.6	15.8	15.4	15.3	15.2	14.9	14.8	14.4	14.2	1.2	0.3	-0.2	-0.4
	Fall	12.6	13.5	13.1	12.9	12.8	12.8	12.6	12.4	12.3	0.9	0.2	0.0	-0.3
EFSFSR between Meadow Cr. and YPP (spawning, rearing, migration)	Summer	17.3	16.3	15.6	15.8	15.9	16.3	15.9	15.2	14.7	-1.0	-1.0	-2.1	-2.6
	Fall	13.9	13.5	12.6	12.6	12.4	12.5	12.3	11.9	11.7	-0.4	-1.4	-2.0	-2.2
EFSFSR between YPP and Sugar Cr. (migration, some rearing)	Summer	14.1	16.1	15.8	15.7	15.6	15.6	15.4	14.8	14.5	2.0	1.5	0.7	0.4
	Fall	11.2	13.0	12.4	12.0	11.8	11.8	11.6	11.3	11.1	1.8	0.6	0.1	-0.1
EFSFSR downstream from Sugar Cr. (spawning, rearing, migration)	Summer	14.9	16.0	15.0	15.1	15.1	15.0	14.9	14.7	14.5	1.1	0.1	-0.2	-0.4
	Fall	11.9	12.5	11.6	11.6	11.5	11.6	11.5	11.3	11.3	0.6	-0.3	-0.6	-0.6

Key: °C = degrees Celsius; EFSFSR = East Fork South Fork Salmon River; YPP = Yellow Pine Pit
[1]Temperatures based on distance weighted average of all QUAL2K reaches.
[2]Temperatures based on distance weighted average of the QUAL2K reaches along the TSF and TSF buttress area. Anadromous salmonids will not inhabit these reaches.
[3]Anadromous spawning, rearing, and migration will only occur downstream in reach MC4 (below the TSF).

Construction. The major activities at the mine site during construction that could impact stream temperatures include construction and activation of the EFSFSR flow diversion, diversion of Meadow Creek and its tributaries around the TSF and TSF buttress area; dewatering the YPP Lake (increased maximum temperatures); and stream enhancements. Modeling was not performed to examine stream temperatures in the years immediately following these activities. It is expected that some activities, such as routing the EFSFSR through the diversion tunnel, will reduce stream temperatures given the reduced exposure to solar radiation. Similarly, diversion of upper Meadow Creek around the TSF may result in some warming of surface flows during the early summer months, but installation of the low flow diversion pipe is expected to reduce stream temperatures during base flows. On the whole, stream temperatures are expected to be similar to baseline conditions and the ability of the habitats to support Chinook salmon and steelhead spawning, rearing, and migration will not be reduced as a result of construction activities.

Operations and Closure/Post-Closure. Stream temperatures for the various stream reaches will be impacted differently over the course of operations and closure/post-closure periods. Impacts to DCH are discussed by stream reach below.

EFSFSR Upstream of Meadow Creek. Baseline stream temperatures in the EFSFSR upstream from Meadow Creek tend to be cooler than the downstream reaches because: (1) it is a headwater reach; (2) it has minimal effects from historic mining; and (3) much of the of riparian vegetation is intact (though still recovering from historic fires). Water temperatures in this section of the EFSFSR under all phases of the SGP will be similar to those under baseline conditions because there will limited mine-related activities in riparian areas. As summarized in Table 54, stream temperatures in this reach of the EFMC are predicted to be lower than temperatures known to be supportive of migration, spawning, incubation, and rearing life stages.

The sanitary wastewater treatment facility will be a source of thermal loading to the stream. While the expected effluent temperature is unknown, the discharge makes up a very small portion of the receiving stream (1 to 3 percent), will be subject to an IPDES permit and CWA requirements, and is not expected to cause thermal shifts to a degree that would negatively impact fish. As such, stream temperatures are expected to continue to support migration, spawning, and rearing life stages of Chinook salmon. This stream could be used as cool water refugia.

Meadow Creek Upstream from EFMC. Meadow Creek upstream from the EFMC is predicted to have decreasing water temperatures relative to baseline conditions during mine operations (MYs 6 through 18) because baseflows will be piped around the TSF and will not be exposed to solar radiation. The predicted MWMT from MY6 through MY22 are predicted to be below thermal thresholds supportive of all salmonid life stages. Vegetation replanting on top of the TSF will take place in the five years following cover placement and stream restoration (i.e., MYs 23 through 27). When the pipeline is removed (MY 22), water temperatures will increase until around MY 27. Stream temperatures are predicted to peak in MY27 at 20.8°C. While these temperatures will not cause outright mortality, exposed fish could experience a myriad of sublethal effects. Absent localized cold water refugia that may be created by hyporheic flow additions to this stream reach, juvenile fish may move into adjacent, thermally-suitable habitat (e.g., EFMC). Predicted summer MWMTs will remain at levels that could cause sublethal effects in rearing juveniles through at least MY52. Therefore, implementation of the proposed action will create a long-term negative effect to the temperature PBF for Chinook salmon. Predicted fall temperatures will generally be below 13°C, suggesting Chinook salmon spawning and incubation will not be negatively impacted most mine years. However, the predicted MWMTs for the fall period will exceed 13°C in this reach from MY27 through MY32 and potentially up to MY52. It is possible that some embryo mortality will occur during this time. Stream temperatures are expected to decrease in the years following MY 27 as replanted riparian vegetation becomes more established and provides more effective stream shading. This decrease is expected to continue through MY 112 as vegetation grows and shading increases. While habitat is expected to be continued to be used for Chinook salmon adult migration, spawning, incubation, and rearing, temperature conditions will not provide optimal conditions for adult migration in MYs 23 through 27, incubation of embryos during the early part of the spawning season in MYs 23 through 27, or juvenile rearing spawning/incubation in MYs 23 through 52.

Meadow Creek Downstream from EFMC. Water temperatures in the warmer summer and fall months in Meadow Creek downstream from EFMC substantially decrease relative to the baseline conditions during mine operations and closure/reclamation activities (MY 6 through MY 18), though there is an increase at MY 27 (post-closure), which then continues to decline until MY 112. These decreases during mine operations are a result of decreased solar radiation in upper Meadow Creek. The removal of the low-flow piping along the TSF in MY 22 will result in water temperatures increasing, though temperatures are predicted to remain lower than baseline conditions. Temperatures are predicted to subsequently decrease as vegetation grows and provides more shade. This section retains some connection to groundwater which will help maintain a lower temperature as well.

The predicted MWMT during MY 6 is 17.6°C, which could lead to decreased juvenile fitness. Predicted temperatures during MY 12 through MY 22 are slightly above 16°C, which may also lead to some small reductions in individual fitness. The predicted summer MWMT for MY 27 is 18.5°C, which is a temperature where reduced growth and increased disease risk may occur in rearing juvenile fish. Stream temperatures will remain elevated beyond MY 52, creating a long-term adverse impact to the temperature/water quality PBF in this reach. Similarly, predicted fall temperatures will exceed 13°C in MY 6 through MY 18. It is possible that some Chinook salmon embryo mortality will occur during this time.

Although the USFS indicated the MY 6-model run does not incorporate shade benefits (Stantec 2024), it is possible that MYs immediately following Meadow Creek channel relocation efforts in restoration reaches MC4, MC5, and MC6, may not be as cold as predicted. A similar channel reconstruction and riparian restoration effort took place in 2005 on Meadow Creek. Photos of this restoration reach are available for 2005, 2007, 2010, and 2015 (Arkle and Pilliod 2021; Zurstadt 2022). In 2007, grasses and some small shrubs were growing along the streambank. In 2010, the grasses and shrubs were denser along the streambanks, but were not large enough to provide much shade to the stream. By 2015, alder and willow had grown to sizes that afforded some stream shading. Arkle and Pilliod (2021) collected stream temperature data upstream and downstream of restored reaches on Meadow Creek. Maximum downstream temperatures were about 5°C greater than upstream temperatures in 2006 and 2007. In addition, no temperatures greater than 16°C were recorded at the upstream monitoring location, but there were 78 and 171 occurrences of stream temperatures greater than 16°C at the downstream location in 2006 and 2007, respectively. While the monitoring locations were located about 1.4 miles apart and temperature data immediately upstream and downstream of the restored reach are not available, it is reasonable to infer that water traveling through the restored reach was exposed to greater solar radiation and as a result, stream temperatures warmed. It is possible for MY 4 and 5 (the years immediately following channel relocation), the 1.8°C reduction in summer MWMT will not be realized.

Predicted stream temperatures in lower Meadow Creek are expected to be less than 18°C in all modeled mine years, with the exception of MY 27, when stream temperatures are anticipated to be slightly elevated. These slightly elevated temperatures are likely to persist up to MY 32, which is when predicted summer MWMT will fall below 18°C. Adult migration is expected to continue in this reach during these five years; however, individuals may experience sublethal effects. Conditions for Chinook salmon spawning and incubation are expected to improve, but will continue to be elevated above 13°C from MY 6 through MY 18 and also in MY 27 through MY 32. During these time periods, some Chinook salmon embryo mortality may occur. Similarly, conditions for Chinook salmon juvenile rearing will improve, but will remain slightly elevated above 16°C through MY 52. Temperatures are not predicted to reach lethal levels; however, the predicted warm temperatures are expected to cause some individual fish to experience sublethal effects. Considering the elevated stream temperatures that are likely to persist in this reach, the ability of the temperature PBF to support Chinook salmon spawning, incubation, adult migration, and juvenile rearing will be reduced in this reach.

East Fork Meadow Creek. EFMC experiences around a 1°C increase in summer and fall maximum water temperatures during mine operations and into the post-closure phase (starting at MY 6) through sometime before MY 52 (post-closure phase), at which point the temperatures decline compared to the baseline conditions. Predicted summer MWMTs for all model years are less than 16°C, indicating juveniles rearing in the reach will not experience adverse effects from elevated temperatures. The temperature increases in EFMC during the operations phase are due to the removal of vegetation as part of the channel restoration work. Restoration activities on the EFMC are scheduled to begin in MY 1, with the construction of the rock drain starting in MY 3. Once the restoration activities (including the establishment of sufficient riparian vegetation to provide stream shading) are fully completed, water temperatures are expected to begin to decrease. Water temperatures are predicted to drop below baseline conditions by MY 52. By MY 112, the reduction in water temperature between the upper meadow and the lower EFMC is around 0.3 and 0.4°C for both the summer and fall maximums. Stream temperatures in lower EFMC will fully support juvenile rearing in all years, which is the only Chinook salmon life stage anticipated in this reach.

EFSFSR Between Meadow Creek and the YPP. The EFSFSR between Meadow Creek and YPP experiences decreases in summer MWMTs relative to baseline conditions during the operations period. There is a minor increase in temperatures after MY 22 once the Meadow Creek low-flow piping along the TSF is removed; however, temperatures are predicted to remain lower than baseline conditions. Temperatures continue to decrease once the riparian vegetation in upstream reaches grows to a size that will provide stream shade. Stream enhancements made to the reach above the YPP are predicted to lower temperatures relative to baseline conditions. This lowering is expected to be greater than the increase associated with warmer water entering the EFSFSR from Meadow Creek in the closure period. Fall maximum water temperature is predicted to decrease throughout the operations, closure, and post-closure periods. While the SGP is expected to improve stream temperatures in this reach of the EFSFSR relative to baseline conditions, temperatures will remain above levels needed to fully support Chinook salmon juvenile rearing, particularly in MYs 6 and 27; and maximum fall temperatures will be slightly above levels known to fully support Chinook salmon spawning and incubation at least for the first few weeks of the season in MY 6. Stream temperatures will fully support adult Chinook salmon migration and holding.

Predicted maximum summer stream temperatures in this reach are below 16.5°C, therefore, the ability of the temperature PBF to support adult migration will not be reduced. The ability of the temperature PBF to support juvenile Chinook salmon rearing will be slightly reduced in MY 6 and MY27 because predicted stream temperatures are 16.3°C and juveniles rearing in these temperatures for extended periods of time may experience sublethal effects. Predicted maximum fall stream temperatures will be below 13°C, with the exception of MY 6 (predicted temperature of 13.5°C). This slightly elevated fall stream temperature will slightly reduce the ability of the temperature PBF to support spawning and incubation during the early portion of the spawning period (stream temperatures can decline relatively quickly in the fall, as shown in Figure 26).

EFSFSR Between YPP and Sugar Creek. Summer and fall maximum temperatures in the EFSFSR between YPP and Sugar Creek are predicted to increase during MY 6. This increase is caused primarily by the draining of the YPP lake followed by active mining and mine dewatering that removes cooling influences of upstream shading and groundwater discharge to surface water. By MY 12, water temperatures are expected to drop, as the YPP is backfilled, the EFSFSR stream channel is restored, and Stibnite Lake is created. The Stibnite Lake is expected to reduce maximum water temperatures in the EFSFSR downstream of the lake outlet, similar to the existing YPP lake. As riparian vegetation establishes along the EFSFSR riparian corridor and begins to provide stream shade, water temperatures will continue to drop. By MY 112, predicted summer maximum water temperatures in the EFSFSR between YPP and Sugar Creek are about 0.4°C higher than baseline conditions, but fall maximum temperatures end up 0.1°C below baseline conditions. Stream temperatures in this reach of the EFSFSR are predicted to be less than 16°C during the summer for all modeled years except MY 6 and temperatures will be equal to or less than 13°C during the fall for all modeled years. Based on these model results, the temperature PBF will be able to support migration, spawning, and incubation for Chinook salmon. During MY 6, the maximum predicted summer temperature is 16.1°C. This small increase in temperature above 16°C will slightly decrease the ability of the water temperature PBF to support salmon and juvenile rearing.

EFSFSR Below Sugar Creek. The EFSFSR, roughly 0.62 miles (1 km) downstream from Sugar Creek, is influenced by both the changes in temperature in the EFSFSR upstream (described above), as well as inflow from Sugar Creek. The substantial increase in temperatures in the early operations phase is caused primarily by the YPP dewatering and mining. By MY 12, temperatures are expected to drop below baseline conditions due to the restoration of the EFSFSR and creation of the Stibnite Lake. After this point in time, temperature changes will be minimal (due to the influence of Sugar Creek) and are expected to remain below baseline conditions. The predicted summer stream temperatures for all modeled years will be equal to or less than 16.0°C. Considering this, the temperature PBF will continue to support juvenile salmon and steelhead rearing and adult migration (Chinook are the only species where adults are likely to be present in this reach during the summer months). Predicted fall tempeaturs will remain below 13°C, therefore the temperature PBF will be able to continue to support spawning and incubation.

Uncertainty. There are a number of inherent sources of uncertainty when interpreting results from the SPLNT temperature model. The most important of described below.

Riparian Vegetation. The SPLNT model assumed that vegetation will not grow to their full potential height, but rather, vegetation would only reach the midpoint of their growth potential range (Brown and Caldwell 2021e). Incorporation of this assumption into the model accounts for some uncertainty regarding the effectiveness, timing, and sustainability of the shading effects of riparian plantings. Even so, performance standards such as percent cover, and measured stream temperatures will be used to assess restoration and reclamation success and to determine the need for adaptive management.

Stibnite Lake. The assumed influence of the lined Stibnite Lake feature on stream temperatures and whether the simulated surface water temperature reductions will be realized. Lining the lake feature atop the lined and covered backfill in the YPP will modify the volume of diffuse subsurface groundwater inflow. While the lined Stibnite Lake feature will receive minor inflow from the cover material, it will not exactly mimic the existing groundwater inflow from native bedrock into the YPP Lake. Depending on the hydraulic properties of the cover material compared to the native bedrock, the volume of groundwater inflow to the lake could differ from existing inflow rates. To address this uncertainty in a conservative manner, the current temperature model did not incorporate any potential cooling effects from subsurface inflow into the Stibnite Lake feature.

Groundwater Levels. The reduction and recovery of groundwater levels and groundwater discharge to surface water varies spatially and temporally. This difficult-to-predict spatial and temporal variability contributes uncertainty in the stream temperature predictions.

Wastewater Treatment Plant Discharge to Meadow Creek. The SPLNT model does not include thermal contributions from the wastewater treatment plant discharge to Meadow Creek. During colder months (October through April), the temperature of treated water is estimated to be 7.3ºC (Brown and Caldwell 2021b). During the warmer months, retention times for contact water in ponds will be up to 34 days, resulting in warmer water treatment plant influent. The wastewater treatment plant discharge will have the greatest influence during the operational period, specifically MYs 4 through 6. During this period, the effluent will comprise seven and 55 percent of the flow in Meadow Creek. The USFS predicts the discharge will increase stream temperature in Meadow Creek by 1 to 3°C below the outfall during the summer and fall. However, warmer water treatment plant discharge temperatures will be offset by the cooling effect of the piped diversion of Meadow Creek around the TSF with the net effect of water treatment on temperature of Meadow Creek expected to be less than 0.25ºC (Brown and

Caldwell 2021b). This additional source of thermal loading, if limited to be less than 0.25 ºC, is not expected to preclude the habitat from supporting adult migration; however, it will further reduce the ability of Meadow Creek to support spawning/incubation (likely restricted to the first few weeks of spawning) and juvenile rearing.

Climate Change Considerations. The SPLNT model does not account for future climate change effects on air temperature, meteoric precipitation, weather events, wildfire, and plant growth. This means that modeled future water temperatures assumed that without the SGP, stream temperatures will be similar to the historic water temperature data (Brown and Caldwell 2018). In reality, water temperatures will likely be higher if climate change had been incorporated into the model. Climate change will be expected to increase water temperatures from baseline estimates to the end of the mine operations by as much as 0.1°C to 2.0°C based on forecasts for 2030-2059 (Isaak et al. 2016), depending on the stream reach. Into the future, baseline estimates for water temperatures could increase by as much as an additional degree (2070-2099).

Given ongoing climate change, model results likely underpredict future temperatures. The extent to which the model may have underpredicted stream temperatures is difficult to quantify because not only does climate change modeling have inherent uncertainties, there are uncertainties associated with climate change impacts on stream restoration and revegetation success. The effects of different air temperature conditions on stream temperatures were evaluated through a sensitivity analysis (Brown and Caldwell 2018) and an uncertainty analysis (USFS 2023a). Brown and Caldwell (2018) evaluated the sensitivity of the model to altered air temperatures by increasing and decreasing model inputs by 5°C. Across this 10°C variation, simulated water temperatures varied by up to approximately 1°C (Brown and Caldwell 2018). Stream water temperature modeling uncertainty relates largely to spatially and temporally variable implementation success of closure activities. This uncertainty, combined with broader climate conditions, could result in higher than predicted stream temperatures (USFS 2023a).

Ultimately, climate change with or without implementation of the SGP will make it more difficult to maintain temperatures that are protective of all anadromous salmonid life stages within the action area. Climate change is expected to exacerbate the effects of the proposed action on stream temperatures directly as well as indirectly through impacts to air temperature, streamflow, and vegetative recovery.

The above sources of uncertainty relate largely to spatially and temporally variable implementation success and sustainability of closure activities, further complicating the simulation of future stream temperatures. Qualitatively, insufficient and/or ineffective closure activities and/or adverse changes in broader climate conditions may result in higher than predicted stream temperatures. Because of this uncertainty, the USFS is requiring additional monitoring and mitigation measures for the SGP including increased riparian planting, mechanical shading, and snow harvesting during the closure/post-closure period.

2.10.1.1.7. Turbidity.

Water quality could be affected through project generated turbidity, which could occur due the following ground disturbing activities: (1) BRGI site investigations; (2) road building, use, and maintenance; (3) facility and infrastructure construction; (4) mining and mining exploration (i.e., operations); or (5) through road decommissioning and site/stream restoration. Ground disturbing activities will generate sediment and deliver it to action area streams to some degree from BRGI investigations (MY -3), from the onset of construction (MY -3, to -1), through closure and reclamation (MY 16+).

Pre-Construction. Travel on unpaved roads, test pit investigations, and drilling associated with the BRGI portion of the project could result in fine sediment reaching streams. Because travel on unpaved roads will be via maintained USFS roads, will mostly be via light vehicles, and heavy vehicles will be routed to minimize adverse effects on roads adjacent to streams, the fine sediment effects of travel on unpaved roads should be minimal. Because proven erosion control practices will be implemented while test pits are active, because test pits will be appropriately reclaimed, because test pits will in relatively flat areas, and because most test pits are on the upslope side of FR 447, the sediment-related effects will be effectively minimized, and the effect on the water quality PBF from the BRGI portion of the project will be minor.

During construction, turbidity is expected from all ground-disturbing activities associated with developing the site (e.g., channel restoration, road work, powerline and facility construction, etc.). During operation and closure, turbidity can be expected from mine road use/maintenance, surface exploration, road decommissioning, channel restoration, etc.

The most critical aspects of a sediment effects analysis are timing, duration, intensity, and frequency of exposure (Bash et al. 2001). Depending on the level of these parameters, turbidity can cause lethal, sublethal, and behavioral effects in juvenile and adult salmonids (Newcombe and Jensen 1996). For salmonids, turbidity has been linked to a number of behavioral and physiological responses (i.e., gill flaring, coughing, avoidance, and increase in blood sugar levels) which indicate some level of stress (Bisson and Bilby 1982; Berg and Northcote 1985; Servizi and Martens 1987). The magnitude of these stress responses is generally higher when turbidity is increased and particle size decreased (Bisson and Bilby 1982; Servizi and Martens 1987; Gregory and Northcote 1993). Although turbidity may cause stress, it has been shown that moderate levels of turbidity (35 to 150 NTUs) accelerate foraging rates among juvenile Chinook salmon, likely because of reduced vulnerability to predators (camouflaging effect). Turbidity and fine sediments can reduce prey detection, alter trophic levels, reduce substrate oxygen, smother redds, and damage gills, among other deleterious effects (Bjornn and Resier 1991; Spence et al. 1996).

For our assessment, we considered sediment delivery in the temporary (0-3 years), short-term (3-15 years), and long-term (greater than 15 years) timeframes. Sediment generated from construction-related activities (i.e., in the temporary timeframe) is addressed qualitatively. Sediment modeling conducted by the Tetra Tech (2024) informed our assessment of the impact of the project on short- and long-term sediment delivery to streams from roads within the action area relative to baseline conditions. While the GRAIP-Lite model used by the Tetra Tech represents some of the best available tools for evaluating potential project impacts, there are some limitations. Model outputs are influenced by the assumptions made about: (1) storm damage risk reduction (SDRR) treatment type, extent, and effectiveness; (2) erodibility of road segments based on maintenance level and other factors; and (3) probability of sediment delivery to nearby streams. Considering their limitations, NMFS views these modeling results as one line of evidence for potential effects of the action. NMFS also relied heavily on the assumption that EDFs and BMPs will be properly implemented in our overall assessment of the degree and extent to which, adverse effects may occur.

Construction. Construction of a road network can greatly accelerate erosion rates in a watershed (Haupt 1959; Swanson and Dyrness 1975; Swanston and Swanson 1976; Beschta 1978; Gardner 1979; Cederholm and Reid 1987). Sediment generated through road construction and reconstruction can reach streams through surface erosion and mass movements of destabilized soil, the effects of which can be both dramatic and long-lasting (Meehan 1991). Unpaved road surfaces continually erode fine sediments, adding significant amounts of sediment to streams (Reid and Dunne 1984; Swanston 1991). Roads and related ditch networks are often connected to streams, providing a direct conduit for sediment. On steep slopes, road construction or improper maintenance can greatly increase landslide rates relative to undisturbed forest (Swanson and Dyrness 1975; Swanston and Swanson 1976; Furniss et al. 1991), delivering large amounts of sediment to streams.

Increases in sediment supply beyond the transport capability of the stream can cause channel instability, aggradation (sometimes to the extent that perennial streams become intermittent) (Cederholm and Reid 1987), widening, loss of pools, and a reduction in gravel quality (Sullivan et al. 1987; Furniss et al.1991; Swanston 1991). For salmonids, these changes can mean reduced spawning and rearing success when spawning areas are covered, eggs and fry suffocate or are trapped in redds, food abundance is reduced, and over-wintering habitat is reduced (Cederholm and Reid 1987; Hicks et al. 1991).

Roads built in riparian areas often eliminate part of the riparian vegetation (Furniss et al. 1991), reducing LWD recruitment and shade. Riparian roads also constrain the natural migration of the stream channel where channel migration zones are present. Roads can intercept, divert, and concentrate surface and subsurface water flows, thereby increasing the watershed's drainage network (Hauge et al. 1979; Furniss et al. 1991; Wemple et al. 1996). This can change peak and base stream flows and increase landslide rates. Stream crossings can restrict channel geometry and prevent or interfere with migration of adult and juvenile anadromous fish (Furniss et al. 1991). Culverts also can be a source of sedimentation, especially if they fail or become plugged with debris (Furniss et al. 1991; Murphy 1995).

Surface erosion from forest roads affects the fine sediment budget in streams and may impose a chronic condition of sediment inputs that directly affect the stream substrate and the health of aquatic life (Luce et al. 2001). Road work results in increased runoff rates and fine sediment delivery, particularly during rain events at tributary crossings or where roads are in close proximity to streams. Road surfaces are compacted, and impermeable surfaces lack vegetation. As a result, most water falling on the road surface in the form of rain or delivered there from upslope does not infiltrate, but rather, quickly runs off the road surface. Water flowing on the road surface picks up fine sediment and delivers it to nearby streams, resulting in increased turbidity and fine sediment deposition onto substrate. Widening of the roads exposes new soil and prevents vegetation from becoming established on a larger portion of the watershed. Generally, a vegetative strip between the road and the stream allows runoff to infiltrate or be filtered prior to entering streams. However, in many locations within the action area, vegetation between the road and action area streams is narrow to non-existent, and runoff is quickly delivered directly into waterways (particularly along the EFSFSR and Johnson Creek).

Planned activities such as placement of cross drains, ditching, grading and graveling may result in disturbances that typically create short-term increases in sediment delivery that taper off after disturbed areas become compacted or after several runoff events occur. To facilitate new road construction and road widening during the construction phase, existing vegetation will be cleared and trees will be felled. Land clearing and tree cutting will create a temporary disturbance to the ground and will expose more soil to potential erosion by eliminating the soil binding capabilities of the roots. This will result in sediment delivery to streams, with the greatest impacts likely to take place along the Burntlog route in the short term (0 to 3 years[11]) as disturbed cut and fill slopes become revegetated.

Although exposed cut and fill slopes are likely to increase sediment delivery in the temporary and short-term timeframes, erosion control and road maintenance EDFs should limit the amount of sediment delivered to action areas in the long term. Maintaining roads in good condition decreases chronic delivery of fine sediment to streams, as roads in close proximity to streams can convey large amounts of fine sediments (Furniss et al. 1991). As proposed, surfacing these road segments and their ditches with gravel aggregate, insloping the road prism to drain to the ditchline, and treating the gravel surface with dust abatement chemicals, should result in a localized reduction on overall sediment delivery to the action area streams over the long term. Although not likely to be of a magnitude sufficient to benefit conditions at the stream reach or watershed scales, these localized improvements could locally reduce factors which limit reproductive success and juvenile survival, abundance, and productivity.

In the temporary and short-term timeframes, construction equipment and roadwork are expected to result in increased sediment delivery to action area streams. Sediment-related effects are most likely to be realized to Chinook salmon habitat along the EFSFSR, and Johnson, Meadow, Sugar, and lower Burntlog Creeks; and steelhead habitat along the EFSFSR, and Johnson, Sugar, Burntlog, Trapper, and Riordan Creeks.

The level of turbidity is likely to exceed ambient levels and potentially affect critical habitat downstream of project activities. Ground-disturbing activities will likely deliver a series of temporary sediment pulses or plumes (expected duration of minutes to hours). However, quantifying turbidity levels and their effect on fish species and their habitat is complicated by several factors. First, turbidity from an activity will typically decrease as distance from the activity increases. The time needed to attenuate these levels depends on the quantity of material in suspension (e.g., mass or volume), particle size, the amount and velocity of ambient water (dilution factor), and the physical/chemical properties of the sediments. Second, the impact of turbidity on fish is not only related to the turbidity levels but also to the particle size of the suspended sediments. Whether these increases in sediment production delivers to nearby streams depends on a variety of factors including the proximity of the road to a stream (Nelson et al. 2012), construction methods employed, and effectiveness of erosion control BMPs. Instream work will also lead to increased sediment delivery during and immediately following

[11] In this analysis, we use definitions for duration of effects as defined in the Southwest Idaho Forest Plan and used in its Matrix (i.e., temporary = <3 years, short term = 3 to 15 years, and long term >15 years.

construction. Fording of streams can also cause temporary spike in turbidity and subsequent sediment deposition.

The project will initiate with three years of construction (MY -3, to -1). During the initial 2 years of project construction, mine-related traffic will access the mine site via the Johnson Creek route, much of which is located in close proximity to streams (i.e., within 100 feet of Johnson Creek and the EFSFSR). A total of 65 vehicle trips per day will occur along Johnson Creek and the EFSFSR during the construction phase, consisting of 20 light vehicles and 45 heavy vehicles. There will be no road alignment modification or widening of the road prism along this route in this phase, as the current road is able to accommodate the equipment and materials needed to be transported during the construction period. However, minor surface improvements (e.g., ditch and culvert repair, adding gravel, winter snow removal, resurfacing (i.e., gravel addition) if required, and summer dust suppression, will occur on the route to reduce sediment runoff and dust generation during this phase.

Under baseline conditions, turbidity is reportedly low (less than 5 NTU) with occasional spikes of up to 70 NTU during snowmelt or rainfall events (USFS 2023b). The greatest potential for Project-related increases in sediment delivery will come during storm events causing overland flow across exposed soil, excavated areas, and roads. Implementation of EDFs and BMPs are expected to minimize the amount of sediment delivered to nearby streams. However, temporary spikes in turbidity are still expected to occur during or following instream or ground-disturbing activities. Turbidity increases will occur immediately adjacent to and downstream of activities and will dissipate as suspended materials settle to the channel bottom.

The magnitude, duration, and extent of turbidity pulses is dependent upon the type and extent of work being performed along with the EDFs implemented. Based on observations from full-size vehicle fording, spikes in turbidity are expected to dissipate quickly and have relatively small magnitudes. Dewatering will also occur at all culvert removals or installation locations, and all reaches will be rewatered slowly to minimize turbidity. Instream work should be completed within a few hours (i.e., maintenance or removal of a culvert) to a few weeks (i.e., the more extensive work required for stream restoration, bridges, and larger culvert replacements).

Turbidity plumes associated with instream work (e.g., excavating culverts, re-watering, etc.) are anticipated to travel up to 1,000 feet downstream prior to dissipating to levels that are no longer harmful to aquatic species. This assumption is based on turbidity monitoring reports from past projects in the region which involved reconstruction of stream channels, including culvert, bridge, and diversion replacement projects (Eisenbarth 2013; Connor 2014). In many cases turbidity plumes upon rewatering will last less than 2 hours, but the plumes may last for up to 24 hours (Connor 2014; Jakober 2002; Casselli et al. 2000; Eisenbarth 2013). Similar turbidity monitoring results have been reported for rewatering reconstructed side channels (CH2MHill 2012). However, based on review of turbidity monitoring reports for habitat restoration projects completed between 2015 and 2017, turbidity plumes in excess of 50 NTUs were usually of short duration of 15 to 30 minutes, but sometimes lasted up to just under 6 hours. Giving the proposed conservation measures to address turbidity, turbidity plumes are rarely expected to reach levels where they mix across entire stream channels, more typically tending to hug one streambank.

In an effort to better understand how much sediment will be produced, delivered, and accumulated in receiving streams over time, Tetra Tech conducted GRAIP Lite modeling (Tetra Tech 2024) for roads in the action area. GRAIP Lite modeling (Tetra Tech 2024) simulated three scenarios, existing conditions, construction conditions, and operational conditions. Results estimated a 32 percent decrease in sediment production during the construction period, with a 30 percent decrease to sediment delivery, and 31 percent decrease in sediment accumulation as compared to baseline conditions (Table 55). Table 56 breaks down sediment delivery by structure type and watershed.

BMPs will be employed for near-stream or instream work, such as removal of legacy materials and stream restoration, to minimize the potential for coarser sediment generation or mass wasting that will affect sediment transport and deposition. Under baseline conditions, sediment entering the EFSFSR primarily comes from Sugar Creek, Meadow Creek, and EFMC (USFS 2023b). Applicable sediment control BMPs will be used to minimize sediment runoff and erosion along roads and excavated areas. On the mine site and along the Burntlog Route, EDFs will protect streambank vegetation, require culvert maintenance, and require low impact snow removal techniques. Efforts to resurface the road, improve drainage, and maintain project-related roads are expected to reduce effects from access roads over their existing condition.

Baseline conditions are generally FA for turbidity in action area streams (Table 30). Proposed sediment control measures and road maintenance are expected to effectively limit the amount of sediment delivered from road-related activities. NMFS believes that the road upgrades proposed and the conservation measures described should be adequate to keep turbidity and erosion to levels to a minimum. Although sediment delivery will occur in reaches bordering roadwork, GRAIP-Lite modeling suggests the amount is not likely to appreciably diminish the conservation value of DCH at the 5th field HUC level.

Table 55. Sediment Production, Delivery, and Accumulation under Baseline and Construction Conditions (Stantec 2024).

Metric	Baseline Conditions	Construction	Percent Change from Baseline
Kilometers of Roads Modeled	125	125	0
Sediment Production (kg/year)	387,955	264,925	-32%
Sediment Delivery to Streams (kg/year)	93,371	65,622	-30%
Sediment Accumulated in Streams (kg/year)	8,901,299	6,142,548	-31%

Table 56. Annual Sediment Delivery (kg/year) to Drainage Crossings under Baseline and Construction Conditions (Stantec 2024).

Sediment Delivery per Drainage Crossing Type	Johnson Creek	Stibnite Road	Burntlog Route	On-Site Roads
Bridges				
Baseline	627	111	740	4
Construction	566	69	682	3
Culverts				
Baseline	1,477	3	1,238	208
Construction	1,340	50	757	461
Total				
Baseline	**2,104**	**114**	**1,978**	**212**
Construction	**1,906**	**119**	**1,439**	**464**

New and existing roads also pose an increased risk of landslide; however, the GRAIP-Lite model used to estimate sediment delivery does not account for landslides (Dixon 2019). Many of the subwatersheds in the action area have a high inherent risk of landslides, which are exacerbated by the presence of roads (Dixon 2019). Although studies on the effect of road obliteration on landslide risk are lacking, it is reasonable to assume that road decommissioning with full obliteration proposed for new road segments at the end of operation will reduce the long-term risk of road-related landslides that could contribute sediment to streams because those roads will no longer intercept and route water.

As previously mentioned, turbidity will also be created during the construction and retrofitting of stream crossings, the bulk of which will take place during construction of the Burntlog Route. Erosion and sediment control for this in-water work will be consistent with BMPs being used for other aspects of the SGP. To minimize turbidity effects to the water quality PBF, cofferdams will be installed, streams bypassed, and in-channel work will be completed in the dry. Water will be slowly reintroduced to minimize turbidity levels, and turbidity monitoring will be conducted. Should turbidity exceedances occur, work will stop to address the turbidity issues.

In addition to the transportation network, additional infrastructure will also need to be constructed during the site preparation phase (MY -3 to -1). This will include the construction of surface facilities, water management features, power transmission lines and substations, OSV routes, and channel diversions, all of which have the potential to cause ground disturbance and sediment delivery to action area streams.

Ground disturbance will occur during the construction of the worker housing facility, main gate, administrative office, and Burntlog maintenance facility. As facilities are being developed during pre-construction, water management BMPs will be constructed to reduce erosion and sediment delivery to streams, including sedimentation ponds; run-on water diversion ditches, trenches, and/or berms; runoff water collection ditches; silt fences; water bars; culverts; energy dissipation structures; terraces, etc. Although construction of these facilities will generate sediment, the pre-disturbed nature of the majority of these construction sites, the relatively flat nature of the construction sites, and the application of proven erosion control practices, are expected to combine to effectively minimize the amount of sediment delivered to action area streams during the pre-construction phase of the project.

A new, temporary 16-foot-wide groomed OSV trail will be created adjacent to Johnson Creek Road between the proposed Cabin Creek Groomed OSV Route (Section 1.6.4 and Figure 7). There will also be a 2-acre parking area constructed west of FR 467, and a new 1.9-mile groomed access trail from the USFS Warm Lake Project Camp on Paradise Valley Road (FR 488). Another 16-foot-wide groomed OSV trail will be created and maintained north of Warm Lake Road to connect the southern end of the Cabin Creek Road OSV trail to the Warm Lake Road (FR 579), providing access to North Shoreline Drive (FR 489) from the Cabin Creek Road OSV trail. This 0.3-mile route will be used throughout construction and operations and will require the removal of some vegetation and trees.

The new segment of OSV trail near Johnson Creek is on the upstream side of the Johnson Creek Road and not expected to deliver measurable quantities of sediment to Johnson Creek before it becomes stabilized. The remaining OSV trails will be constructed largely along existing roads. Although some vegetation and tree removal will need to occur to ensure safe snowplowing, these OSV trails are not expected to produce meaningful sediment delivery and turbidity beyond that already generated by the existing road network.

Work associated with power transmission lines will also clear vegetation and disturb soils, potentially contributing to sediment delivery to action area streams. During the construction phase of the project, access roads for powerlines, communicator towers, and repeater sites will be constructed, and vegetation clearing will be necessary at tower locations and along the powerline ROW. The powerline will cross 37 different streams, 26 of which are related to the upgrade of existing IPC infrastructure where the existing transmission line ROW crosses various streams. The existing transmission line currently crosses Cabin Creek, Trout Creek, and Riordan Creek. The new transmission line will cross three creeks with only one being perennial (Riordan Creek).

Riordan Creek supports *O. mykiss*, and although the BA considered these fish resident rainbow trout versus steelhead, steelhead are present in Johnson Creek, and NMFS is not aware of any passage barrier in Riordan Creek that would preclude steelhead access to this stream. Therefore, in this analysis, NMFS considers *O. mykiss* in Riordan Creek steelhead upstream to approximately Riordan Lake.

During transmission line upgrades and new transmission line construction, the potential exists for increased runoff, erosion, and sedimentation as a result of vegetation removal within the ROW, and the localized excavation of soil, rock, and sediment for structure work and/or ROW access roads. Although often requiring a wider clearing zone, vegetation clearing along the ROW is not expected to generate large amounts of sediment as work will be limited to trimming of trees that pose a fire risk to the power line. During all vegetation clearing activities, IPC will ensure there is no disturbance of the soil surface that will create an added risk of erosion, the promotion of the establishment or expansion of invasive species (including noxious weeds), damage to cultural resources, sensitive species, or ESA-listed species. Vegetation clearing will retain vegetation root structure within soils, therefore reducing erosion concerns.

Access routes will be required from the existing access road to reach powerline structure locations without current access (Table 11). Roads will be opened/cleared for use by trucks transporting materials, excavators, drill rigs, bucket trucks, pickup trucks, and crew-haul vehicles. These overland service routes will require a 14-foot-wide ROW to accommodate construction and maintenance equipment. Access roads will generally be left as close to an undeveloped nature (i.e., two-track road) as possible without creating environmental degradation (e.g., erosion or rutting from poor water drainage). Specific actions, such as installing water bars and dips to control erosion and stormwater, will be implemented to reduce construction impacts and will follow standard designs. Routine inspection and maintenance of service and access roads, such as blading the road to maintain the surface condition and drainage, removing minor physical barriers (i.e., rocks and debris), replacing culverts or rock crossings, and rehabilitating after major disturbances requiring heavy equipment (such as slumping). Heavy equipment will travel and maneuver on existing service and access roads. Given proposed road maintenance and application of erosion control EDFs will be similar to those used for other SGP access roads, NMFS therefore expects that powerline access roads will deliver some quantity of sediment to action area streams, but they are not likely to become a chronic source of sediment delivery, and are not expected to meaningfully impact the water quality PBF.

The new powerline ROW overlaps with 14.8 acres of RCAs. Overall, the transmission line ROW overlaps with 132.4 acres of RCAs (including non-anadromous RCAs) (Stantec 2024). Riparian vegetation removal as a result of powerline construction has the potential to decrease bank stability, which may result in bank erosion and an increase in sediment to the waterways. For the new portion of the powerline, vegetation will need to be cleared for structure footings. However, the utility poles are not directly along creeks or within RCAs, so clearing of construction pads for footings is not likely lead to sediment deliver and turbidity impacts to the water quality PBF. Instead, vegetation removal in RCAs, if it occurs, will target taller vegetation that exceeds the maximum height specified for the wire and border zones. Because lower-growing vegetation will be maintained along the ROW, bank stability is not expected to be compromised to a degree that will result in high levels of sediment delivery.

Overall, for the powerline transmission line portion of the action, turbidity plumes are expected to be limited to storm events following construction activities due to the distance project activities occur from streams. In addition, implementation of various erosion control BMPs is expected to limit not only the amount of sediment produced, but also subsequent delivery to nearby streams. As such, turbidity pulses are expected to be low-intensity, localized, infrequent, and short-lived. Therefore, the conservation value of the water quality PBF in the action area is not expected to be appreciably diminished from transmission line activities.

As described in the BA (Stantec 2024), surface water quality also could be impacted during construction by fugitive dust from vehicles and heavy equipment that settles into adjacent waterbodies. Perpetua plans to address these potential impacts through dust abatement measures on the roads and at the SGP. In dry months, Perpetua will spray water and dust abatement chemicals on mine haul roads as necessary to mitigate dust emissions in compliance with state and USFS requirements.

In addition to runoff from new ground disturbance, diversions of stream channels during the construction period have the potential to introduce turbidity as water is diverted into new channels. A 0.9-mile-long tunnel will be built in MY -1 to direct the EFSFSR around the west side of YPP to allow mining in the pit and fish passage during construction and operations (Figure 13). Fiddle, Hennessy, and Midnight Creeks will also be diverted in MY -1. Meadow and Garnet Creeks will be diverted in MY -2, while segments of Garnet Creek and EFMC will also be reconstructed during this same period. Diversion tunnels will be completed in the dry, and EDFs require pre-rinsing of diversion channels and introducing flows slowly will effectively limit the amount of turbidity caused by these actions (i.e., limited to short, low magnitude pluses, extending less than 1,000 ft. downstream).

New surface and underground exploration activities will be conducted beginning in the construction period and continuing through operations. Although underground exploration is unlikely to deliver sediment to action area streams, surface exploration may. Surface exploration is estimated to occur on approximately 65 acres of disturbance within the operations boundary

(Figure 15), including approximately 25 acres of temporary roads and 40 acres of drill pads. Other than at 11 locations, the exact locations of the drilling pads have not yet been determined, with general areas expected to be targeted displayed in Figure 16. The locations will be located in, but not necessarily limited to, areas around the WEP, YPP, Fiddle Creek GMS, and HFP. As outlined in the proposed action, foreseeable drill areas are offset from flowing streams with no exploration areas along Sugar Creek.

Perpetua proposes using the same or similar drilling methods and environmental protection measures that have been employed for exploration drilling in the past (i.e., exploration under the Golden Meadows Exploration Plan). However, the BA did not provide any specificity regarding this approach. This considered, NMFS includes a list of project design features and BMPs in Appendix B that we deem most pertinent to protection of ESA-listed fish species and critical habitat in the ESA Section 7 consultation completed on that project (NMFS No.: WCR-2015-3169). Our analysis assumes that all of these project design features and BMPs will be followed for exploration activities.

Drilling support equipment will include helicopters, water trucks, crew trucks, portable mud tanks, pipe trucks or skids, portable toilets, light plants, portable generators, motor graders, excavators, and dozers. In terms of ground disturbance, the proposed action will utilize a rolling maximum of five acres of active temporary road disturbance (10,500 liner ft. of road) and eight acres of active drill pad disturbance (140 pads) within the total 65-acre authorization and will reclaim road and pad disturbance to remain below that rolling maximum of active disturbance. Where practicable, Perpetua plans to establish drill pads in reclaimed roadbeds and only open temporary roads in the vicinity of authorized mine disturbance in order to access exploration targets. Therefore, NMFS presumes some degree of minor brush clearing and minimal tree cutting may be required to clear areas for each platform. Drill pads created for truck-mounted or crawler-mounted drill rigs will require a 75 to 100-foot-long by 50 to 60-foot-wide working area (less than 0.15 acres), while drill pads supported by helicopter require working areas approximately 45 feet long by 35 feet wide working areas (less than 0.05 acres).

Drilling activities and road preparation/use will potentially cause increased sediment delivery to the EFSFSR and its tributaries, causing temporary turbidity pulses and subsequent sediment deposition. No excavation is anticipated for construction of the pads; however, excavation will be required for sump construction. The SGP will implement a variety of erosion and sediment control EDFs to minimize the amount of sediment mobilized and transported to streams. Sediment basins and traps will be used at each drill site to collect drill cuttings and to manage and circulate drilling fluids.

As in the Golden Meadows Exploration project (NMFS No.: WCR-2015-3169) and summarized in Appendix B, the risk of sediment delivery to streams should be minimized by ensuring all drill locations are at least 100 feet away from the nearest surface waterbody. And, should a drill pad be needed in an RCA, NMFS expects Perpetua will submit a written request to the PNF for approval of the location. The request must include an explanation as to why there is no reasonable alternative to siting the pad in an RCA. MGI must receive approval from the PNF prior to pad construction. Drill pads in RCAs will be sited to avoid removing any large trees to the extent possible. Any trees that are felled within the RCA will be left in the RCA. Due to drilling pad locations, it is likely that much of the sediment not trapped by erosion control PDFs will be filtered by vegetation and other obstructions on the ground.

Reclamation of exploration disturbance will be conducted as soon as practicable following data collection and at least three growing seasons is estimated to be needed to establish vegetation and determine reclamation success. Areas disturbed for exploration will be contoured to blend into surrounding terrain; water bars and surface water channels will be retained to handle flows through the area. Compacted areas will be de-compacted as necessary prior to fertilizing and seeding.

Considering project design features and erosion control EDFs associated with exploration, these activities are unlikely to deliver any more than low-intensity, localized, infrequent, and short-lived turbidity pulses and plumes, minimally affecting the conservation value of the water quality PBF.

Operations. During operations, active mining will disturb, excavate, and move soil and overburden, thereby raising the potential for sediment runoff and suspended sediment increases in surface waters. However, contact water controls will be in place to capture runoff from mine facilities. During this phase (approximately 15 years), a total of 50 vehicle trips per day are anticipated on average (year-round) during operations utilizing the Burntlog Route, consisting of 17 light vehicles and 33 heavy vehicles. On the mine site and along the Burntlog Route, road maintenance, dust abatement, and proposed erosion control EDFs are expected to be effective in minimizing the amount of sediment delivered, suspended, and deposited in action area streams.

Also, during the operational period, surface discharge of treated waters has the potential to generate turbidity. To address this effect, IPDES-permitted outfalls will be constructed with energy dissipation at their discharge location, a design expected to minimize sediment delivered to and suspended in action area streams at these locations.

As previously described, the greatest potential for Project-related increases in stream sedimentation will come during storm events causing overland flow across exposed soil, excavated areas, and roads. However, proposed erosion control BMPs (e.g., mulching, planting of vegetation, silt fences, removal of legacy materials, etc.) [Appendix A] to be employed should be effective in limiting the amount of sediment transported, suspended, and deposited in action area streams.

During operations, the GRAIP-Lite model results show an increase in sediment delivery, input, and accumulation, likely because of the additional 55 km (34.1 miles) of road compared to baseline. Table 57 shows the modeled change in sediment production, delivery, and accumulation during operations. Table 58 describes the sediment delivery by road segment, where modeling indicates that sedimentation in waterways under construction will be decreased compared to baseline conditions. Table 59 breaks down sediment delivery by structure type and watershed. Additional details regarding the GRAIP-Lite model and its results are provided in Tetra Tech 2024.

Table 57. Sediment Production, Delivery, and Accumulation under Baseline and Operations.

Metric	Baseline Conditions	Operations	Percent Change from Baseline
Kilometers of roads modeled	125	180	+44%
Sediment Production (kg and tons/year)	387,955 (482)	419,478 (462)	+8%
Sediment delivery to streams (kg and tons/year)	93,371 (103)	120,609 (133)	+29%
Sediment accumulated in streams (kg and Tons/year)	8,901,299 (9,812)	11,778,886 (12,984)	+32%

Note: Tons per year indicated in brackets.

Table 58. Predicted Sediment Loading by Road Segment under Baseline and Operations (Terra Tech 2024).

Road Segment	Baseline Conditions		Operations Phase	
	Sediment Generated (kg and tons/year)	Sediment Delivered (kg and tons/year)	Sediment Generated (kg and tons/year)	Sediment Delivered (kg and tons/year)
Johnson Creek Road	78,441 (86)	27,736 (31)	18,458 (20)	7,544 (8)
Stibnite Road	23,407 (26)	10,875 (12)	12,792 (14)	5,992 (7)
Burnt Log Road/Burntlog Route	65,233 (72)	13,450 (15)	118,706 (131)	40,306 (44)
On-Site Roads	102,156 (113)	24,637 (27)	140,988 (155)	46,820 (52)
Meadow Creek Lookout Road and Thunder Mountain Road	118,717 (131)	16,675 (18)	128,534 (142)	19,947 (22)

Note: Tons per year indicated in brackets.

Table 59. Annual Sediment Delivery to Drainage Crossings Under Baseline and Operations (kilograms and tons/year) (Stantec 2024).

Sediment Delivery per Drainage Crossing Type	Johnson Creek	Stibnite Road	Burntlog Route	On-Site Roads
Bridges				
Baseline	627 (0.69)	111 (0.12)	740 (0.82)	4 (0.01)
Construction	168 (0.19)	118 (0.13)	874 (0.96)	330 (0.36)
Culverts				
Baseline	1,477 (1.63)	3 (0.01)	1,238 (1.37)	208 (0.23)
Construction	514 (0.57)	172 (0.19)	5,346 (5.89)	415 (0.46)
Total				
Baseline	**2,104 (2.32)**	**330 (0.36)**	**2,713 (2.99)**	**496 (0.55)**
Construction	**682 (0.75)**	**727 (0.80)**	**21,992 (24.24)**	**2,084 (2.30)**

Note: Tons per year indicated in brackets.

In an effort to put these sediment delivery figures from Tables 57 to 59 in context, we compared these estimated sediment budgets[12] found in the literature. Parkinson et al. (2003) estimated the

[12] As defined in Parkinson et al. (2003), a sediment budget accounts for all sediment entering, leaving, and being stored in a river system.

annual sediment budget for the SFSR as ranging from 730 to 12,775 tons/mi.^{2}/year. IDEQ (2011) also estimated the sediment budget for the SFSR, where they reported logging roads as responsible for up to 2,000 tons/year, with natural sources of sediment contributing 15,900 tons/year. Considering results from the GRAIP-Lite modeling presented in Tables 57 to 59, NMFS expects that the predicted increases in sediment delivery will not degrade the water quality PBF at the stream reach, watershed, or subbasin scales.

Although fugitive dust from road use will also contribute fines during the operations period, the greatest extent of sedimentation effects from dust will be concentrated at the mine site itself. However, due to the nature of sediment transport by streams, the geographic extent of the impact could extend farther downstream in the EFSFSR depending on site- and event-specific factors. The duration for traffic-related dust and erosion/sedimentation will last throughout the mine operation period. As previously mentioned, Perpetua plans to address these potential impacts through dust abatement measures on the roads and at the SGP. In dry months, Perpetua will spray water and dust abatement chemicals on mine haul roads as necessary to mitigate dust emissions in compliance with state and USFS requirements.

Although blasting has the potential to disturb soils, generate dust, and deliver sediment to action area streams, areas requiring blasting will typically occur on steeper side slopes and in upland areas (Stantec 2024). Limiting charge sizes, controlled blasting techniques, and proposed setback distances from streams designed to be protective of fish should prove effective at minimizing the amount of sediment delivered to streams by blasting.

As described for the construction phase, underground exploration is unlikely to deliver sediment to action area streams, but surface exploration may. New surface and underground exploration activities will be conducted during the operations phase. As previously described, drilling activities and road preparation/use will potentially cause increased sediment delivery to the EFSFSR and its tributaries, causing temporary turbidity pulses and subsequent sediment deposition. However, following project design criteria for the Golden Meadows Exploration project and other proposed erosion and sediment control EDFs are expected to effectively minimize the amount of sediment mobilized and transported to streams.

In summary, during the operations period, ground-disturbing sediment impacts to DCH will include temporary turbidity increases during runoff events and localized deposition of fine sediment in stream channels. Some sediment may be later resuspended and transported to downstream areas, although not expected to greatly affect the overall sediment budget at the reach, watershed, or subbasin scales. Turbidity increases during runoff events could affect the water quality PBF to the degree that it temporarily changes fish behavior, but these increases are unlikely to be long-lasting or severe enough, to affect the long-term conservation value of the water quality PBF.

Closure/Restoration. During the post closure period, erosion control BMPs will remain in place as mine disturbance is covered, reclaimed, and revegetated to control runoff from mine facility areas (Stantec 2024). Stream flow will be reintroduced into restored stream segments in Meadow Creek across the TSF. Upon completion of mining in the YPP, the pit will be backfilled and covered with a geosynthetic liner. A restored segment of the EFSFSR will be routed on top of the backfilled and covered pit and flow diverted through the tunnel will be re-routed to the restored channel. EDFs and BMPs described in Table 22 and Appendix A will be employed to pre-rinse diversion channels and introduce flows slowly to limit generation of new turbidity caused by these activities.

During the closure and reclamation phase, traffic along the Burntlog Route will be reduced to a total of 27 vehicle trips per day (year-round). Once the Burntlog Route is complete, the OSV route will return to Johnson Creek Road. Closure road usage will resemble the operational conditions with usage reducing over time. Post-closure road usage will resemble the existing conditions once new portions of the Burntlog Route have been obliterated and reclaimed as part of the closure activities.

Although facility reclamation will also generate sediment, the relatively flat nature of the construction site, combined with the application of proven erosion control practices, are expected to reduce the likelihood of effects from facility construction and reclamation to negligible levels.

Surface discharge of treated waters will continue until no longer necessary. Although these discharges have the potential to generate turbidity, these outfall structures will be constructed with energy dissipation at their discharge location to which should effectively minimize potential turbidity.

The duration for traffic-related dust and erosion/sedimentation will last throughout the mine construction, operations, and post-closure periods; however, these effects will be incrementally reduced during closure and reclamation due to reduced activity at the SGP and stabilization of disturbed areas.

In summary, sediment generating activities will include frequent, sporadic turbidity effects to water quality across action area streams, with those increases occurring most frequently occurring during runoff events and resulting in localized deposition of fine sediment in action area stream channels. These effects are likely to affect action area streams from the beginning of construction through closure and reclamation. Although turbidity increases during runoff events are likely to affect water quality to the point that they periodically affect fish behavior, they are unlikely to reach levels severe enough or long enough to affect the long-term conservation value of the Water Quality PBF.

2.10.1.2. **Water Quantity**

The changes in surface water quantity described in this section are compared to those of the simulated existing conditions. Changes in surface water flows in the analysis area are expected to result primarily from:

- Water drafting for dust suppression and test drilling for the BRGI;
- Stream diversion around mine facilities affect the path of surface water flows;
- Interception of contact water and other mine-impacted water prior to runoff;
- Development and dewatering of three open pits;
- Groundwater production for consumptive use;

- Stream water diversion above the EFSFSR tunnel for consumptive use; and,
- Discharge of treated water.

These activities have the potential to modify the location and/or flow rate of stream flows in the analysis area.

Pre-construction. The BRGI portion of the proposed action would reduce flow in Johnson Creek by up to 6,050 gallons for one year (M Y-3), which represents approximately 0.00002 percent of available flow during an average year. This considered, there is very little water use in the Johnson Creek drainage, and flow in Johnson Creek is nearly unimpaired. Therefore, the effects of the BRGI portion of the project is expected to have only temporary, and very minor effects on the water quantity PBF.

Construction and Closure. The proposed action will result in diversion of water from the EFSFSR and from groundwater wells in the project area (Table 16), which will reduce flows in Meadow Creek and the EFSFSR). The proposed action will also result in changes in hydrology within the project area, which will alter flows in Meadow Creek, Sugar Creek, and the EFSFSR. The estimated effects on flow, by MY and reach, are in described in Table 60.

Table 60. Estimated reduction (cfs) in average July-September, flow, by reach and Mine Year (MY).

Mine Year	Net Flow Reduction (cfs) Due to Water Diversion and Discharge				Flow Reduction (cfs) Due to Drainage Area Reduction	Total Net Flow Reduction in the EFSFSR Downstream from Sugar Creek and The SFSR Downstream from the EFSFSR
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP and Sugar Creek	Sugar Creek	
-2	-0.20	0.00	-0.20	-0.21	0	-0.21
-1	0.20	0.00	0.20	0.82	0	0.82
1	0.42	0.00	0.44	1.50	0.39	1.90
2	0.77	0.00	0.76	3.42	0.39	3.82
3	0.84	0.00	0.86	2.40	0.39	2.80
4	1.40	0.00	1.35	2.61	0.39	3.01
5	-0.21	0.01	-0.15	0.97	0.39	1.37
6	1.12	0.02	1.34	2.48	0.39	2.88
7	2.23	0.02	2.38	3.69	0.39	4.09
8	1.75	0.01	1.70	3.54	0.39	3.94
9	0.55	0.00	0.56	2.10	0.39	2.50
10	0.55	0.00	0.54	2.20	0.39	2.60
11	0.54	0.00	0.56	2.40	0.39	2.80
12	0.62	0.00	0.63	1.97	0.39	2.37
13	0.67	0.08	0.75	2.14	0.39	2.54
14	0.47	0.14	0.61	1.45	0.39	1.85
15	0.53	0.10	0.48	1.02	0.39	1.42
16	0.20	0.05	0.13	0.45	0.39	0.85
17	0.21	0.14	0.30	0.54	0.39	0.94
18	0.26	0.11	0.34	0.57	0.39	0.97
19	0.18	0.08	0.22	0.34	0.39	0.74
20	0.11	0.07	0.15	0.33	0.39	0.73
20+	0.00	0.00	0.00	0.00	0.39	0.39

We compared the estimated effects on flow, provided in the BA, to USGS gage data to determine the downstream extent of the flow analysis. The estimated flow effects summarized in Table 60 translate to reductions in average January flow (i.e., the lowest average monthly flow) of 31.6% to 33.9% in the EFSFSR below the confluence of Sugar Creek, 5.2% to 5.5% in the EFSFSR below the confluence of Johnson Creek, 2.0% to 2.2% in the SFSR below the confluence of the EFSFSR, and 0.31% to 0.33 % in the Salmon River below the confluence of the SFSR. In systems with minimal development of water resources, such as the SFSR drainage, Tehan (2014) stipulates analyzing effects on flow downstream to the point at which effects are less than one percent of the lowest base flows. The flow effects of the proposed action are substantially greater than one percent of the base flow of the SFSR below the confluence of the EFSFSR, and are less than one percent of the lowest base flows in the Salmon River at the confluence of the SFSR. We therefore analyzed the flow-related effects of the proposed action downstream to the confluence of the SFSR and the Salmon River.

The water rights associated with the proposed action include conditions that restrict diversion when flows are less than 5.0 cfs from October 1 – June 29, or 7.25 cfs from June 30 – September 30, in the EFSFSR between Meadow Creek and the YPP; and when flows are less than 3.0 cfs in lower Meadow Creek. These "minimum flows" should ensure that the proposed action will not reduce flows sufficiently to substantially impair migration PBFs. The SFSR drainage typically has a high ratio of peak to base flows, and the estimated flow effects represent a relatively small percentage of peak flows. We therefore presume that effects on channel maintenance functions of flow would be relatively small. However, reducing flow in streams affects salmonid habitat in a variety of ways in additional to passage and channel function. Reductions in flow reduces water quality (Ebersole et al. 2001; Poole and Berman 2001; Dahm et al. 2003; Ebersole et al. 2003; May and Lee 2004; Miller et al. 2008), increases the amount of fine sediment in substrates (Baker et al. 2011), reduces health of riparian vegetation (Smith et al. 1991), reduces the amount and/or availability of drifting invertebrates (Townsend and Hildrew 1976; Elliott 2002; Boulton 2003; Lake 2003; Nislow et al. 2004; Harvey et al. 2006; Hayes et al. 2007; Miller et al. 2007; Carlisle et al. 2011; Jager 2014), reduces access to escape cover (Hardy et al. 2006), and reduces the amount of cold water refugia (Ebersole et al. 2015). Through these pathways, the flow reductions resulting from the proposed action will reduce quality of SR Spring/summer Chinook salmon spawning gravel, water quality, cover/shelter, food, space, substrate, and water temperature PBFs; and SRB steelhead water quality, substrate, forage, and natural cover PBFs. Reducing flow also affects the water quantity PBFs for both SR Spring/summer Chinook salmon and SRB steelhead, the floodplain connectivity PBF for SRB steelhead, and the space PBF for SR Spring/summer Chinook salmon.

Detecting and quantifying the effects of reducing flow on individual PBFs could possibly be accomplished with intensive modeling, but even the most refined flow habitat models tend to underestimate optimal flows (Rosenfield et al. 2016) suggesting that modeling would likely underestimate the effects of flow reductions on fish habitat. Because relationships of population productivity and streamflow are well documented (see section 2.10.4.3), we used the relationships of population productivity and flow to estimate the flow-related effects of the proposed action on SR Spring/summer Chinook salmon and SRB steelhead DCH. The magnitude of effects peak at MY 7 and are greatest in lower Meadow Creek, where the estimated reduction in flow would reduce productivity of SR Spring/summer Chinook salmon and SRB steelhead DCH by 29% and 62%, respectively. Estimated reductions in productivity due to reduced flow, by stream reach and MY, are in Appendix G.

The flow-related effects of the proposed action would affect DCH within the EFSFSR Chinook salmon and SFSR Chinook salmon population areas, and in the SFSR steelhead population area. On a population scale, the flow-related effects of the proposed action would reduce productivity of DCH in the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead population areas by maximum of 2.2%, 0.15%, and 0.81%. This maximum effect will occur during MY 7, and will gradually decrease between MY 7 and MY 20 (Appendix G). The average reduction in productivity for MYs -2 through 20 will be 1.1%, 0.007%, and 0.36%, respectively, for DCH in the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead population areas. After mining activity stops, in MY 20, water will no longer be diverted, and streamflow throughout most of the mine footprint will return to normal. However, flows in Sugar Creek and the EFSFSR would continue to be reduced due to filling of the WEP Lake. This flow reduction would reduce annual productivity of the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead population areas by 0.13%, 0.001%, and 0.082% respectively. This reduction would last for approximately 57 years post mining (i.e., through MY 77).

2.10.1.3. **Physical Habitat Conditions – Spawning Gravel, Passage, and Space/Cover/Shelter.**

Several PBFs (i.e., physical habitat conditions, safe passage, and space/cover/shelter) represent elements of salmon and steelhead DCH for spawning, rearing, and migration. Potential effects for these PBFs were described in the BA as potential effects to the habitat access and habitat element WCIs (i.e., interstitial sediment, LWD, pool frequency/quality, off-channel habitat, and refugia). A discussion of how the SGP may affect each of these PBFs follows.

2.10.1.3.1. Spawning Gravel/Substrate

The spawning gravel/substrate PBFs are essential to steelhead and Chinook salmon spawning and rearing. The condition of the Interstitial Sediment WCI is indicative the condition of these PBFs, characterized as currently FA for both the EFSFSR and Johnson Creek watersheds (Table 30; and BA Appendix C [Stantec 2024]).

Salmonid spawning habitats are created by and depend on channel characteristics and complexities that cause hydraulic sorting and gravel accumulation into suitable spawning beds. If well established, these beds are relatively resistant to scour during periods of egg incubation. Increased sediment deposition may lead to increased embeddedness of downstream substrates. Fine, redeposited sediments have the potential to adversely affect primary and secondary productivity (Spence et al. 1996), and reduce incubation success (Bell 1991) and cover for juvenile salmonids (Bjornn and Reiser 1991).

As previously discussed, ground disturbing activities and roadwork are expected to result in sediment delivery to action area streams, beginning during the pre-construction phase, tailing off during closure and restoration. Sediment delivered by the project is generally expected to first settle out within 1,000 feet of the points of introduction. Deposited sediments are likely to later be transported farther downstream during storm events and periods of high flow. For Chinook salmon habitat, substrate-related effects are most likely to be realized in the EFSFSR and Johnson Creek during the construction phase, and the EFSFSR, Johnson Creek, Meadow, Sugar, and lower Burntlog Creeks during the operations and closure/restoration phases. For steelhead, substrate-related effects are most likely to be realized in the EFSFSR, and Johnson, Burntlog, Trapper (lower 0.75 miles), and Riordan (downstream from Riordan Lake) Creeks during all phases of the project. Steelhead substrate in Sugar Creek will be potentially affected during the operations and closure/restoration phase of the SGP.

Rio ASE (2021) identified EFMC as the single largest source of sediment delivery to the EFSFSR in the project area, contributing up to an estimated 77.4 tons per year to the upper EFSFSR watershed. The proposed action will attempt to address this chronic source of sediment delivery, by: (1) raising groundwater levels to restore wetland function and improve the incised stream channels in upper EFMC; and (2) by stabilizing the confined, high gradient channel in the lower reach.

During and after mine operations, EFMC will flow into the restored Meadow Creek channel around HFP, habitat expected to be used for rearing and spawning Chinook salmon and steelhead as soon as MY3 (table 45). Increases in fine sediment deposition within stream channels have the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles, potentially impacting spawning/incubation and rearing/feeding life stages of Chinook salmon and steelhead. However, spawning substrates are generally FA in action area streams, and GRAIP-Lite modeling suggests that the amount of sediment delivered to action area streams will decrease in comparison to the baseline condition. With application of proposed sediment control BMPs, the deposition of sediment in action area waters is predicted to be measurable but not severe. It is not expected to degrade this PBF in the temporary or short-term; and following closure of the mine, obliteration of access roads, and restoration efforts in the EFMC, the proposed action is expected to result in a substantial decrease in annual sediment delivery into Meadow Creek and the EFSFSR. Therefore, the effects of the proposed action on substrate will be minor and will not affect the conservation value of this PBF in the short term, and may benefit this PBF in the long term.

2.10.1.3.2. Fish Passage

Habitat access was characterized as FUR for the EFSFSR, and ranged between FA and FUR in Johnson Creek (Table 30). BioAnalysts (2021) evaluated fish passage for the EFSFSR and its tributaries in the project area, identifying five artificial barriers and one natural barrier in fish-bearing streams. Barriers were also classified as either complete or partial (Table 32). Major barriers to fish passage at the mine site include: (1) the high gradient cascade in the EFSFSR upstream from the YPP Lake; (2) EFSFSR box culvert; and (3) the high gradient cascade in Meadow Creek upstream from the confluence with the EFMC (at the downstream end of the engineered channel). The cascade upstream from the YPP Lake is a complete barrier to natural fish passage. When Chinook salmon are not stocked upstream of this barrier, the barrier blocks about 92 percent of available Chinook salmon DCH upstream of Sugar Creek (ESS 2022). The other two major barriers, the EFSFSR box culvert and Meadow Creek barriers, are flow-dependent partial barriers that can block seasonal migration, and only hinder migration of fish that reside in or were stocked upstream from the YPP Lake cascade barrier (i.e., translocated Chinook salmon) (Stantec 2024).

During the construction phase, the proposed action will begin to address fish passage in the EFSFSR subbasin. The tunnel to bypass YPP Lake, and the high gradient cascade upstream from the lake, will be complete by MY -1. Designs for the tunnel have been reviewed by NMFS' fish passage engineer, and although it is suspected that the tunnel will pass all life stages of ESA-listed salmonids, whether fish will actually use the tunnel and what the actual passage rate will be are both unknowns. However, because Perpetua will alternatively use trap and haul (facility also reviewed by NMFS' fish passage engineer) to get fish upstream of the YPP cascade should passage not work as designed, NMFS assumes that ESA-listed salmonids will access stream segments upstream of the cascade beginning in MY -1 whether the tunnel functions as intended or not.

The EFSFSR box culvert will also be removed by MY -1. Although the partial gradient barrier in Meadow Creek just upstream from EFMC will also be removed during the construction phase of the Project, a new barrier will be created in MY -2 just upstream from the existing barrier to prevent fish passage into upper Meadow Creek where the TSF will be constructed. This new barrier, will block access to approximately 0.43 miles of otherwise accessible Chinook salmon DCH through MY 12. By MY 18, the only barrier that impacts Chinook salmon DCH will be the steep gradient section of Meadow Creek associated with the TSF buttress created as part of the SGP, a barrier that will remain indefinitely and will continue to eliminate volitional access to approximately 3.87 miles of Chinook salmon DCH (ESS 2022).

Although Chinook salmon were already using habitat upstream from the YPP cascade in years following release of excess hatchery fish, removal of these barriers will result in volitional passage into the upper EFSFSR for the first time since the 1930s. Passage upstream of the cascade will provide access to up to 12.2 miles (19.65 km) of potential Chinook DCH, 5.51 miles (8.87 km) of which was modeled as having intrinsic potential for Chinook spawning and rearing (Stantec 2024).[13]

The only surface water diversion associated with the proposed action will be on the EFSFSR between Sugar Creek and the YPP. This diversion will meet NMFS criteria for upstream and downstream fish passage (NMFS 2022a), and will therefore not impair upstream fish passage. However, some juveniles will migrate downstream via the bypass system, which will cause migration delay and will increase migration mortality, thereby adversely affecting the fish passage PBFs. Reduced flow, caused by surface and groundwater diversion, also has the potential to impair fish passage. However, the conditions for water rights 77-7122, 77-7293, 77-7285, 77-14378, preclude diversion when flows are less than the stipulated minimums (i.e., 5.0 cfs from October 1 to June 29, and 7.25 cfs from June 20 to September 30) at the EFSFSR POD, and limit diversions when flows are less than 25 cfs in the EFSFSR below Sugar Creek. Also, the conditions in water right 77-14378 preclude diversion when flows in Meadow Creek are less than 3.0 cfs. Adherence to these conditions should ensure that flows are adequate for upstream and downstream migration of Chinook salmon and steelhead in Meadow Creek and in the EFSFSR within and downstream from the project area.

As outlined in the BA (Stantec 2024), during the construction of the Burntlog Route and other temporary roads, culverts will be constructed or replaced, which may affect fish access. There are 18 existing crossings along the Burntlog Road (FR-447) that will be replaced and 10 new crossings along newly constructed portions of the Burntlog Route. There are approximately 53 miles of stream segments upstream of the Burntlog Route. Currently almost all stream crossings along the Burntlog Road are impassable culverts, particularly at low flow conditions. The key perennial streams that will be crossed are Burntlog, Trapper, and Riordan Creeks, the headwaters of which do not support Chinook salmon nor steelhead. The route will cross DCH for SR Basin steelhead once in upper Burntlog Creek, and cross SR Spring/summer Chinook DCH once in upper reaches of the EFSFSR. Chinook salmon and steelhead have not been found this far upstream in either of these locations during past survey efforts. Because all new or reconstructed crossings are required to be fish passable, the proposed action will only impact the fish passage PBF temporarily as work areas are dewatered to construct the crossings. By the end of the construction phase, retrofitted crossings are likely to improve or reestablish fish passage where it had previously been reduced or blocked.

[13] Although steelhead will also be able to access approximately 5.42 miles (8.72 km) of intrinsic potential habitat upstream of the cascade, there is no DCH for steelhead present upstream of the cascade.

Riparian roads can also affect the passage PBF by constraining the natural migration of the stream channel where channel migration zones are present. Stream crossings can affect passage by restricting channel geometry and preventing or interfering with migration of adult and juvenile anadromous fish (Furniss et al. 1991). New road segments constructed for the Burntlog Route will cross multiple streams, but will generally not closely parallel or constrict streams. Most of the constructed and retrofitted stream crossings will occur high in tributary headwaters, well upstream of waters occupied by ESA-listed salmon and steelhead, and therefore having little if any effect on this PBF.

Transmission lines will cross streams or border streams occupied by ESA-listed fish, including the SFSR, and Cabin Creek, Trout, Johnson, Trapper, and Riordan Creeks. No new stream crossings are anticipated for transmission line access roads. Therefore, transmission line construction is not expected to affect fish passage.

Migratory fish passage could also be affected through chemical contamination resulting from an accidental spill, stormwater discharge, wastewater treatment plant discharge, or nonpoint sources of pollution associated with permanent mine facilities. Fish passage is not expected to be affected by chemical spills because spills in quantities sufficient to impede passage are not expected to occur. Determining whether a contaminant or contaminant mixtures will impede fish passage is difficult. First, it is difficult to predict avoidance responses with any degree of certainty because avoidance responses depend on many different factors such as water chemistry, species and life stage exposed, variability in metal mixtures, temperature, cover, shade, acclimation, prey availability, presence of predators, and competition with other fish. Alone, copper can elicit avoidance responses in juvenile Chinook salmon and steelhead in soft water at concentrations as low as 0.7 µg/L (Hansen et al. 1999a). Researchers have studied fish avoidance of chemical mixtures in the lab and in the field. In laboratory tests, copper and zinc mixtures have been shown to act together to cause a lower threshold of avoidance than would result from either metal alone (Giattina and Garton 1983). Hansen et al. (1999a) reported that behavioral avoidance to copper and cobalt mixtures in soft water differed greatly between the rainbow trout and Chinook salmon. Rainbow trout avoided 1.6 µg/L concentration of copper and 180 µg/L cobalt individually, but when exposed to a mixture of the two chemicals, the response occurred at significantly lower concentrations (i.e., a mix of 2.6 µg/L copper and 2.4 µg/L cobalt). Chinook salmon were more sensitive than rainbow trout, avoiding mixtures of 1.0 µg/L copper and 0.9 µg/L cobalt (Hansen et al. 1999a).

Studies of avoidance behavior to the mixture of metals in the Clark Fork River found that rainbow trout were more sensitive than brown trout, which in part may explain why rainbow trout populations appear to be more severely affected than brown trout populations (Woodward et al. 1995; Hansen et al. 1999b). Cutthroat trout avoided a metals mixture of 6 µg/L copper, 0.3 µg/L cadmium, 0.6 µg/L lead, and 28 µg/L zinc (Woodward et al. 1997). Rainbow trout avoided all metal concentrations tested from 10 to 1,000 percent of a fixed ratio of ambient metal concentrations (12 µg/L copper, 1.1 µg/L cadmium, 3.2 µg/L lead, and 5 µg/L zinc) (Hansen et al. 1999b). In a Coeur d'Alene River study (Goldstein et al. 1999), 70 percent of the adult Chinook salmon migrated up the North Fork (the control stream with zinc concentrations of around 9 µg/L) and 30 percent migrated up the South Fork (a mining impacted stream with zinc concentrations of about 2,200 µg/L). The authors concluded the salmon migrated up the North

Fork because it had lower ambient concentrations of zinc and other metals. However, the North and South Forks make up roughly 70 and 30 percent of the flows in the Coeur d'Alene River, respectively. Adult salmon movements in rivers in the absence of any homing cues (as was the case in this study) tend to simply follow larger flows (Anderson and Quinn 2007). Whether or not metals concentrations influenced adult salmon movement in this study is debatable. The proposed action is not expected to result in contaminant concentrations that will elicit avoidance.

Fish passage is not expected to be meaningfully affected by chemical contamination from the project. First, predicted average copper concentrations are less than 0.5 µ/L, which is below thresholds known to elicit avoidance. However, predicted maximum copper concentrations will be above concentrations that have been associated with some avoidance (e.g., lowest observed effect concentration, EC_{20}, etc.). The predicted maximum concentration may cause a few individual fish to avoid stream reaches during operations, early closure, and/or late closure, depending on the stream reach. While some fish may avoid reaches, other fish are expected to not avoid the impacted reaches. This is evidenced by juvenile fish utilizing habitats with copper concentrations currently greater than, or nearly equal to, predicted concentrations. Finally, mixing zones for copper and other contaminants are not expected to be authorized; further minimizing the potential reducing fish passage. When considering the risk of a contaminant spill and predicted contaminant concentrations, the conservation value of the safe passage PBF will not be reduced at the scale of the action area. for the following reasons: (1) individual fish appear to utilize habitat that is physically accessible to them currently and the proposed action will not substantially alter water quality relative to current conditions; (2) predicted contaminant concentrations are expected to generally be below thresholds known to elicit avoidance; (3) spills are not expected to occur; and (4) mixing zones for contaminants in point source discharges are not expected to be authorized.

Once the mining activities at the YPP are completed (MY 11), the EFSFSR will be reconstructed into a volitionally passable stream channel across the top of the YPP backfill. As soon as the stream channel restoration is complete, and EFSFSR flows are routed through the restored channel, a long-term improvement to the fish passage PBF in the upper EFSFSR watershed should be fully realized. However, NMFS' engineering review expressed a potential concern with the lack of redundancy for the liner used in the YPP backfill. The concern was raised that should the liner be damaged or ultimately fail, surface flows could go subsurface creating a new passage barrier and blocking access to habitat in the upper watershed. The ultimate depth of the geosynthetic layer is not currently clear; and it appears as though the synthetic layers may be placed as low as (or very near) the lowest calculated scour depth.

2.10.1.3.3. Space, Cover, and Shelter

Space, cover, and shelter are provided by instream habitat, and the functionality of the LWD, pool frequency, pool quality, off-channel habitat, and refugia WCIs are a direct indication of the condition of these PBFs. Despite significant historical impacts to riparian vegetation caused by mining and streamside roads in the action area, the amount of LWD in action area streams is FA in both the EFSFSR and Johnson Creek watersheds. Large, landscape-scale wildfire and landslides have contributed large amounts of LWD to streams; and these large amounts of LWD have in turn created habitat complexity and quality refugia by increasing both the number and quality of pools in action area streams (generally FAR in EFSFSR, and FA in Johnson Creek) (Table 30; and BA Appendix C [Stantec 2024]).

During construction (MYs -3 to -1), several activities have the potential to affect space, cover, and shelter available to salmon and steelhead, including: (1) Burntlog route construction; (2) transmission line construction; (3) EFSFSR tunnel; (4) Meadow Creek realignment; (5) stream enhancement in EFSFSR and lower Meadow Creek; and (6) YPP Lake dewatering.

Crossings along the Burntlog route cross DCH in only three locations, bridges at Johnson Creek (Chinook and steelhead DCH), upper Burntlog Creek (steelhead DCH), and upper EFSFSR (Chinook DCH). Space, cover, and shelter will only be temporarily affected at these stream crossing structures while they are being constructed/upgraded and the work areas are dewatered. Because all new or reconstructed crossings are proposed to be fish passable, the construction of the road network will maintain or restore passage at all crossings, and in the long term, is likely to provide access to additional steelhead DCH (e.g., upper Burntlog Creek) and therefore additional space, cover, and shelter that may have previously been seasonally reduced or blocked.

Transmission lines will cross or border streams occupied by ESA-listed fish, including the SFSR, and Trail, Curtis, Cabin Creek, Trout, Johnson, Trapper, and Riordan Creeks. No new stream crossings are anticipated for transmission line access roads. Therefore, transmission line construction is not expected to affect access to the space, cover, or shelter PBFs. Should crossings need to be upgraded, they will follow the same EDFs as for the Burntlog route, affecting access to habitat only temporarily while streams are dewatered to construct the crossing(s).

As previously mentioned, at the beginning of the construction phase, volitional fish passage for Chinook salmon and steelhead is not possible beyond the cascade immediately upstream of YPP Lake (unless planted). Until the tunnel is complete, and the YPP Lake is drained, there will be no change to the space, cover, or shelter PBFs. Construction of the EFSFSR tunnel and fishway will take two years to complete, completed in MY -1. The tunnel will be constructed around the existing YPP Lake and the cascade barrier upstream from the lake. Once access is established, Chinook salmon will gain volitional access to approximately 5.5 miles DCH with intrinsic potential, or 5.5 miles of additional space, cover, and shelter in the EFSFSR and Meadow Creek upstream of the cascade.

The dewatering of the YPP Lake, is scheduled to begin in MY -1. At this point in time, a fish weir will be constructed on the EFSFSR to redirect fish into the tunnel, and fish passage will be blocked in the EFSFSR downstream from the YPP Lake through MY 11. In addition to habitat lost in the YPP Lake itself, placement of this weir will result in the 12-year loss of approximately 500 linear feet of space, cover, and shelter in the EFSFSR for both Chinook salmon and steelhead DCH.

Also, during construction (MY -1), channel restoration and enhancement will occur in Meadow Creek downstream from the HFP. Habitat enhancement will also occur in the EFSFSR upstream from the YPP restoration reach during this same timeframe. Conceptual stream designs have largely been developed to accommodate physical site conditions and geomorphic suitability, but biological objectives were used to refine the design within each reach to maximize habitat potential to the extent practicable. Although biological objectives and associated stream design (restoration and enhancement) actions will improve migration/passage and provide limited spawning potential for Chinook salmon DCH, designs were tailored to optimize spawning and rearing habitat for steelhead which is not DCH upstream from the YPP (Rio ASE 2021).

Restored stream segments and habitat enhancement will involve the addition of instream habitat structures, including LWD jams, boulder clusters, and excavated pools, intended to improve habitat conditions for salmonids within reaches not directly impacted by the SGP but previously impacted through historical mining. Revegetation will also take place to develop riparian, wetland, and upland zones for long-term bank stability, future LWD recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity. See Appendix E, Figures D-1 to D-12, in Rio ASE (2021) for typical design drawings for bank treatments, willow planting, constructed riffles, floodplain roughness, toe log and LWD structures,

Enhancement in the EFSFSR will begin in MY -1 (EF2 and EF4; Figure 34). Efforts will be focused on increasing hydraulic and geomorphic diversity while removing potential fish passage barriers. Enhancement in these stream reaches is intended to provide habitat for spawning and rearing Chinook salmon and steelhead. LWD and rock clusters will be used to enhance instream conditions, increase instream friction, sort sediment, and create localized velocity gradients. Grade control structures such as engineered riffles and/or channel-spanning rock or wood may be used to facilitate the development of relatively large pools intended to accommodate adult salmonids migrating upstream through these relatively steep reaches. The newly constructed EFSFSR, constructed across the surface of the YPP backfill, will be designed to interact with its floodplain, and will include side-channels, LWD, boulders, wetlands, and the lowest reaches of Hennessy (HC2), Garnet (MNC 1 and 2) and Midnight Creeks (MNC1 and MNC2) (Figure 34) (Rio ASE 2021).

In MY 3, a segment of lower Meadow Creek (MC4B, MC5, and MC6A; Figure 34) will be realigned around HFP in a bioengineered channel designed to provide short- and long-term function for Chinook and steelhead spawning and rearing habitat (Chinook DCH only). The channel and its floodplain will be lined to prevent excessive losses to groundwater during mining. The liner will be placed at a sufficient depth below the streambed and entire floodplain to accommodate a perched aquifer that will enable the natural function (e.g., channel migration, scour, hyporheic flow, etc.) of the stream for its geomorphic character (Rio ASE 2021). After mining, groundwater levels are expected to rebound, making the stream liner in this reach obsolete. The lowest reach of Meadow Creek will be enhanced with LWD and boulder clusters for improved habitat. Sediment controls and the rock drain will also be installed in EFMC at this time to address chronic sediment delivery to instream habitat in Meadow Creek. The lowest reach in EFMC (BC3) (Figure 34) is designed to provide additional rearing habitat for Chinook salmon and steelhead. This restoration will be complete in EFMC by MY 3 (Rio ASE 2021).

By MY 10, the YPP backfill will be complete, and by MY 11 a restored stream channel and Stibnite Lake will be created across the surface of the backfill. Once the stream channel restoration is complete, the EFSFSR flows will be routed through the restored channel and

Chinook salmon and steelhead will gain access to the space, cover and shelter PBFs not available to ESA-listed Chinook salmon since the 1930s.

The lower reaches of Midnight (MNC1 and 2) and Garnet Creeks (GC1 and 2; Figure 34), where they flow across the EFSFSR floodplain, have been designed to provide juvenile rearing habitat for Chinook salmon and steelhead. These reaches of Midnight Creek will be constructed in MYs 12 and 13. In Garnet Creek, the lowest reach (GC2) will be restored downstream from the plant from MY -3 to -1, while reach GC1 will not be restored until plant decommissioning is complete in MY 23. The uppermost reach of Meadow Creek that will be accessible to anadromous fish (MC4A), will be reconstructed in MY 18, with a biological objective of providing additional spawning and rearing habitat for Chinook salmon and steelhead (Stantec 2024; Rio ASE 2021).

Overall, although temporary and short-term effects will occur to these PBFs for Chinook salmon upstream of the YPP, and for both Chinook and steelhead from the YPP downstream to the confluence with Sugar Creek, proposed stream restoration and enhancement should ultimately increase habitat complexity in reaches accessible to anadromous fish in the upper EFSFSR and Meadow Creek, resulting in long-term improvements to the space, cover, and shelter PBFs in these portions of the action area. However, as previously mentioned, NMFS' engineering review expressed a potential concern with the lack of redundancy for liners used for engineered stream channels, concern that surface flows could go subsurface should the liners fail. These concerns also apply to all new channels in Meadow Creek, the EFSFSR, and their tributaries.

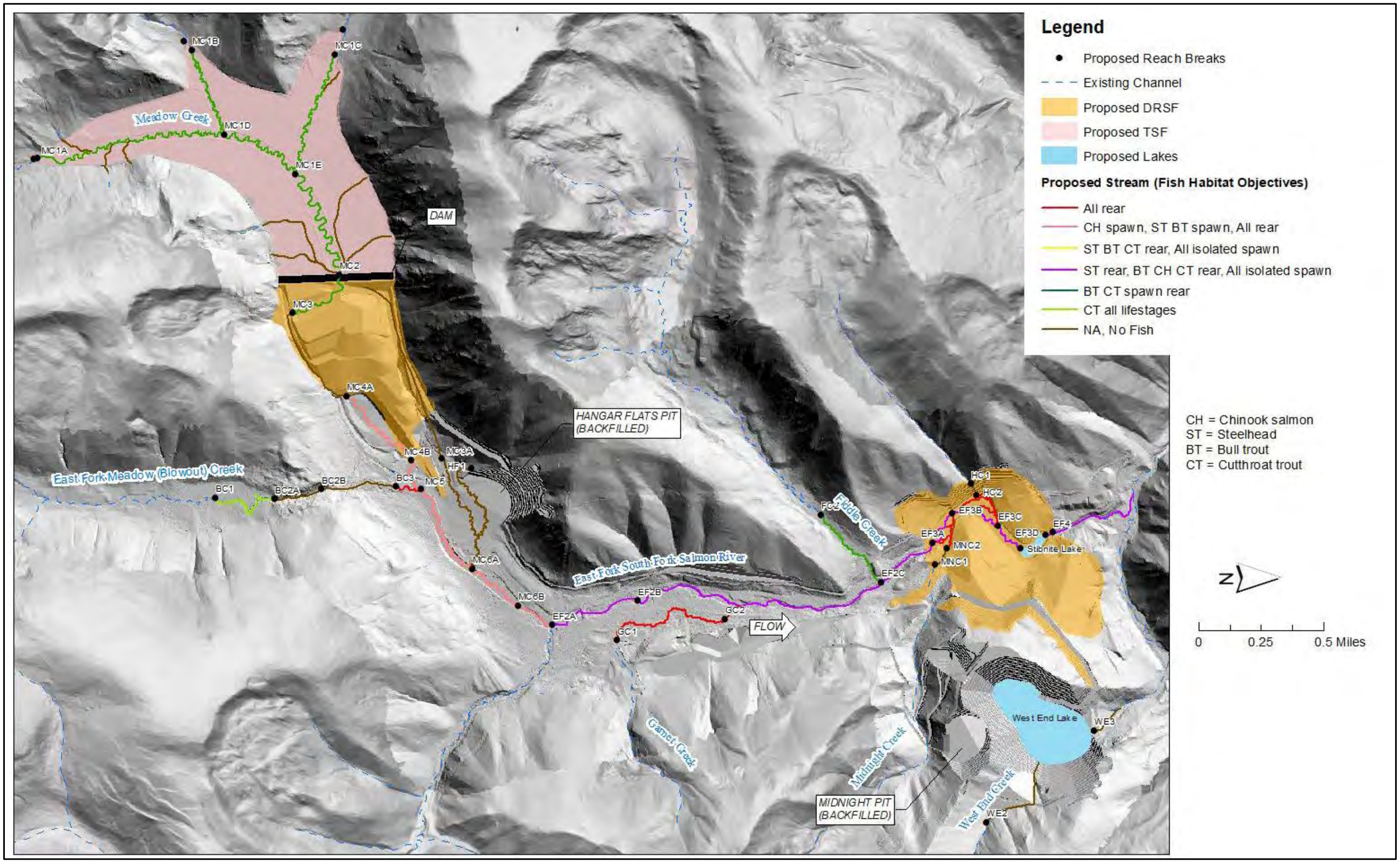


Figure 34. Proposed Stream Design Reaches (Rio ASE 2021).

2.10.1.4. **Floodplain Connectivity**

The floodplain connectivity PBF, a PBF specific to rearing steelhead, is represented by the floodplain connectivity WCI. This WCI was characterized as FAR for both the EFSFSR and Johnson Creek watersheds (Table 30). Streamside roads along Johnson Creek, Burntlog Creek, Sugar Creek, and the EFSFSR negatively affect floodplain connectivity in the action area. Floodplain connectivity has also been negatively affected by past mining practices in the upper EFSFSR and Meadow Creek, where valley bottom roads and past restoration efforts have constrained the ability of the streams to function and interact with contaminated mine tailings.

Although not a Chinook salmon PBF, the DCH designation for Chinook includes the area within 300 feet of the OHWM. As soon as MY11, functional floodplains will be created for Chinook salmon DCH across Meadow Creek and much of the mining footprint upon closure (Appendix E, Figures G-5 and G-6, Rio ASE 2021). In terms of benefits realized to the floodplain connectivity PBF for steelhead, creation of functional floodplains bordering the EFSFSR constructed across the YPP backfill (i.e., the upstream extent of steelhead DCH) should result in localized improvements to the floodplain connectivity PBF for steelhead beginning MY 11.

2.10.1.5. **Riparian Vegetation**

The riparian vegetation PBF, specific to Chinook spawning, rearing, and migration, is represented by the Watershed Conditions WCIs (i.e., road density/location, disturbance history, RCAs, and disturbance regime). These WCIs were characterized as FUR for the EFSFSR, where mining and streamside roads have heavily impacted overall watershed condition and riparian vegetation along the EFSFSR and Sugar Creek. Wildfires in 2017 have also impacted riparian vegetation to a lesser degree in the EFSFSR watershed. In the Johnson Creek drainage, these WCI have been characterized as ranging between FAR and FUR, with historic wildfire and streamside roads along Johnson and Burntlog Creeks heavily impacting this PBF (Table 30; and BA Appendix C [Stantec 2024]).

Riparian and wetland vegetation provide a diversity of ecological functions and services that include avian, wildlife, pollinator, fish, and insect habitat, refugia, and food resources, as well as shade that buffers stream temperatures. Additionally, riparian and wetland vegetation reduces scour and sediment loss and, through uptake, filtering, and microbial processing, riparian and wetland vegetation can help reduce target compounds such as nutrients, heavy metals, and undesirable effluent (Tetra Tech 2018, as cited in Rio ASE 2021).

Roads built in riparian areas often eliminate part of the riparian vegetation (Furniss et al. 1991), reducing LWD recruitment and shade. Disturbance of riparian vegetation has the potential to result in decreased shade and increased solar radiation, which potentially could further increase water temperatures in the action area. Riparian vegetation will be disturbed during construction of the Burntlog Route, during construction of the powerline corridor, and across the mine footprint in the upper EFSFSR watershed. Elevated water temperatures can affect the Chinook salmon riparian vegetation PBF to the degree that it affects salmonid physiology, growth, development, life history patterns, disease, and predator-prey interactions (Spence et al. 1996).

The BRGI portion of the proposed action will result in travel across an EFSFSR riparian wetland to access site B-22 and may result in felling trees in RCAs. Because BMPs described to protect the EFSFSR riparian wetland (Table 20) would likely be effective and few trees (possibly none) would be felled within 150 feet of streams, the overall effect of the proposed action on the riparian vegetation PBF from this portion of the action will be minor.

Riparian vegetation removal as a result of powerline construction has the potential to decrease bank stability, which may result in bank erosion and an increase in sediment to SFSR and Johnson Creek watersheds. Overall, the transmission line ROW overlaps with 132.4 acres of RCAs (including non-anadromous RCAs). However, the new portion of the powerline ROW overlaps with 14.8 acres of RCAs (Stantec 2024). For the new portion of the powerline, vegetation will need to be cleared for structure footings (size). However, the utility poles are not directly along creeks or within RCAs. Instead, vegetation removal in RCAs, if it occurs, will target taller vegetation that exceeds the maximum height specified for the wire and border zones. Because lower-growing vegetation will be maintained along the ROW, and utility poles are not directly along the creeks or within the RCAs, the localized removal of this small amount of riparian vegetation should not appreciably alter riparian functions and processes at the river reach or watershed scales.

Similarly, construction of access roads (including the Burntlog Route) will occur along headwater tributaries of Johnson Creek. Riparian vegetation will not be removed except along the new road, and where possible, removal of trees will be avoided. The construction of the road crossings may result in a loss of riparian vegetation, as well as reduced vegetation overhead cover and stream shade until riparian vegetation can be reestablished (Stantec 2024). It is anticipated that there will be limited, if any, effects to the PBF as a result of construction of the Burntlog Route.

Perpetua will seed and plant stream reaches, riparian areas, and wetlands with native plant species present currently in existing wetlands and riparian areas along streams within the SGP footprint. Seed mixes, live stakes, and nursery-grown container plants and plugs of native graminoids, forbs, shrubs, and trees would be utilized for revegetation (Tetra Tech 2023). The revegetation plan has been developed for specific riparian, wetland, and upland zones to improve long-term bank stability, LWD recruitment, overhead cover, shade, and terrestrial/wetland habitat (Brown and Caldwell 2021e). In an effort to provide shade to action area streams, riparian plantings will be 18 feet wide, with a higher percentage of taller and denser species (e.g., spruce trees) than originally planned (Brown and Caldwell, Rio ASE, and BioAnalysts 2021).

The riparian planting plan is described in Appendix F of the Stream Design Report, where local native seed, cuttings, and containerized materials will be used wherever feasible to increase the likelihood of survival (Rio ASE 2021). Riparian habitat restoration and enhancement will occur concurrently with mining where practicable, beginning early in the mining process, during construction, and would continue through site closure. The restoration of EFMC (upstream from Chinook DCH) would occur early in mine construction and operations, and the enhancement of portion of the EFSFSR would occur during the early years of mining (Brown and Caldwell, Rio ASE, and BioAnalysts 2021), with riparian plantings occurring in the EFFSR and lower Meadow

Creek planted by MY 1 to 3 (Brown and Caldwell 2021e). Riparian plantings incorporated into the newly constructed channel across the YPP backfill will be planted by MY 11.

Perpetua proposes to conduct riparian monitoring on a regular basis, looking to measure changes over time to establish species survival, composition, and diversity, while controlling the influence of invasive weeds in newly restored riparian habitats. Representative sampling within the riparian area and photo-documentation will be used to provide information on the performance of newly planted riparian communities (Brown and Caldwell, Rio ASE, and BioAnalysts 2021).

Proposed weed treatment activities have the potential to affect riparian vegetation in the action area. However, by following the PNF weed treatment program, and applying PDFs and BMPs designed to be protective of non-target riparian vegetation, weed treatment activities in RCAs are expected to locally improve riparian conditions in the future through decompaction of soils and establishment of native vegetation. For these reasons, the conservation value of the riparian vegetation PBF within the action area is not expected to be meaningfully degraded by weed treatment activities.

In summary, riparian vegetation has been negatively affected by streamside roads and mining activity in the project area, and additional riparian vegetation will be disturbed as a result of project implementation. However, proposed revegetation efforts will work to begin restoration of functional riparian vegetation as soon as practicable, beginning as early as MY 1. This considered, the project will have temporary and short-term negative effects to this Chinook salmon PBF, but will result in a long-term improvement to this PBF as the Burntlog Road is obliterated and revegetation efforts at the mine site take hold. Implementation of a successful monitoring plan, along with an effective adaptive management strategy to ensure that revegetation efforts meet desired objectives, will be key to ensuring that the proposed action does not affect the long-term function of the riparian vegetation PBF.

2.10.1.6. **Food/Forage**

The food/forage PBF can be affected by changes in water quality (e.g., stream temperature, chemical contamination), water quantity, sedimentation, clearing of riparian vegetation, and channel relocation.

Chemical contamination resulting from an accidental spill or through point and nonpoint sources of pollution has the potential to affect the quantity and quality of prey for juvenile salmon or steelhead. Mortality of aquatic invertebrates from a spill of toxic materials would be dependent upon the type and amount of material spilled. Since toxicity is expected to attenuate in a downstream direction, and spills most likely to occur are expected to be in small quantities, mortality from a spill is not likely to extend more than a mile or two downstream. These discrete events, if they were to occur, would be expected to temporarily reduce the food/forage PBF in localized area. Elevated concentrations of metals (e.g., mercury, arsenic, antimony) or TDS from point and nonpoint sources at the mine site may alter benthic community assemblages, reducing the availability of preferred invertebrate prey organisms. Such reductions or changes in prey availability could translate to adverse effects on juvenile salmonid populations.

In the Panther Creek field studies that NMFS (2014) reviewed, no obvious effects to salmonids from extinctions of macroinvertebrate species were observed. This suggests either or both that juvenile salmonids are able to switch prey when preferred prey are diminished, or that the food web effects were too subtle to tease out of the natural variability inherent in field monitoring studies using available information. Restoration efforts in Panther Creek have led to substantial reductions in copper concentrations (i.e., copper concentrations improved to below the BLM-based chronic copper criterion of ~2.3 µg/L), and within a few years, stoneflies reappeared in the invertebrate assemblage. Mayflies also reappeared in the assemblage, although it took longer for mayfly species to reestablish in the system. Predictive modeling suggests that water column concentrations of contaminants are not going to be at levels that will substantially alter benthic invertebrate communities. Furthermore, concentrations of arsenic and antimony are expected to be reduced. Given macroinvertebrate communities are considered to be healthy (i.e., high MBI and O/E scores) under current water quality conditions (EcoAnalysts, Inc. and MWH Americas, Inc. 2017; LaVoie and Stantec 2019), it is reasonable to conclude that prey quantity will not be reduced and prey composition will not be altered from predicted changes in chemical concentrations. Given that juvenile salmonids are opportunistic feeders, as long as a diverse group of macroinvertebrates are protected, some loss of prey items would not be expected to reduce individual fitness of juvenile salmonids rearing in the area.

It is not certain to what extent arsenic and mercury will bioaccumulate in the prey base, indirectly affecting fish survival and growth downstream. As described in the Section 2.10.1.1, arsenic concentrations in prey of approximately 20 mg/kg dw or greater can lead to harmful concentrations of arsenic in fish. Concentrations of arsenic are currently above this threshold in macroinvertebrates collected from the EFSFSR below Meadow Creek and in Meadow Creek below the SODA. Macroinvertebrate tissue concentrations are also elevated in Sugar Creek near West End Creek. The speciation of arsenic in macroinvertebrate tissues are unknown and in light of this uncertainty, we assume the more toxic form of arsenic is prevalent. Arsenic concentrations, while decreased, are expected to remain above levels that will lead to reduced prey quality. Mercury concentrations will increase in streams within the Project area, resulting in greater potential for bioaccumulation of mercury in macroinvertebrates. As described in Appendix F, dietary mercury concentrations exceeding 2 mg/kg dw (DePew et al. 2012) can result in adverse behavioral effects. Berntssen et al. (2003) documented increased oxidative stress in Atlantic salmon parr fed diets of 4.35 mg/kg dw MeHg. Concentrations of mercury in macroinvertebrate tissues in the EFSFSR are below this threshold. Maximum mercury concentrations of 0.43 mg/kg dw were document in the EFSFSR downstream of Sugar Creek. Concentration of mercury in macroinvertebrate tissues exceeded 2 mg/kg dw in Sugar Creek. Increased water column mercury concentrations will further diminish the prey quality; however, the extent to which it is diminished will depend on the methylation potential in the habitat as described previously.

Decreased streamflows in Meadow Creek, Sugar Creek, the EFSFSR, and the SFSR during construction through closure (MYs -1 to 20) (see BA Table 4.1-35, Stantec 2024), and in Sugar Creek and downstream reaches during post-closure (MYs 20+) will cause a reduction in food availability and suitable habitat, which could increase competition for both habitat and available food/forage (Appendix G).

Proposed ground-disturbing activities could affect instream sediment levels. Increases in fine sediment deposition within stream channels have the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles, potentially impacting spawning/incubation and rearing/feeding life stages of Chinook salmon and steelhead. However, spawning substrates are generally FA in action area streams, and GRAIP-Lite modeling suggests that the amount of sediment delivered to action area streams will decrease in comparison to the baseline condition. With application of proposed sediment control BMPs, the deposition of sediment in action area waters is predicted to be measurable but not severe. Therefore, the deposition of sediment is not expected to degrade the food/forage PBF in the temporary or short-term.

As discussed previously, proposed revegetation efforts will work to begin restoration of riparian vegetation as soon as practicable, beginning as early as MY 1. This considered, revegetation efforts should ensure that effects to forage realized by alteration of riparian vegetation are expected to be temporary and short-term, and not expected to affect the food/forage PBF in the long term.

Habitat alteration will also decrease forage available for juvenile salmonids. Re-routing portions of Midnight Creek and Hennessey Creek in MY -1 will dewater short stream segments locally affecting forage drift to downstream habitats. However, re-routing the EFSFSR through the tunnel will result in a larger, but short-term loss of about a mile of aquatic forage production through MY 11. Re-routing the channel around proposed mining efforts and piping upper Meadow Creek into a constructed ditch with a low flow pipe will also eliminate or substantially reduce forage drift. The majority of these effects from work in Meadow Creek will be realized only from MY 1 to 3, while habitat is restored in lower Meadow Creek. The constructed ditch will most likely become an intermittent channel over rock at project completion, and macroinvertebrate diversity will continue to be locally reduced. This will adversely affect forage drift to downstream habitats (Meadow Creek and the EFSFSR) up until around MY 23, following introduction of flows in the newly created Meadow Creek channel over the TSF.

2.10.2. Effects to Critical Habitat – Lemhi

The Lemhi Restoration component of the Project aims to enhance habitat for ESA-listed fish species at critical life stages and restore natural stream processes for long-term habitat diversity. Specific objectives include increasing habitat quality and complexity, reducing channel W:D, enhancing floodplain connectivity, improving instream structure and velocity, increasing pool quantity and complexity, facilitating surface/groundwater interchange for temperature moderation, providing instream cover for fish, and establishing a riparian corridor for shade, cover, and bank stability. Project elements include developing a multi-threaded channel network, installing woody material for complexity, adding floodplain roughness structures, increasing floodplain activation frequency, and revegetating riparian zones with native species (see Appendix D). These efforts aim to bolster fish population abundance, productivity, and spatial structure.

Critical habitat within the action area has an associated combination of PBFs essential for supporting freshwater spawning, rearing, and migration of the Lemhi River spring/summer Chinook and steelhead populations. The action area provides very limited spawning habitat for both Chinook salmon and steelhead due to current and historical anthropogenic impacts. The project is funded with the intent of improving habitat conditions in the Lemhi River basin, which will in turn move the affected populations toward recovery. The project will enhance habitat conditions across approximately 7,000 ft. of the Lemhi River channel (RM 42.63 to 41.32), restoring floodplain access, and revegetating the floodplain within the project area. The creation of approximately 12,426 ft. (2.35 mi.) of perennial and non-perennial side channel and another 4,965 ft. (0.94 mi.) on non-perennial tertiary side-channel will locally improve spawning and rearing habitat quantity and quality and reestablish natural channel processes. Ultimately, the project will improve the conservation value of the action area's critical habitat. During construction, minor and temporary effects to critical habitat are likely to occur. These effects are primarily related to increased turbidity (water quality) and associated sedimentation of spawning gravels.

2.10.2.1. **Water Quality**

The water quality PBF will likely be affected by short-term turbidity pulses or plumes occurring during installation of temporary cofferdams and bypass channels and when introducing water to newly constructed channel segments. In efforts to control turbidity, no work will occur in flowing water. Project staging will allow the new off-channel habitat to be created first, before introduction of flowing water. Once the side channel complex is complete, channels will be 'pre-washed' into a reach equipped with sediment control structures. The Lemhi River bank will then be breached, and flow gradually routed into the side channel complex. A cofferdam will be installed to block the flow in the mainstem so work in the mainstem can also occur in the dry. Once work is complete, the channel will again be 'pre-washed' before re-watering the Lemhi River. Design criteria (e.g., in-water work window, site dewatering, pumping turbid water to the floodplain to filter rather than discharging to fish-bearing channels, pre-washing channels, staged rewatering, and erosion control BMPs) are anticipated to effectively minimize the amount of sediment delivered to and suspended in the Lemhi River.

In addition to undertaking sediment control measures, Perpetua will monitor turbidity levels during re-watering efforts. Monitoring will include collecting background turbidity samples 100 feet upstream of the disturbance area. Depending upon the width of the channel, recordings will be made, 50, 100, or 200 feet downstream from the disturbance, monitored every 4 hours while work is being conducted. Should exceedances occur for more than two consecutive monitoring intervals (after 8 hours), the activity will stop until the turbidity level returns to background, and OSC will be notified. If turbidity controls (cofferdams, wattles, fencing, etc.) are determined ineffective, crews will be mobilized to modify, as necessary.

Temporary increases in turbidity are most likely to occur when adding water to newly constructed off-channel habitat, installation of the cofferdam on the Lemhi River, and when re-watering the Lemhi River channel (3 defined plumes or pulses). Based on review of the literature and the proposed sediment control measures, NMFS expects: (1) resulting sediment plumes will not exceed 100 NTUs; (2) should not extend farther than 1,000 feet downstream; (3) should dissipate within a few minutes to hours; and (4) progressively diminish as they progress downstream (Casselli et al. 2000; Jakober 2002; USFS 2005). In addition to effects remaining within 1,000 feet of the disturbance, suspended sediment levels are likely to quickly return to background considering the expected small volume of sediment likely to be introduced and suspended (Jakober 2002; Casselli et al. 2000).

Turbidity pulses are expected to be infrequent, and short-lived (a few hours), before returning to background levels. These levels may temporarily cause up to 1,000 feet of the Lemhi River to be temporarily less suitable for fish. Because the Lemhi River is relatively large, the plumes are likely to be confined to one bank and many exposed fish will be able to easily move to adjacent non-turbid habitats, thereby avoiding exposure. Although these levels may be sufficient to cause minor behavioral modifications or an increase in foraging rates for some fish, these effects are expected to be minor and temporary in nature, and will not degrade the water quality PBF.

The use of heavy machinery adjacent to the stream channel increases the risk for the potential of an accidental spill of fuel, lubricants, antifreeze, hydraulic fluid, or similar contaminant into the riparian zone, or directly into the water where they could adversely affect the water quality PBF. However, all equipment performing work will workprimarily from streambanks and within dewatered stream channels, significantly reducing the likelihood of toxic materials entering live water. In addition, all equipment operated within 150 feet of any waterbody will be inspected daily for leaks and, if necessary, repaired before leaving the staging and refueling areas. A SPCC plan will be developed for the project, and all equipment will have spill containment kits onsite.

Considering the described EDFs, it is unlikely that fuel, lubricants, antifreeze, hydraulic fluid, or similar contaminant will be present on-site or spilled in volumes or concentrations large enough to harm water quality in or downstream from the project site. NMFS believes that fuel spill and equipment leak contingencies and preventions described in the proposed action are sufficient to effectively minimize the risk of negative impacts to water quality from toxic contamination; therefore, potential for adverse effects from chemical contamination is unlikely to occur to this PBF.

2.10.2.2. **Substrate/Spawning Gravel**

Temporary pulses of sediment and turbidity plumes are expected to cause small increases in downstream sediment deposition (increased surface fines), negatively affecting substrate in the short term. Fine, re-deposited sediments have the potential to adversely affect primary and secondary productivity (Spence et al. 1996), and reduce incubation success (Young and Hubert 1991; Henley et al. 2000; Wu 2000) and cover for juvenile salmonids (Bjornn and Reiser 1991). As described above, project design and conservation measures (e.g., work will occur in dewatered work areas, during low flow periods, pre-washing and slowly re-watering channels) should effectively minimize the amount of sediment generated and delivered to action area waters. Additionally, all disturbed sites will be replanted with native vegetation to reduce any potential long-term sediment inputs. This considered, only minor amounts of fine sediment deposition are expected as a result of the proposed action. In the long term, projected increases in pool to riffle ratio, increased habitat complexity, and access to new off-channel habitat are expected to significantly improve the quantity and quality of spawning substrate locally available. This would be a localized, long-term improvement in the conservation value of this PBF.

2.10.2.3. **Floodplain Connectivity**

Historic channel straightening and grazing has occurred throughout the project reach. These impacts have led to loss of floodplain connectivity. Reestablishing connectivity along 7,000 ft. of the Lemhi River will greatly improve the ability of the river to interact with its floodplain in the action area, locally improving the conservation value of this PBF.

2.10.2.4. **Space, Cover, and Shelter**

Channel confinement and straightening, bank erosion, lack of riparian vegetation, and sedimentation have contributed to low pool frequencies and decreased pool quality (e.g., lack of cover, complexity, and depth) in this stream segment. The stream channel design increases access to approximately 3.29 mi. of new off-channel perennial and seasonal habitat. NMFS expects a significant corresponding improvement in the quality and quantity of fish cover and shelter within the subject reach. Overall the results of the action are a significant, long-term, localized improvement in the conservation value of this PBF.

2.10.2.5. **Riparian Vegetation, Water Temperature, Food/Forage**

The project area is in a disturbed location with riparian vegetative cover lacking in much of the stream reach. Existing streambank vegetation shall be preserved and protected to the extent practical, with the contractor only removing trees and shrubs necessary for the execution of the work. No tree or shrub shall be removed unless approved by the contracting officer. The contractor shall not disturb the roots of woody vegetation in this area during project excavations to the extent practical. Riparian vegetation will be replanted prior to or at the beginning of the first growing season following construction. Reestablishment of vegetation will be achieved in disturbed areas to at least 70 percent of the pre-project conditions within three years. The W:D in the mainstem will be reduced, which will locally provide long-term improvements to water temperature by creating a deeper, narrower stream channel, and creating a condition that is more conducive to stream shading over a larger percentage of the channel width.

Naturally functioning riparian vegetation and improved floodplain connectivity will increase the amount of available habitat and provide better habitat complexity. The planting, seeding, and transplanting of riparian vegetation will be a critical component of the long-term restoration process of the project area. Improved riparian conditions will help stabilize streambanks, decrease sediment loading, reduce stream temperatures, and improve habitat complexity. The planting of riparian vegetation could result in a localized long-term benefit to streamside shade, bank stability, cover for fish, water temperatures, and habitat for macroinvertebrates in the project area. Therefore, this project is anticipated to improve the conservation value of these PBFs in the action area.

2.10.2.6. **Fish Passage**

There will be no physical barriers created or removed other than cofferdams to temporarily block or redirect flows depending on the construction stage. Low flows may result in temporary passage barriers during construction; however, fish will not have access to the construction area during construction activities. Once the side channel habitat is constructed, the Lemhi River bank will be breached to redirect flow away from the mainstem and into the new channels.

2.10.3. Summary of Effects to Designated Critical Habitat

The SGP will affect SR Basin steelhead DCH for the Salmon River MPG, specifically the SFSR population; while effects of the Lemhi Restoration portion of the project will also affect the same MPG, but the Lemhi River population. Effects to steelhead DCH are most likely to occur in the Lemhi River, SFSR, the EFSFSR (downstream from YPP), Johnson Creek, Cabin Creek, and Sugar Creek.

The SGP will affect SR Spring/summer Chinook salmon DCH for the SFSR MPG, specifically the SFSR and EFSFSR populations; while the Lemhi Restoration portion of the proposed action will affect DCH for the Upper Salmon MPG, specifically the Lemhi River population. Effects to Chinook salmon DCH are most likely to occur in the Lemhi River, SFSR, EFSFSR, Johnson Creek, Cabin Creek, Sugar Creek, lower reaches of Burntlog Creek, Trapper Creek, Riordan Creek, and EFMC.

Adverse effects will be primarily related to potential effects to: (1) water quality (turbidity, contaminants, or temperature); (2) water quantity; (3) riparian vegetation; (4) natural cover/space; (5) food and forage (due to chemical contaminants and water quantity effects); (6) substrate/spawning gravels; (7) fish passage; and (8) floodplain connectivity. Modification of these PBFs may affect freshwater spawning, incubation, rearing, or migration in the action area.

Sediment generating activities will include frequent, sporadic turbidity effects to water quality across action area streams, with those increases occurring most frequently occurring during runoff events and resulting in localized deposition of fine sediment in action area stream channels. These effects are likely to affect DCH from the beginning of construction through closure and reclamation. Although turbidity increases are likely to affect water quality to the point that they periodically affect fish behavior (particularly during runoff events), they are unlikely to reach levels severe enough or long enough to affect the long-term conservation value of the Water Quality PBF.

Potential effects could be realized to the water quality PBFs for both steelhead and Chinook should an accidental spill of contaminants occur. However, the risk of a hazardous material spill is low, and proposed transport EDFs should effectively minimize the potential for accidental spills and their resulting effects to occur.

Water quality will be affected by both point and nonpoint sources of pollution during construction, operations, and closure. Stormwater discharges from site facilities and roadways will degrade the water quality PBF during and immediately following storm events, and this disturbance is expected to continue to occur sporadically throughout the construction and operations period. Because site facilities will be removed and mine-related traffic will be substantially reduced following closure, this impact will not persist in perpetuity. The sanitary wastewater treatment facility discharge is also expected to reduce the water quality PBF in the EFSFSR during construction and operations.

Removal of the historical, unlined mine waste disposal material will have an early, positive impact on water quality; however, placement of permanent mine facilities (e.g., TSF embankment and buttress, and waste rock backfill into the HFP) and discharge of treated mine contact water will negatively impact water quality. The net effect of these actions during operations will be an overall reduction in antimony, arsenic, and copper concentrations in Meadow Creek and the EFSFSR during operations. However, during operations concentrations of these contaminants will remain at levels that will reduce the ability of the water quality PBF to support incubation and early life stages (in the EFSFSR when maximum predicted concentrations of antimony and arsenic are realized for extended periods of time), juvenile rearing, and adult/juvenile migration. Total mercury contributions from West End Creek to Sugar Creek will increase by at least an order of magnitude. During early closure, the water quality PBF will continue to be impacted by permanent mine facilities (e.g., TSF embankment and buttress and waste rock backfills) and discharge of treated mine contact water. Arsenic, antimony, and copper concentrations are expected to continue to be lower than existing conditions in Meadow Creek and the EFSFSR. Mercury concentrations will decrease in Meadow Creek and the EFSFSR; however, concentrations will remain slightly elevated in Sugar Creek. Mercury concentrations in lower West End Creek will decrease substantially as the WEP Lake fills. Although concentrations are decreased, they will remain above levels that can contribute to harmful bioaccumulation of mercury. Ultimately, individual contaminants and contaminant mixtures are expected to continue to negatively impact the ability of the water quality PBF to support spawning and incubation, juvenile rearing, and adult/juvenile migration. During late closure, the water quality PBF will continue to be impacted by permanent mine facilities. Mine contact water will no longer need treatment because any seepage from the TSF and TSF embankment and buttress is predicted to meet water quality criteria. Arsenic concentrations will continue to decrease in Meadow Creek and will be below concentrations associated with sublethal effects from waterborne exposures. Similarly, arsenic concentrations will continue to decrease in the EFSFSR; however, maximum predicted concentrations are likely to cause some mortality of embryos. In addition, arsenic concentrations will contribute to sublethal effects to rearing juveniles feeding as a result of dietary exposure. Antimony concentrations will either decrease slightly or remain the same, and will be below levels associated with lethal or sublethal effects. Copper concentrations will decrease, though are still associated with potential sublethal olfaction effects. Mercury concentrations will generally decrease in stream reaches upstream of Sugar Creek. Concentrations will remain above 2 ng/L, and depending on methylation potential, could accumulate in fish tissue and result in some sublethal effects such as reduced growth or altered behavior. Overall, the ability of the water quality PBF in Meadow Creek, EFSFSR, and Sugar Creek to support incubating embryos, rearing juvenile salmonids, and migrating adult and juvenile salmonids will be negatively impacted by the proposed action.

Water temperatures are not expected to be negatively impacted in streams near or overlapped by the transportation or transmission line corridors. Similarly, temperatures will not be negatively impacted in Sugar Creek or EFMC to a degree that would impact the ability of stream temperatures to support rearing (both streams), or migration and spawning (Sugar Creek). At the mine site, water temperatures in the EFSFSR and Meadow Creek will be impacted as a result of channel relocation and reconstruction, EFSFSR diversion tunnel construction, riparian vegetation removal, and point source discharges. During the construction phase, stream temperatures are expected to be similar to baseline conditions and the ability of the designated critical habitats to support spawning, rearing, and migration will not be reduced. During operations, closure, and post-closure, stream reaches will respond differently to SGP activities as summarized below.

Stream temperatures in Meadow Creek upstream of the EFMC as a result of the SGP are predicted to improve relative to baseline, during operations and will be warmer than baseline conditions during early and late closure. Stream temperatures in Meadow Creek downstream of the EFMC will improve relative to baseline conditions during all years of project implementation. Yet, the habitat's ability to support Chinook salmon juvenile rearing will continue to be diminished during portions of the warmer summer months for a period of 25 years. Temperatures are predicted to increase in between MYs 23 and 27; particularly in the reach upstream of the EFMC. This reach will be further impacted by thermal loading from the wastewater treatment plant discharge. During this 5-year period, the maximum weekly maximum summer temperature in this reach is predicted to be 20.8°C, which will limit juvenile rearing as well as adult migration and spawning (particularly during the early weeks of the spawning season). During the fall, the maximum weekly maximum temperature is predicted to be 16°C which will reduce survival of incubating embryos. Considering the rapid decline of stream temperatures in the fall months, late spawners utilizing this habitat will have more success. While there will be a long-term reduction in the temperature PBF of Chinook salmon critical habitat in Meadow Creek, these reaches represent a small fraction of the designated critical habitat for Chinook salmon in the action area. Temperatures in the EFSFSR between Meadow Creek and the YPP are expected to improve relative to existing baseline conditions during all years of project implementation, and will be less than 18°C. The predicted temperatures in this reach will fully support adult Chinook salmon migration and holding. Predicted temperatures will remain above 16°C, diminishing the value of the temperature PBF for Chinook salmon juvenile rearing, particularly in MYs 6 and 23 through 27. Maximum fall temperatures will be 13.5°C, which is slightly above optimal levels for Chinook salmon spawning and incubation at least for the few weeks of the season in MY 6. Below the YPP, stream temperatures in the EFSFSR are expected to fully support salmon and steelhead adult migration (temperatures less than 18°C), spawning (temperatures less than 13°C), and incubation (temperatures less than 13°C). Temperatures in this reach are expected to be slightly above 16°C during the summer, which will slightly decrease in the ability of stream temperatures to support salmon and steelhead juvenile rearing during MY 6. That is, some individuals are likely to experience sublethal effects as a result of increased stream temperatures. Temperatures in Sugar Creek and the EFSFSR below Sugar Creek are expected to increase. While the conservation value of the temperature PBF for rearing will be diminished through MY 32 and some rearing juveniles may experience sublethal effects, the habitat will support adult migration, spawning, incubation, and rearing for Chinook salmon and steelhead.

Climate change with or without implementation of the SGP will make it more difficult to maintain temperatures that are protective of all anadromous salmonid life stages within the action area. Climate change is expected to exacerbate the effects of the proposed action on stream temperatures directly as well as indirectly through impacts to air temperature, streamflow, and vegetative recovery.

Physical habitat conditions, represented by the spawning gravel, passage, and space/cover/shelter PBFs, will be affected by the proposed actions. Modeling suggests that the amount of sediment delivered to action area streams will be effectively minimized and decrease in comparison to the baseline condition – considering proposed sediment control BMPs. Therefore, the deposition of sediment in action area waters is predicted to be measurable but not severe, and is not expected to degrade this PBF in the temporary or short term. Following closure of the mine, obliteration of access roads, and restoration efforts addressing chronic sediment delivery in the EFMC, the proposed action is expected to result in a substantial decrease in annual sediment delivery into Meadow Creek and the EFSFSR, and may benefit this PBF in the long term.

Passage, and access to additional space, cover, and shelter, will be improved for steelhead DCH in East Fork Burntlog Creek when the Burntlog Route stream crossings is retrofitted to ensure season-long fish passage. Volitional passage will be restored for Chinook DCH upstream of the YPP, with Chinook able to access an additional 12.2 miles (19.65 km) usable habitat, of which 5.5 miles is identified as having intrinsic potential for Chinook salmon. These increases in Chinook space, cover, and shelter will be realized as soon as tunnel construction is complete in MY -1. Restored and enhanced stream channels in Meadow Creek and the EFSFSR upstream and downstream from the YPP (MY -1), and across the YPP backfill (MY -11), will increase habitat complexity in stream reaches in the project area, resulting in long-term improvements to the space, cover and shelter PBFs for Chinook upstream and downstream from the YPP, and downstream of the YPP for steelhead DCH. Passage will not be affected for steelhead or Chinook in the Lemhi River portion of the action, although both species will gain additional space, cover, and shelter as a result of the proposed restoration project in the Lemhi River basin.

The floodplain connectivity PBF is specific to rearing steelhead. Reconnecting the EFSFSR to its floodplain across the YPP backfill by MY -11, will locally improve floodplain connectivity for the portion of this stream reach that is formally steelhead DCH (EFSFSR upstream to the base of the YPP cascade). Floodplain connectivity will be restored across a 7,000 linear ft. section of the Lemhi River, locally restoring this steelhead PBF by MY -1.

Riparian vegetation has been heavily impacted by historic mining and streamside roads (and wildfire to a lesser extent) in the EFSFSR and Sugar Creek. This PBF has also been heavily impacted by historic wildfire and streamside roads along Johnson Creek and Burntlog Creek. Localized riparian vegetation may be cleared or trimmed to accommodate the new access roads for mining and the powerline. However, riparian habitat restoration and enhancement will occur concurrently with mining, beginning early in the mining process, during construction, and would continue through site closure. The SGP will have temporary and short-term negative effects to this Chinook salmon PBF, but will result in a long-term improvement as the Burntlog Road is obliterated and revegetation efforts at the mine site take hold.

Riparian vegetation in the Lemhi River channel has also been heavily impacted, but impacted by channelization, grazing, development, and agriculture. The Lemhi portion of the project will reestablish connectivity with the river's floodplain, and the revegetation plan will locally restore riparian habitat in the long term.

Proposed ground-disturbing activities could affect instream sediment levels, which could in turn affect benthic invertebrate production. However, spawning substrates are generally FA in action area streams, and modeling suggests that the amount of sediment delivered to action area streams is predicted to be measurable but not severe. Therefore, the deposition of sediment in action area waters is not expected to degrade the food/forage PBF in the temporary or short-term.

The food/forage PBF can also be affected by changes in water quality (e.g., stream temperature, dissolved oxygen, chemical contamination), water quantity, sedimentation, and clearing of riparian vegetation. Reduction in stream flow will reduce food availability in all affected stream reaches during construction through closure, and in Sugar Creek and downstream reaches for approximately 135 years post closure. Increased contamination is not expected to reduce the quantity or diversity of available prey; however, the quality of prey items will be reduced at the mine site and in downstream reaches of the EFSFSR. We expect concentrations of arsenic in prey to decrease as a result of project implementation; however, mercury concentrations are expected to slightly increase in prey items.

2.10.4. Effects to Species – SFSR

With the exception of disturbance and fish sampling effects, all of the proposed action's potential effects to species are directly related to fish responses to the previously described effects on DCH. For this reason, this section incorporates the previous effects to DCH by reference given individual fish and fish populations' response to the habitat in the manner described above. Doing so eliminates redundancy while enabling more clear focus on the effects to the species under consideration. In some cases, we determined stressors that have potential to occur but are unlikely to materialize given the type of activities, the location of activities relative to aquatic habitats, the effectiveness of proposed avoidance and mitigation measures contained in the action, or a combination of these factors. For these instances, the low likelihood of the stressor being generated effectively reduces exposure of ESA-listed species to the stressor itself and thus there is no direct effect anticipated. For these stressors, we do not discuss the mechanisms of effect to the species because exposure is considered unlikely. Changes in water quantity and water quality are both anticipated to occur. Therefore, the species will be exposed to these habitat changes and respond. The following sections discuss these impacts from such exposure and responses.

2.10.4.1. **Water Quality**

2.10.4.1.1. Chemical Contamination

Effects to ESA-listed Chinook salmon and steelhead could be affected through chemical contamination, which could occur: (1) should a spill occur onsite or in the transportation corridor; (2) when construction equipment is working within or adjacent to the stream channel; (3) from herbicide treatment; (4) as a result of effluent discharge; or (5) through groundwater contamination.

Hazardous Materials Spill Risk Analysis. Potential for transportation-related spills of substances associated with construction, operation, and closure of the SGP were discussed in Section 2.10.1.1. That discussion found a low likelihood for diesel, or other chemical spills, to affect critical habitats in the action area during transportation to and from the mine site. Similarly, in Section 2.10.1.2, we concluded the SGP is unlikely to lead to onsite chemical spills that reach designated critical habitats. These conclusions were reached after considering: (1) the transportation routes used; (2) accident probability; (3) historical accident rates; (4) location of mine facilities relative to occupied habitat; (5) onsite access controls; (6) site collection and handling requirements; and (7) anticipated effectiveness of transport EDFs, the SPCC Plan, and the Hazardous Materials Handling and Emergency Response Plan. These measures outline proper material inventory, packaging, transportation, storage, use, disposal, and clean up procedures, which, when implemented properly, collectively reduce the potential for spilled materials reaching waters utilized by ESA-listed salmon and steelhead.

Herbicide Application. As previously described, noxious weed and invasive species plant control will be conducted according to methods approved in the 2020 Programmatic Activities Biological Assessment (PNF 2020) and NMFS opinion (NMFS 2020) on this action. The potential effects of weed treatment when applied as proposed have been described in detail in Section 2.5.4.1 of NMFS' opinion (NMFS 2020), incorporated here by reference and summarized below.

Application of herbicides can contaminate surface waters, harming individual fish. Risks to salmon and steelhead from herbicides are likely to occur primarily through the direct toxicological effects of herbicides and adjuvants on the fish, rather than indirectly through physical changes in fish habitat or effects on aquatic vegetation or prey species. Weed treatments typically occur between April and November, depending on elevation. During this period, all life stages of Chinook salmon and steelhead could potentially be exposed to herbicides, including incubating eggs, rearing juveniles, and migrating/holding adults. Herbicides will not be directly applied to water, with only spot spraying or hand application techniques allowed within 100 ft. of streams, making direct application to waters unlikely.

Herbicides (including the active ingredient, inert ingredients, and adjuvants) can potentially harm fish directly or indirectly. Herbicides can directly affect fish by killing them outright or causing sublethal changes in behavior or physiology. Indirect effects to fish may occur when herbicides alter the aquatic environment by way of causing changes in cover, shade, runoff, and prey availability (Scholz et al. 2005).

Herbicide exposure may directly result in one or more of the toxicological endpoints identified below. These endpoints are generally considered to be important for the fitness of salmonids, and include:

- Direct mortality at any life history stage;
- An increase or decrease in growth;
- Changes in reproductive behavior;
- A reduction in the number of eggs produced, fertilized, or hatched;
- Developmental abnormalities, including behavioral deficits or physical deformities;
- Reduced ability to osmoregulate or adapt to salinity gradients;
- Reduced ability to tolerate shifts in other environmental variables (e.g., temperature or increased stress);
- An increased susceptibility to disease;
- An increased susceptibility to predation; and,
- Changes in migratory behavior.

Herbicides applied by the applicant are not expected to reach streams in concentrations that kill fish; but, weed treatment may result in concentrations of sufficient magnitude to elicit short-term sublethal effects. However, implementation of weed control PDFs, including BMPs designed to minimize the amounts of herbicide getting to active water, will effectively reduce the risk of chemical contamination associated with weed treatment activities.

Application of many herbicides proposed for use could potentially drift to waterways or leach into soils, contaminate groundwater, and eventually show up in streams where ESA-listed fish spawn and rear. This risk depends on a number of variables, including but not limited to the rate of application, concurrent precipitation, herbicide degradation, solubility, and distance to water. Again, identified design criteria minimize risks of these occurrences. Although unlikely to occur, accidental spill of herbicides directly to waterways could result in conditions toxic to salmonid fish species and result in harm/death of ESA-listed fish.

In spite of the PDFs, herbicides (and adjuvants) cannot be kept entirely out of the water. Although direct lethal effects are not expected, the types of chemicals used are ones that can be capable of causing harmful sublethal effects. It is possible that individual or smaller groups of fish could be exposed and experience sublethal effects, potentially experiencing changes in behavior, reduced growth, survival, etc. However, herbicide applications will not occur over large contiguous areas (less than 500 acres of chemical application per year in the entire SFSR subbasin) (PNF 2020), and most of the action area will not be subjected to spraying in any given year. Considering the low level of effects that may occur, coupled with the very small impact area, we do not expect there to be any realized reductions in the abundance or productivity of any potentially affected populations.

Surface and Groundwater Quality Analysis. Section 2.10.1.1 describes in detail how the SGP is predicted to alter water quality in the action area. Appendix F and Section 2.10.1.1 summarize the best available information regarding the toxicity of contaminants that present the greatest risk of reducing individual fitness. The primary pathways of effect for SR Spring/summer Chinook salmon and SR Basin steelhead is through waterborne exposure to contaminants during all life stages and through dietary exposure as juveniles are feeding as they rear in and migrate through the action area.

Waterborne Exposures. As previously described, historic sources of contamination will be removed and new sources chemical contaminants will be introduced to action area streams as a result of stormwater runoff, point source discharges from a sanitary wastewater treatment plant and mine contact water treatment plant, and nonpoint source contributions from mine facilities. Juvenile fish are generally the most sensitive to contaminants through waterborne exposures, although in some cases, early life stages (incubation through early exogenous feeding) may be even more sensitive. All life stages of fish are expected to be exposed to contaminants originating in stormwater runoff from roadways and maintenance and housing facilities as well as to contaminants in sanitary wastewater treatment plant effluent. These exposures are not expected to cause outright lethality; however, some sublethal effects (e.g., altered behavior) from exposures to individual contaminants or contaminant mixtures may occur. There is substantial uncertainty about the degree to which these sublethal effects lead to latent mortality.

Adult SR Spring/summer Chinook salmon and SR Basin steelhead are expected to be exposed to arsenic, mercury, antimony, copper, and other contaminants that leach from mine facilities as they migrate through and hold in the action area (access to habitat upstream of the YPP is expected to occur by MY -1). Predicted concentrations of these contaminants are not expected to reach levels that will kill adult salmonids or reduce spawning activities. Copper is the only contaminant that may affect adult life stages at the mine site. Copper concentrations may reach levels that cause adult salmonids to avoid habitats; however, we consider there to be low risk of this type of response. This is because copper concentrations are expected to decrease relative to existing conditions and adult SR spring/summer Chinook salmon redds have been documented in the EFSFSR, Sugar Creek, and Meadow Creek (when adults are outplanted) in recent years, suggesting copper concentrations are not preventing, and will not prevent, seeding of available spawning habitat. Although SR Basin steelhead redd surveys have not been conducted, we assume this species would respond similarly.

Juvenile life stages are generally more sensitive than adult life stages. As such, there is greater risk of adverse responses for juvenile exposures to arsenic, antimony, and copper. There is a very low risk of mortality of some developing embryos or newly emerged fish from exposures to concentrations of antimony and arsenic in some reaches during project implementation. Maximum predicted antimony concentrations in the EFSFSR below the YPP during operations are near concentrations associated with low levels (1 percent) of mortality in incubating embryos (Birge et al. 1978). If redds are exposed to this maximum predicted concentration for extended periods of time, then it is possible some low levels of mortality could occur. Similarly, predicted arsenic concentrations in the EFSFSR are near concentrations associated with low levels of mortality in incubating embryos (Birge et al. 1978). If redds are exposed to this maximum predicted concentration for extended periods of time, then it is possible some low levels of mortality could occur. This risk exists in the EFSFSR upstream of the YPP only during operations; however, this risk exists in the EFSFSR downstream of the YPP through late closure. Juvenile fish are not expected to experience any other lethal or sublethal effects as a result of waterborne exposures to antimony or arsenic at the predicted concentrations.

There is some risk of juvenile fish experiencing reduced olfactory function as a result of exposure to the maximum predicted copper concentrations. Such reductions in olfaction may lead to death through impairment of the ability of salmonids to avoid predators or find prey. Individual fish rearing in Meadow Creek, EFSFSR, and Sugar Creek are at risk of experiencing this type of response. Because copper concentrations are expected to decrease or remain essentially the same relative to existing conditions in all stream reaches during all mine phases, the proposed action is not expected to result in reduced abundance, productivity or spatial structure.

Considering evidence of successful incubation and early rearing in Meadow Creek and the EFSFSR under current water quality conditions, and considering the SGP will substantially reduce antimony and arsenic concentrations in these streams and copper concentrations will remain substantively the same, we do not believe these potential low levels of mortality or sublethal effects will reduce abundance or productivity in the population.

Dietary Exposure. Juvenile Chinook salmon and steelhead primarily feed on macroinvertebrates and are at risk of accumulating arsenic and mercury. Adult salmon and steelhead are not expected to be feeding in the project area, therefore, the risk of arsenic or mercury bioaccumulation in adults from on-site exposure is negligible.

As described in Section 2.10.1.1, dietary concentrations of arsenic of around 20 mg/kg dw are associated with reduced growth, organ damage, and other physiological effects (Cockell et al. 1991; Hansen et al. 2004; Erickson et al. 2010, 2011). These sublethal effects are thought to occur when arsenic concentrations in prey are approximately 20 mg/kg dw or greater, which can accumulate when water levels are about 10 μg/L. Average arsenic concentrations are predicted to substantially decrease and average concentrations are expected to generally be below the 10 μg/L threshold thought to be associated with dietary toxicity. Yet, predicted maximum concentrations will occasionally exceed the 10 μg/L (i.e., for some years at the start of operations and during early closure). As such, there is some risk of individual fish experiencing sublethal effects as a result of dietary arsenic exposure.

As described in Section 2.10.1.1, the proposed action is expected to cause incremental increases in total mercury in the water column of stream inhabited by salmon and steelhead. These increases could lead to greater bioaccumulation of mercury in fish tissues. Additionally, an incremental increase in organic carbon content in the EFSFSR due to sanitary wastewater effluent could increase in methylation potential in the EFSFSR. Bioaccumulation of mercury in fish tissue is not expected to reach lethal levels; however, some fish may experience sublethal effects. The degree to which these sublethal effects may manifest to reduced survival is unknown.

Baseline data (presence of redds, juvenile Chinook salmon, and juvenile steelhead) in the EFSFSR, Sugar Creek, and Meadow Creek (Chinook salmon only due to outplanting efforts) indicates spawning, rearing, and migration currently occurs in streams with elevated arsenic and detectable, and in some cases elevated, concentrations of total mercury. While arsenic and mercury body burdens may continue to cause sublethal effects in some individual juvenile fish as a result of project implementation, we do not have adequate information to be reasonably certain that these effects will result in population-level effects.

2.10.4.1.2. Water Temperature.

Water temperatures is an important factor affecting the survival of each Chinook salmon and steelhead life stage. Sublethal water temperatures may influence behavior, respiration, growth rates, metabolism, and ecological interactions such as predation, competition, or disease, migration timing, and egg viability. Elevated water temperatures may also trigger avoidance of areas in which may result in crowding of other rearing or holding habitat that offers more suitable temperatures. A number of factors influence how individual fish respond to elevated temperatures, including thermal variation, access to thermal refugia, prey availability, and presence of other stressors (such as low dissolved oxygen). Streams in the mine site area exhibit significant seasonal and diurnal variations, and for mobile life stages (i.e., adults and juveniles), if MWMTs are above the optimal thresholds, fish may seek suitable habitat nearby (e.g., EFMC or EFSFSR). Through stream restoration and enhancement actions, stream cover and instream structures may also provide thermal refugia that does not currently exist. A summary of adverse effects that each life stage may experience when exposed to elevated temperatures is provided in Table 61.

Section 2.10.1.1 details the temperatures changes that may occur as a result of SGP implementation and the effects the predicted stream temperatures are likely to have on the various life stages. As previously described, temperature impacts in parts of the action area that are not within the mine site area are not expected to be great enough to elicit lethal or sublethal responses from individuals. Similarly predicted temperature impacts in Sugar Creek and the EFSFSR below Sugar Creek are not expected to cause any lethal or sublethal responses in exposed individuals. Chinook salmon and steelhead will have volitional access to habitat upstream of the YPP as soon as the EFSFSR diversion tunnel is completed, which is anticipated to occur in MY -1. As such, our analysis considered exposure and response of all life stages of salmon and steelhead to these habitats.

Steelhead adult migration and spawning life history stages are not expected to be adversely affected by the SGP given they occupy the habitat during the spring when flows are higher and temperatures are lower. Incubating embryos could potentially be impacted by the proposed action if development is advanced due to elevated temperatures in June/July. Given the elevation of the mine site and the anticipated climate conditions at the site, the risk of this potential exposure pathway leading to effects that negatively impact individual fitness is quite low. Juvenile steelhead rearing at the mine site will be adversely affected by changes in stream temperature and their exposure and response is expected to be similar to that of Chinook salmon.

Chinook salmon migrate, spawn, and rear at the mine site, and all life stages are expected to be negatively affected in one or more reaches as a result of stream temperature changes cause by the SGP.

Individual salmon and steelhead are expected to respond to temperature changes in Meadow Creek and the EFSFSR (reaches between Meadow Creek and Sugar Creek) during mine operations and closure. The biological objectives underlying the stream designs for Meadow Creek reaches MC4, MC5, and MC6 are to support both Chinook salmon and steelhead spawning and rearing. Temperatures in Meadow Creek are expected to be reduced from existing conditions during operations and early closure. Although reduced, temperatures will exceed 16°C for many years. It is likely that some individuals will experience sublethal effects (e.g., reduced growth, increase risk of disease) during their rearing time period, particularly if macroinvertebrate drift is reduced from upstream sources. Warmer temperatures result in higher metabolic rates, and without adequate forage, fish may not grow sufficiently. Individual fish that fail to grow adequately in natal and rearing streams have less chance of successfully returning as adults (Mebane and Arthaud 2010).

Table 61. Potential biological responses, by life stage, that may occur if individuals are exposed to elevated temperatures.

Life Stage	Temperature (°C)	Biological Response
Adult Migration	21-22	• Direct mortality (sustained exposures) • Migration blockage and delay
	>20	• Reduced swimming performance • Reduced individual survival
	>18	• Elevated disease risk • Reduced gamete viability • Overall reduction in migration fitness
Spawning/Incubation	>18	• Mortality • Development abnormalities
	>13	• Increased risk of embryo mortality
Juvenile Rearing	>23	• Direct mortality
	>20	• Reduced competitive success • Increased risk of predation
	>16	• Elevated disease risk • Reduced growth

Source: EPA 2003; EPA 2023

Temperatures in Meadow Creek above EFMC are expected to experience the greatest thermal change and may reach MWMT of 20.8°C during MY 27. It is possible that adult Chinook salmon, if they elect to remain in this reach for extended periods of time could experience prespawn mortality as a result of elevated temperatures coupled with other stressors (e.g., elevated contaminants) in the reach. In addition, gamete viability will likely be reduced. Embryos will also experience mortality as a result of redd exposure to elevated temperatures during the first few weeks of incubation. Juvenile fish rearing in this reach may experience reduced competitive success and may be at greater risk of predation from predators (e.g., bull trout) for MYs 23 through 27. Predicted stream temperatures may also reduce embryo survival, particularly at the early stages of spawning. Overall, temperature conditions in Meadow Creek are expected to support production of Chinook salmon and steelhead during SGP implementation; however, the contribution of salmon or steelhead to population productivity is expected to vary over time, with the lowest contributions occurring in MYs 23 through 27. The Meadow Creek reaches that may be used for spawning and rearing represent less than 0.1 percent of the total intrinsic potential habitat for the SFSR steelhead population and less than 1 percent of total intrinsic potential habitat for the EFSFSR Chinook salmon population. Considering the habitat represents a small fraction of the population production potential and considering only a few individuals are likely to experience lethal effects (e.g., Chinook salmon embryos; or delayed mortality of juvenile salmon or steelhead due to sublethal effects from exposure to elevated temperatures), we do not believe the productivity of the populations will be reduced to a degree that will preclude the populations from achieving their desired status.

The biological objectives underlying the stream restoration and enhancement designs for the EFSFSR are to support both steelhead (primary) and Chinook salmon (secondary) spawning and rearing. These reaches are expected to support adult migration, spawning, and rearing for both species. During MY 6, MWMT are expected to be slightly above that which is considered "optimal" for juvenile rearing. It is possible that individual fish may experience some limited sublethal effects as a result of these slightly elevated temperatures. Sublethal impacts to a few individuals inhabiting this reach of the EFSFSR is not expected to alter the productivity of the SFSR steelhead or EFSFSR Chinook salmon populations.

2.10.4.2. **Suspended Sediment, Spawning Gravel/Substrate**

As previously described in the DCH effects analysis, action area streams could be affected through project generated turbidity and subsequent sediment deposition. However, the proposed action includes measures to reduce or avoid sediment delivery and turbidity impacts, including silt fences, straw waddles, graveling and applying dust control chemicals on roads, limiting equipment stream crossings, operating in dewatered work areas, etc.

Increased sediment delivery can cause turbidity pulses and lead to excessive deposition on the channel bottom. Elevated turbidity can cause lethal, sublethal, and behavioral effects in juvenile and adult salmonids; depending on the duration, frequency, and intensity of the exposure (Newcombe and Jensen 1996). Increased turbidity levels in the action area may result in temporary displacement of fish from preferred habitat or potentially sublethal effects such as gill flaring, coughing, avoidance, and increase in blood sugar levels (Bisson and Bilby 1982; Sigler et al. 1984; Berg and Northcote 1985; Servizi and Martens 1992). Literature reviewed in Rowe et al. (2003) indicated that NTU levels below 50 generally elicit only behavioral responses from salmonids, and Lloyd (1987) suggested that salmonids reacted negatively, by moving away, when turbidity reached 50 NTU. Although elevated turbidity levels may cause stress, Gregory and Northcote (1993) have shown that moderate levels of turbidity (35 to 150 NTU) can also accelerate foraging rates among juvenile Chinook salmon, likely because of reduced vulnerability to predators (camouflaging effect).

Sediments suspended in the water column reduce light penetration, increase water temperature, and modify water chemistry. Once in streams, fine sediment is transported downstream and is ultimately deposited in slow water areas and behind obstructions. Sediment deposition can locally alter fish habitat conditions through partly or completely filling pools, increasing the width to depth ratio of streams, and changing the distribution of pools, riffles, and glides. In particular, fine sediment has been shown to fill the interstitial spaces among larger streambed particles, which can eliminate the living space for various microorganisms, aquatic macroinvertebrates (i.e., prey items for juvenile salmon and steelhead), and juvenile fish (Bjornn and Reiser 1991).

As previously described, the proposed action will cause increased sediment delivery to streams from pre-construction through closure and restoration. The resultant turbidity plumes will be sufficient in magnitude and duration for fish to experience biologically meaningful behavioral changes or ill effects as previously described. It is likely that turbidity spikes, especially those associated with instream work will cause fish to find refuge away from the turbid water, which may expose them to predation. Fish unable to escape turbid waters may experience short-term behavioral changes described above. Turbidity plumes associated with instream work are anticipated to travel up to 1,000 feet downstream prior to dissipating to levels that are no longer harmful to aquatic species. These plumes are expected to be short-lived (lasting only a matter of minutes to hours), and no turbidity related injury or morality is expected to occur as a result of the project.

When sediment delivery exceeds the sediment transport capability of the stream, the amount of fine sediments will increase on and within stream substrates. Potential problems associated with excessive instream sediment have long been recognized for a variety of salmonid species and at all life stages, from possible suffocation and entrapment of incubating embryos (Coble 1961; Phillips et al. 1975; Hausle and Coble 1976; McCuddin 1977; Cederholm and Salo 1979; Peterson and Metcalfe 1981; Tagart 1984; Reiser and White 1988; Lisle and Lewis 1992), to loss of summer rearing and overwintering cover for juveniles (Bjornn et al. 1977; Hillman et al. 1987; Griffith and Smith 1993), to reduced availability of invertebrate food for resident adults (Tebo 1955; Cederholm and Lestelle 1974; Bjornn et al. 1977; Alexander and Hansen 1986). Salmonid populations are typically negatively correlated with the amount of fine sediment in stream substrate (Chapman and McCleod 1987).

The BRGI portion of the action could affect the substrate/spawning gravel PBFs through mobilization of fine sediments. However, as described above, proven erosion control measures are expected to effectively limit the amount of sediment delivered to action area streams. In addition to BMPs mentioned above in the critical habitat effects section, streams near drilling sites will be monitored during drilling, and drilling will cease if turbidity is detected; and, because drilling activities typically do not result in mobilization of sediment, sediment effects on Chinook salmon or steelhead due to the proposed drilling activities are expected to be minor and not expected to reach levels causing harm.

Initial vegetation clearing and the construction, use, and maintenance of access roads may increase delivery of sediment to waterways and increase sediment deposition. New construction of access roads, upgrades of existing access roads, use of roads, and construction of facilities and transmission line foundations have the greatest potential for sediment delivery. Localized sediment deposition is expected to occur from these activities from pre-construction through closure and restoration. It is likely that some localized rearing habitat may be negatively impacted by sediment deposition to a degree that may contribute to sublethal effects (e.g., reduced growth, density dependence effects due to reduced habitat space, etc.) to juvenile fish rearing in the action area. Whether sediment delivery will cause direct mortality of incubating embryos depends on whether sediment is deposited directly on top of redds in sufficient amounts to cause suffocation or entrapment.

Overall, the magnitude of the increase in sediment delivery and its impact on fish spawning, incubation, and rearing through elevated turbidity and subsequent sediment deposition is difficult to predict. These effects will occur throughout the construction and the active mining periods (approximately 20 years), and over that timeframe NMFS expects that sediment-related effects will extend downstream to the confluence with the SFSR. However, implementation of BMPs and PDFs should effectively minimize the amount of sediment being delivered, and because these PDFs are known to be both proven and effective, turbidity pulses from with project-generated sediment are expected to be localized, low-intensity, infrequent, and last for only minutes to hours. Channel dewatering and fish salvage will remove fish from streams where in-water work and mining overlap. Direct impacts from sediment runoff will be restricted to access routes and areas at the edge of the active mine; and sediment impacts in these areas will be further limited by erosion control BMPs (e.g., silt fences, straw waddles, etc.).

Any increase in fine sediment deposition within stream channels has the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles, effects that would impact spawning/incubation and rearing/feeding life stages of Chinook salmon and steelhead. However, with the application of sediment control BMPs and stormwater treatment techniques, the impacts of sediment in surface water, as well as interstitial sediment, to fish are predicted to be measurable but not severe, and should not meaningfully affect salmonid spawning and rearing success.

Provided GRAIP-Lite modeling (Tetra Tech 2024) is accurate, restoration efforts to address chronic sources of sediment delivery in the EFMC, planned road closures, and mine site revegetation efforts will lead to a substantial reduction in sediment delivery to action area streams. Site restoration should ultimately benefit spawning and rearing Chinook salmon and steelhead with an overall, long-term, localized decrease in sediment input into Johnson Creek, Meadow Creek, and the EFSFSR.

2.10.4.3. **Water Quantity**

During the pre-construction phase, water will need to be withdrawn to support drilling activities associated with the BRGI portion of the project. However, because flow in Johnson Creek is nearly unimpaired, the flow reduction due to the BRGI portion of the proposed action is very small, and the reduction would occur for only one year, the overall effect of reducing flow in occupied Chinook salmon and steelhead habitat will be minor and not likely to result in harm of ESA-listed salmon and steelhead.

During operations, water rights associated with the proposed action authorize a total of 9.9 cfs of diversion from PODs in the EFSFSR drainage, 9.6 cfs of which will be used for mining, ore processing, etc., with the remainder used for domestic purposes and support of a vehicle maintenance facility (Table 16). The four water rights authorizing diversion of the 9.6 cfs for mining, ore processing, etc., include conditions that will protect "minimum flows" in lower Meadow Creek, in the EFSFSR between the YPP and Sugar Creek, and in the EFSFSR below Sugar Creek (Water Right details for 77-7122, 77-7293, 77-14378,77-7285). These "minimum flows" should ensure that the flow effects of proposed action will not appreciably impair upstream and downstream fish passage. However, the anticipated reductions in flow will affect other aspects of SR Spring/summer Chinook salmon and SRB steelhead biology.

Reducing stream flow affects stream dwelling salmonids in a variety of ways. Food availability for stream dwelling salmonids is generally positively related to streamflow across the entire range of base flows (Harvey et al. 2006; Hayes et al. 2007; Davidson et al. 2010) and reducing stream flow reduces growth of individual salmonids (Harvey et al. 2006) and productivity of salmonid populations (Nislow et al. 2004). Reducing streamflow reduces access to escape cover (Hardy et al. 2006a) which could increase predation risk and could reduce the amount of suitable habitat, thereby increasing competition for suitable habitat. Reducing flow can cause long-term increases in fine sediments in stream substrates (Baker et al. 2011), thereby reducing food production, availability of cover for rearing juveniles, and survival of eggs in redds. Reducing flow increases summer water temperature (Tate et al. 2005; Miller et al. 2007), which will reduce growth and survival of rearing juveniles and could reduce survival of adult holding Chinook salmon. Cold water refugia are important for rearing juvenile Chinook salmon and steelhead

(Sauter et al. 2001; Richter and Kolmes 2005) and for pre-spawning adult Chinook salmon (Berman and Quinn 1991; Torgersen et al. 1999), suggesting that reducing water from cold tributary streams will adversely affect rearing Chinook salmon and steelhead, and possibly holding adult Chinook salmon.

Modeling effects of flow changes on fish populations has historically been problematic (Shirvell 1986; Bourgeios et al. 1996; Hardy et al. 2006; Beecher et al. 2010) and even the most refined flow habitat models tend to underestimate optimal flows (Rosenfield et al. 2016) suggesting that modeling would likely underestimate the effects of flow reductions on SR Spring/summer Chinook salmon and SRB steelhead. Year class strength of many salmonid populations is positively related to streamflow (Ricker 1975; Mathews and Olson 1980; Mitro et al. 2003; Elliott et al.1997; Nislow et al. 2004; Arthaud et al. 2010; Beecher et al. 2010; Warkentin et al. 2022; Morrow and Arthaud 2024). A review of 46 studies found that salmonid demography was typically positively related to flow (Kovach et al. 2016). Because relationships of population productivity and streamflow are well documented, we used the relationships productivity and flow for the EFSFSR and SFSR Chinook salmon populations, and the SFSR steelhead population, to estimate the flow-related effects of the proposed action on SR Spring/summer Chinook salmon and SRB steelhead. The regression models also incorporated population density and, because the proposed action would affect flow in only a portion of the EFSFSR Chinook salmon and the SFSR steelhead population areas, we scaled the estimated effects based on the proportion of habitat affected. The flow leverage plots from the regression models are in Figure 34. The methods used to calculate flow effects, and the complete regression results, are in Appendix G.

According to the information provided in the BA, the proposed action would result in a slight increase in flow during MY -2, but flows would be reduced after MY -2. During MY -1 through MY 7, flow reductions will generally increase, each year, reaching a maximum during MY 7, and then will generally decrease through MY 20. A small reduction in flow will persists from MY 21 through approximately MY 78. The analysis in Appendix G uses the relationships of population productivity versus rearing flow (Figure 35) to translate the flow-related effects into effects on population productivity. The maximum flow effect, which will occur during MY 7, will reduce productivity of the EFSFSR Chinook salmon population, the SFSR Chinook salmon population, and the SFSR steelhead population, by 2.2%, 0.015%, and 0.82% respectively. Presuming average population size, these reductions in productivity will result in approximately seven fewer returning EFSFSR Chinook salmon, substantially less than one returning SFSR Chinook salmon, and approximately eight returning SFSR steelhead. The average productivity reduction for MYs -2 through 20 will be 1.1%, 0.007%, and 0.36%, respectively, for the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead populations. The estimated reductions in productivity for MYs -2 through 20, and the resultant reductions in returns for MYs one through 23, are in Figures 36 and 37. Although water diversion for mining will cease after MY 20, the effects on flow will persist, due to the filling of the WEP Lake. From MY 21 through approximately MY 78, the flow reduction due to filling the WEP Lake will reduce productivity of the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead populations by 0.13%, 0.001% and 0.082%, respectively, and will result in an average of 0.4 fewer returning EFSFSR Chinook salmon, 0.006 fewer returning SFSR Chinook salmon, and 0.8 fewer returning SFSR steelhead, each year.

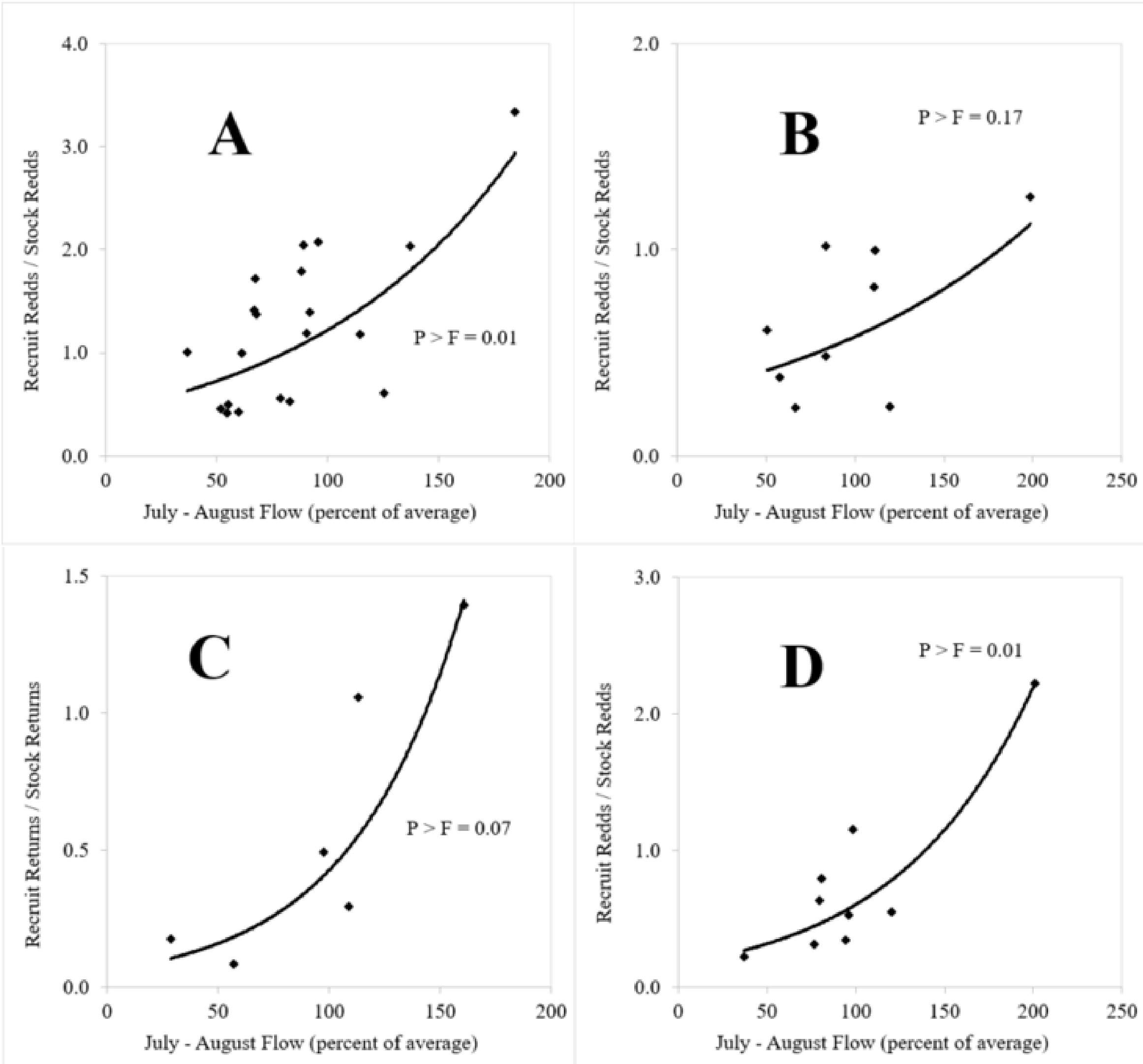


Figure 35. **Flow leverage plots for multivariate regressions of whole life cycle population productivity and average July – September flow (percent of average) for the EFSFSR Chinook salmon population (A), the SFSR Chinook salmon population (B), the SFSR steelhead population (C), and the Secesh River Chinook salmon population (D)**.

Based on the estimated effects on whole life cycle population productivity, the flow related effects of the proposed action would result in 819 fewer juvenile EFSFSR Chinook salmon, ten fewer juvenile SFSR Chinook salmon, and 370 fewer juvenile SFSR steelhead migrating downstream past Lower Granite Dam during MY 7. The estimated annual average reduction for MYs -2 through MY 20, is 406 fewer juvenile EFSFSR Chinook salmon, five fewer juvenile SFSR Chinook salmon, and 163 fewer SFSR steelhead. The long-term effects (i.e., year 23 – 100+) would result in an average of 45, 0.6, and 38 fewer juvenile EFSFSR Chinook salmon, SFSR Chinook salmon, and SFSR steelhead, respectively, migrating downstream past Lower Granite Dam, each year.

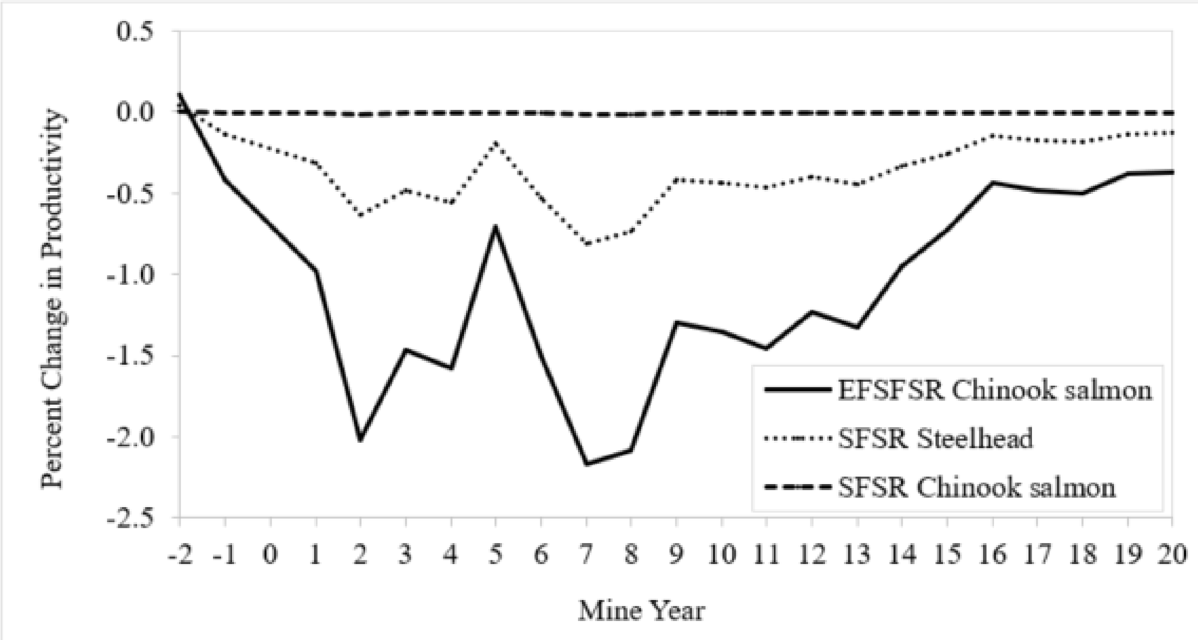


Figure 36. **Change in population productivity for the EFSFSR Chinook salmon population, the SFSR Chinook salmon population, and the SFSR steelhead population, due to flow reductions caused by the proposed action for MYs -2 through 20.**

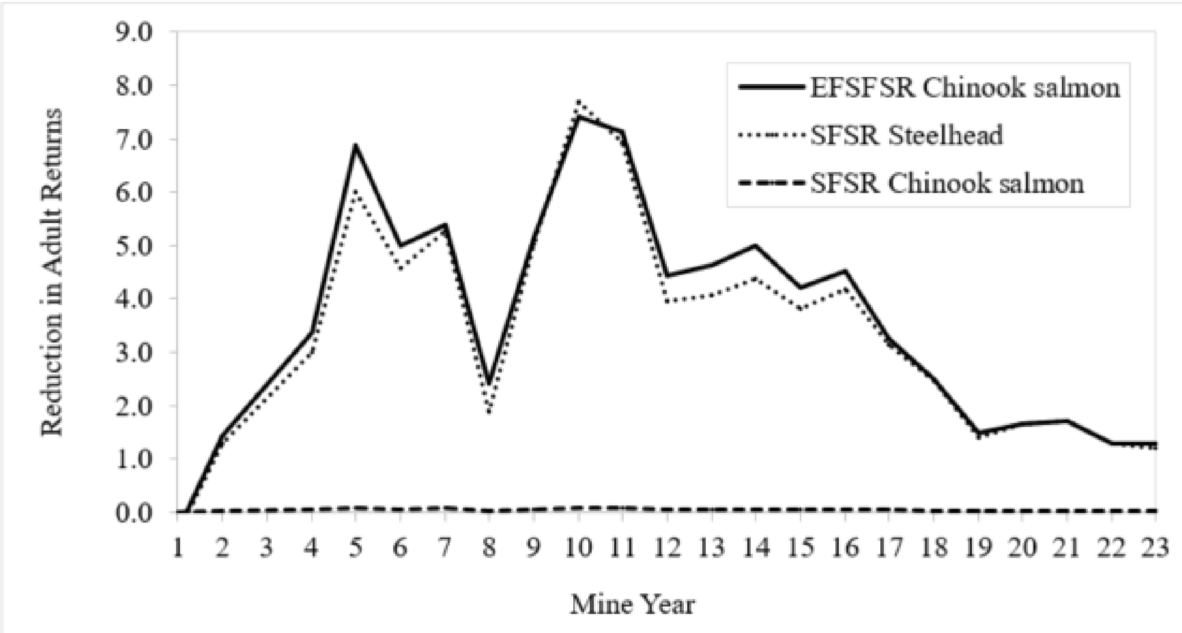


Figure 37. Reduction in adult returns assuming average returning adult population sizes of 341 for the EFSFSR Chinook salmon population, 649 for the SFSR Chinook salmon population, and 945 for the SFSR steelhead population. The EFSFSR Chinook salmon population size is based on Nez Perce Tribe redd survey data, the SFSR Chinook salmon population size is based on IDFG redd survey data, and the SFSR steelhead population size is, respectively, redd survey data, and the SFSR steelhead population size is based on the IDFG steelhead return estimates.

Note: These population sizes represent averages for 1998-2022, for the EFSFSR Chinook salmon population, 2008-2022 for the SFSR Chinook salmon population, and 2011-2020 for the SFSR steelhead population.

2.10.4.4. **Fish Passage, Habitat Access, and Habitat Condition**

As described in the DCH effects section, the proposed action will not likely reduce flows to levels that impair upstream or downstream fish passage and the only surface water diversion (EFSFSR between Sugar Creek and the YPP) will meet NMFS criteria for fish passage (NMFS 2022a). Upstream migration is not likely to be impaired by the water diversion, but some downstream migrants will pass via the fish screen/bypass system and will experience migration delay and increased chance of migration mortality.

During the construction of the Burntlog Route or of temporary roads, culverts will be constructed or replaced, which may affect fish access in different sections of streams. Any new or reconstructed crossing will be designed to be fish passable, which will increase or reestablish fish access where it had been reduced or blocked unless there is a risk of passing non-native fish species. As mentioned in the DCH effects section, there are 18 existing crossings along the Burntlog Road (FR-447) that will be replaced and 10 new crossings along newly constructed portions of the Burntlog Route. There is a total of approximately 53 miles of stream segments upstream of the Burntlog Route. Currently almost all stream crossings along the Burntlog Road are impassable culverts, particularly at low flow conditions. The key perennial streams that will be crossed are Burntlog, Trapper, and Riordan Creeks. Access roads to the new transmission line cross some creeks; however, alteration to most of these crossings may not be necessary. If the crossing needs to be upgraded, the same BMPs will be followed as for the Burntlog Route.

Also, during the construction phase, the proposed action will begin to address fish passage in the EFSFSR subbasin. Construction of the EFSFSR tunnel to bypass the barrier upstream from YPP Lake and removal of the EFSFSR box culvert will both be completed by MY -1 and will facilitate fish passage. Although the partial gradient barrier in Meadow Creek just upstream from EFMC will also be removed during the construction phase of the Project, a new barrier will be created in MY -2 just upstream from the existing barrier to prevent fish passage into upper Meadow Creek where the TSF will be constructed. This new barrier, will block access to approximately 0.43 miles of habitat otherwise accessible to Chinook salmon and steelhead through MY 12. By MY 18, the only barrier impacting ESA-listed salmon and steelhead will be the steep gradient section of Meadow Creek associated with the TSF buttress created as part of the SGP, a barrier that will remain indefinitely and will permanently block volitional access to approximately 3.87 miles of suitable habitat. Because the water rights authorizing water diversion for SGP operations include conditions that protect minimum flows, reduction in streamflow, due to the proposed action, is not likely to further impair fish movement.

Although Chinook salmon were already using habitat upstream from the YPP cascade in years following release of excess hatchery fish, removal of these barriers will result in volitional passage into the upper EFSFSR for the first time since the 1930s. Passage upstream of the cascade will provide access to up to 5.51 miles of habitat with intrinsic potential for Chinook and 5.42 miles of intrinsic potential for steelhead spawning and rearing.

As discussed in the DCH effects section, the amount of instream LWD, pool frequency, pool quality, and off-channel habitat are often indicators of quality fish habitat. Large wildfires in the action area have contributed large amounts of LWD to action area streams, which in turn has increased habitat complexity and created quality refugia by increasing both the number and quality of pools in action area streams. Channel restoration and enhancement will occur in Meadow Creek and the EFSFSR as early as MY -1, work that will involve the addition of instream habitat structures, including LWD jams, boulder clusters, and excavated pools, intended to improve spawning and rearing habitat conditions for salmonids. By MY 11, a restored stream channel and Stibnite Lake will be created across the surface of the YPP backfill. Once this portion of the stream channel restoration is complete, the EFSFSR flows will be routed through the restored channel and Chinook salmon and steelhead will gain access to additional spawning and rearing habitat. Revegetation efforts will also take place to develop riparian vegetation to provide for long-term bank stability, future LWD recruitment, overhead cover, and shade.

Overall, although temporary and short-term effects to Chinook and steelhead could occur from work to restore and enhance these stream reaches, this work will be completed in dewatered work areas, and other than small, temporary, localized, brief turbidity pulses, impacts from these activities will be confined to the effects of fish salvage and handling (see below). Proposed stream restoration and enhancement should ultimately increase habitat complexity in reaches accessible to anadromous fish in the upper EFSFSR and Meadow Creek, resulting in long-term, localized improvements to fish productivity.

2.10.4.5. **Food/Forage**

Quantities of available food/forage can be affected by changes in water quality (e.g., stream temperature, dissolved oxygen, chemical contamination), water quantity, sedimentation, and clearing of riparian vegetation.

Chemical contamination resulting from an accidental spill or through point and nonpoint sources of pollution has the potential to affect the quantity and quality of prey for juvenile salmon or steelhead. Mortality of aquatic invertebrates from a spill of toxic materials would be dependent upon the type and amount of material spilled. Since toxicity is expected to attenuate in a downstream direction, mortality from a spill is not likely to extend more than a mile or two downstream. As discussed in the DCH effects section, contaminant concentrations are not expected to rise to a level acutely toxic to aquatic invertebrates. Furthermore, contaminant concentrations are not expected to substantially alter the quantity or diversity of macroinvertebrate assemblages. Given that juvenile salmonids are opportunistic feeders, as long as a diverse group of macroinvertebrates are protected, some loss of prey items would not be expected to reduce individual fitness of juvenile salmonids rearing in the area.

While the quantity of prey is not expected to be negatively affected, predicted concentrations of arsenic and mercury are expected to impact prey quality. As previously described, arsenic concentrations are predicted to substantially decrease over the life of the project; therefore, we believe accumulation of arsenic in prey tissues will also decrease over time. This conclusion is not unreasonable, as arsenic concentrations in macroinvertebrate tissues were lower in Meadow Creek when measured about 10 years after reclamation. Even though arsenic accumulation is expected to decrease, juvenile fish are still expected to experience sublethal effects as a result of dietary exposures. The proposed action will result in higher mercury concentrations in streams within the Stibnite project area. In addition, the SGP will produce an incremental increase in organic carbon content in the EFSFSR due to sanitary wastewater effluent. Taken together, there will be an increased risk of bioaccumulation of mercury in salmonid prey items and a concomitant increase in bioaccumulation of mercury in fish. Whether, and the extent to which increased mercury bioaccumulation will reduce individual fitness is unknown.

Decreased streamflows in Meadow Creek, Sugar Creek, the EFSFSR, and the SFSR during the construction and post closure (MYs -1 to 20) will cause a reduction in food availability and suitable habitat, which could increase competition for both habitat and available food/forage. This will likely reduce growth and survival of SR Spring/summer Chinook salmon and SR Basin steelhead (Appendix G).

Proposed ground-disturbing activities could affect instream sediment levels, which could in turn affect benthic invertebrate production. However, as discussed in the DCH effects section, the amount of sediment delivered to action area streams is predicted to be measurable but not severe. Therefore, increases in sediment are not expected to impact the quantity or types of food available to ESA-listed salmonids in the action area, and are therefore not expected to impact juvenile Chinook salmon or steelhead growth and survival.

2.10.4.6. **Noise and Vibration**

Noise and vibration from equipment operation and blasting have the potential to disturb or harm ESA-listed Chinook salmon and steelhead. The potential effects from both of these activities will be discussed in more detail below.

2.10.4.6.1. Equipment Operation.

Noise and vibration from heavy equipment operating adjacent to live water may disturb fish in the immediate vicinity causing short-term displacement. As described in the BA (Stantec 2024), to avoid injury, instantaneous sound levels should be less than 206 peak dB and sound emitted over extended time (sound emitted repeatedly) should be less than 187 dB (183 dB for fish less than 2 grams) exposure level, referenced at 1 micropascal for sound traveling through water, measured at a distance of 10 meters (Fisheries Hydroacoustic Working Group 2008). However, sound levels over 150 dB can trigger behavioral effects, such as moving to other locations.

Machinery operation adjacent to streams will be intermittent, with actual activity near the stream occurring at various times on any given day. The Federal Highway Administration (2024) indicates backhoe, grader, drill rigs, rock drill, loader, and dump truck noise production ranging between 80 and 98 dB. According to Bauer and Babich (2006), equipment used for surface limestone mining (i.e., jaw and cone crushers, screens, conveyor belts, etc.) produced noise levels ranging from 67 to 111 dB. For mining related noise, Mintek (2024) reported pneumatic and percussion tools operating at levels ranging from 114 to 120 dB, while loaders and haulage truck levels ranging from 90 to 110 bB. Rock crushing equipment, such as crushers and screens, can generate noise levels that can exceed 85 dB. Noise levels can vary depending on the process, with blasting activities ranging from 102.8 to 130.8 dB, and crushing activities ranging from 97 to 116.2 dB (Pal and Mandal 2021; Hebbal and Kadadevaru 2017).

Because the decibel scale is logarithmic, there is nearly a 100-fold difference between noise levels expected from the action and noise levels known to have generated adverse effects to fish species, as discussed above. Therefore, noise related disturbances of this magnitude are unlikely to result in injury or death. It is unknown if the expected dB levels will cause fish to temporarily move away from the disturbance or if fish will remain present. Even if fish move, they are expected to migrate only short distances to an area they feel more secure and only for a few hours in any given day. NMFS does not anticipate short-term movements caused by equipment noise will result in effects of a duration or magnitude that is expected to result in harm of ESA-listed salmon or steelhead.

In addition to sound effects, excessive ground vibrations have the potential to affect salmonids, particularly the sensitive egg life stage (Timothy 2013; Kolden and Aimone-Martin 2013). Smirnov (1954, as cited in ADFG 1991) found significant egg mortality caused by ground vibrations with a peak particle velocity (PPV) of 2 inches per second (ips). Jensen and Collins (2003) found that a PPV of 5.8 ips resulted in 10 percent mortality of Chinook salmon embryos. Faulkner et al. (2008) found that PPVs up to 9.7 ips resulted in significantly higher mortality in *O. mykiss* eggs but there was no increase in mortality when exposed to PPVs of 5.2 or less. The Alaska Department of Fish and Game (ADFG) have PPV restrictions of 2.0 ips to protect salmonids (Timothy 2013).

The reported PPV value for an in-situ soil sampling rig at a distance of 100 feet is 0.011 ips (ATS Consulting 2013). Dowding (2002, as cited in Aimone-Martin and Kolden 2019) reported vibrations causing PPVs ranging from 0.04 to 0.39 ips for most types of equipment, and up to 0.59 ips for higher impact energy sources like pile drivers. This considered, PPV associated with equipment operation in and around the SGP is not expected to create levels or expected to reach levels known to have generated adverse effects to fish species, as discussed above, and are unlikely to result in injury or death.

2.10.4.6.2. Blasting.

Explosives will be used to fracture rock from mine operations. Explosives detonated near water produce shock waves that may be lethal or damaging to fish, fish eggs, or other aquatic organisms. Outside of the zone of lethal or harmful shock waves, the vibrations caused by drilling and blasting have the potential to disturb fish causing stress or altering behavior.

Blasting has the potential to affect Chinook salmon, steelhead, or salmonid redds during operations. In fish, sudden changes in overpressure can cause injury, behavioral changes, temporary or permanent hearing loss, and mortality in extreme cases. Injuries can include hemorrhaging, embolism, and damage to the swimbladder, liver, or other internal organs. In eggs, blasting can cause ground vibrations in substrate that can physically deform, dislodge, and tear or crush the eggs (Aimone-Martin and Kolden 2019).

However, as previously mentioned, most of the blasting will be away from streams, in and near the Yellow Pine, Hangar Flats, and West End Pits, although some may also be required for construction of stream diversions at the YPP, TSF, and TSF Buttress. According to the BA, areas requiring blasting will typically occur on steeper side slopes and in upland areas (Stantec 2024), but the proposed action further states that where the setback distance cannot be met and alterations to the blasting protocol will not adequately mitigate potential harm to fish communities, Perpetua would implement measures to isolate, capture, and relocate ESA-listed fish species from the stream segment where potential for impact exists. Because the BA did not identify where, how often, and how much area could be affected, and they did not identify how many fish might be salvaged for blasting, NMFS is not able to predict how many fish might be affected by salvage activities associated with blasting. Therefore, we do not factor any fish salvage associated with blasting into our effect’s analysis, and presume that all blasting EDFs will be applied alongside any streams occupied by ESA-listed salmon or steelhead. The proposed action includes limits on charge sizes, controlled blasting techniques, and using setback distances restricting use by streams (section 1.7.2). These EDFs have been designed according to standards established in Wright and Hopky (1998), ADFG (1991), and Timothy (2013). These EDFs have been shown to be protective of fish (Timothy 2013) and should effectively limit the potential for project-related blasting from affecting spawning/rearing Chinook salmon, steelhead, or their redds.

2.10.4.7. **Fish Salvage and Handling**

In-water work associated with the proposed action will take place during in-water work windows, in dewatered work areas, and only after fish salvage has been conducted. Water will be slowly removed from work areas to allow some fish to leave volitionally, and pumps used for dewatering will be screened to meet NOAA Fisheries and IDFG standards to avoid entrainment of juvenile fish. Fish removal methods will use blocknets, seining, minnow traps, dip-netting, and electrofishing. Captured fish will be relocated as quickly as possible to pre-planned release areas using aerated and shaded transport buckets holding limited numbers of fish of comparable size to minimize predation (Stantec 2024). Fish salvage will be necessary beginning in the construction phase (i.e., Burntlog Route and YPP dewatering), continuing through operations and closure (i.e., stream restoration and enhancement).

The proposed action did not identify how many electrofishing passes would be employed during fish salvage, but NMFS assumes that a three-pass electrofishing effort will be employed because it is a standard practice. The proposed action stated that NMFS' electrofishing guidelines (NMFS 2000) will be followed when salvaging fish. The guidelines require that field crews be trained in observing animals for signs of stress and shown how to adjust electrofishing equipment to minimize that stress. Electrofishing is not done in the vicinity of redds or spawning adults. All electrofishing equipment operators will be trained by qualified personnel to be familiar with equipment handling, settings, maintenance, and safety. Only direct current units will be used, and the equipment will be regularly maintained to ensure proper operating condition. Voltage, pulse width, and rate will be kept at minimal levels and water conductivity will be tested at the start of every electrofishing session so those minimal levels can be determined. When such low settings are used, shocked fish normally revive instantaneously. Fish requiring revivification will receive immediate care.

In an effort to quantify effects of fish salvage for the SGP, NMFS included the following information in our calculations. We applied fish abundances provided in the BA, and where not provided, used mean fish densities for intensive snorkeling surveys in the EFSFSR drainage reported by IDFG (Poole et al. 2019). Because all sites will be dewatered in stages, NMFS assumes that approximately half of the fish present in a work area will move out of each work area volitionally and not be subject to any form of fish handling. By seining and dip-netting project areas next, NMFS expects that many fish in the area will flee as the block-nets are maneuvered into place. We estimated a 70% capture rate of those fish that remain in work areas with netting. Although seining of fish is likely to cause some elevated stress levels from the contact with the seine and personnel, these effects are not expected to result in injury or death of juvenile salmonids. NMFS also expects that some fish will simply retreat into cover within the work areas and will be subject to electrofishing.

The effects of electrofishing on juvenile steelhead and spring/summer Chinook salmon will be limited to the direct and indirect effects of exposure to an electric field, capture by netting, and the effects of handling associated with transferring the fish back to the streams. Most of the studies on the effects of electrofishing have been conducted on adult fish >12 inches in length (Dalbey et al. 1996). The relatively few studies that have been conducted on juvenile salmonids indicate that spinal injury rates are substantially lower than for larger fish. Smaller fish intercept a smaller head-to-tail potential than larger fish (Sharber and Carothers 1988) and may therefore be subject to lower injury rates (Dalbey et al. 1996; Thompson et al. 1997).

McMichael et al. (1998) found a 5.1% injury rate for juvenile middle Columbia River steelhead captured by electrofishing in the Yakima River subbasin, while Ainslie et al. (1998) reported injury rates of 15% for direct current electrofishing on juvenile rainbow trout. The incidence and severity of electrofishing damage is partly related to the type of equipment used and the waveform produced (Sharber and Carothers 1988; Dalbey et al. 1996; Dwyer and White 1997). Continuous direct current or low-frequency (equal or less than 30 Hz) pulsed direct current have been recommended for electrofishing because lower spinal injury rates occur with these waveforms, particularly in salmonids (Fredenberg 1992; Dalbey et al. 1996; Ainslie et al. 1998). Only a few recent studies have examined the long-term effects of electrofishing on salmonid survival and growth (Ainslie et al. 1998; Dalbey et al. 1996), indicating that although some fish suffer spinal injury, few dies as a result. However, severely injured fish grow at slower rates and sometimes show no growth at all (Dalbey et al. 1996).

In an effort to estimate the number of fish expected to be injured or killed as a result of this project, NMFS used fish abundances described in the BA (Stantec 2024) and where not provided, used mean fish densities for intensive snorkeling surveys in the EFSFSR drainage reported by IDFG (Poole et al. 2019) to estimate how many fish would be exposed to electrofishing. NMFS assumed a 10% injury rate for fish subject to electrofishing. We have also factored in a 5% electroshocking mortality rate, and a stranding rate of 5% for all project sites. Table 62 estimates the number of Chinook salmon and steelhead likely to be injured, killed, or handled as part of fish salvage operations, by MY and major activity.

2.10.4.7.1. Construction.

Construction of the Burntlog Route will occur from MY -3 to -1, work that will require in-water work associated with bridges and culverts along the route. All bridge work crosses stream segments with fish presence, while only 9 of 25 culverts occur in streams with fish present. Fish salvage is expected to be necessary for anadromous fish as follows:

- Both Chinook and Steelhead: Johnson Creek (Station 1013+00), Burntlog Bridge (Sta. 1597+00), and East Fork Burntlog Bridge (Sta. 1873+00) sites.
- Steelhead Only: Unnamed Trib. to East Fork Burntlog Bridge (Sta. 1803+00), Peanut Creek culvert.
- Chinook Only: EFSFSR Bridge.

Before draining the YPP Lake, a fish barrier will be constructed downstream from the lake (Construction period MY -2 to -1). The barrier will be designed to allow fish to leave the lake but will not allow fish to migrate upstream into the lake. It will be constructed in a window between September 15 to April 1, working to avoid migrating adult salmonids. Once the fish tunnel is complete, EFSFSR water will gradually be diverted into the tunnel and away from the YPP Lake.

Table 62 Estimated Number of Juvenile Chinook Salmon and Steelhead Present, Handled, Injured, or Killed from Fish Salvage Efforts by Stibnite Activity and Mine Year.

Mine Year	Activities	Est. # Present	# Post-drawdown (50%)	# Seined/ Netted (70%)	# Electro-fished	# Injured (10%)	# Killed (5%)	# Stranded (5%)	Est. Total Mortality (# Killed + Stranded)
Chinook Salmon									
-3 to -1	Johnson Ck Bridge (Sta. 1013+00)	19.3	9.7	6.8	2.9	0.29	0.14	0.14	0.29
-3 to -1	Burntlog Ck. Bridge (Sta. 1597+00)	2.9	1.4	1.0	0.43	0.04	0.02	0.02	0.04
-3 to -1	EF Burntlog Tributary Bridge (Sta. 1873+00)	3.1	1.6	1.1	0.47	0.05	0.02	0.02	0.05
-3 to -1	EFSFSR Bridge	2.4	1.2	0.8	0.36	0.04	0.02	0.02	0.04
-2	Upper Meadow Ck. Around TSF	4,632.0	2,316.0	1,621.2	694.80	69.48	34.74	34.74	69.48
-2	EFSFR Temporary Fish Barrier	9.0	4.5	3.2	1.35	0.14	0.07	0.07	0.14
-1	YPP Dewatering	85.0	42.5	29.8	12.75	1.28	0.64	0.64	1.28
-1	EFSFSR Box Culvert	136.0	68.0	47.6	20.40	2.04	1.02	1.02	2.04
-1	EFSFSR Enhancement (Upstream of YPP)	568.0	284.0	198.8	85.20	8.52	4.26	4.26	8.52
-3 to 0	**Construction Subtotals**	**5,457.8**	**2,728.9**	**1,910.2**	**818.67**	**81.87**	**40.93**	**40.93**	**81.87**
3	Lower Meadow Ck. into Restored Channel (MC4b.2, MC5, MC6a)	6,154.0	3,077.0	2,153.9	923.10	92.31	46.16	46.16	92.31
17	Tunnel Decommissioning	57.4	28.7	20.1	8.61	0.86	0.43	0.43	0.86
18	Lower Meadow Ck. Restored from Toe TSF Buttress	2,536.0	1,268.0	887.6	380.40	38.04	19.02	19.02	38.04
23+	Burntlog Route Decommissioning	-	-	-	-	-	-	-	-
0 - 23+	**Operations and Closure Subtotals**	**8,747.4**	**4,373.7**	**3,061.6**	**1,312.11**	**131.21**	**65.61**	**65.61**	**131.21**
	Project Totals	14,205.2	7,102.6	4,971.8	2,130.78	213.08	106.54	106.54	213.08
Steelhead									
-3 to -1	Johnson Ck Bridge (Sta. 1013+00)	11.2	5.6	3.9	1.67	0.17	0.08	0.08	0.17
-3 to -1	Peanut Ck Crossing	2.1	1.0	0.7	0.31	0.03	0.02	0.02	0.03
-3 to -1	Burntlog Ck. Bridge (Sta. 1597+00)	1.7	0.8	0.6	0.25	0.03	0.01	0.01	0.03
-3 to -1	EF Burntlog Bridge (Sta. 1803+00)	1.4	0.7	0.5	0.21	0.02	0.01	0.01	0.02

Mine Year	Activities	Est. # Present	# Post-drawdown (50%)	# Seined/ Netted (70%)	# Electro-fished	# Injured (10%)	# Killed (5%)	# Stranded (5%)	Est. Total Mortality (# Killed + Stranded)
-3 to -1	EF Burntlog Tributary Bridge (Sta. 1873+00)	1.8	0.9	0.6	0.27	0.03	0.01	0.01	0.03
-2	EFSFR Temporary Fish Barrier	5.0	2.5	1.8	0.75	0.08	0.04	0.04	0.08
-1	YPP Dewatering	25.0	12.5	8.8	3.75	0.38	0.19	0.19	0.38
-3 to 0	**Construction Subtotals**	**48.1**	**24.1**	**16.8**	**7.22**	**0.72**	**0.36**	**0.36**	**0.72**
3	Lower Meadow Ck. into Restored Channel (MC4b.2, MC5, MC6a)	597.0	298.5	209.0	89.55	8.96	4.48	4.48	8.96
17	Tunnel Decommissioning	33.1	16.6	11.6	4.97	0.50	0.25	0.25	0.50
18	Lower Meadow Ck. Restored from Toe TSF Buttress	246.0	123.0	86.1	36.90	3.69	1.85	1.85	3.69
23+	Burntlog Route Decommissioning	-	-	-	-	-	-	-	-
	Operations and Closure Subtotals	**876.1**	**438.1**	**306.6**	**131.42**	**13.14**	**6.57**	**6.57**	**13.14**
	Project Totals	**924.2**	**462.1**	**323.5**	**138.64**	**13.86**	**6.93**	**6.93**	**13.86**

Once most of the flow has been re-routed into the tunnel, fish salvage of the Lake will begin, and it will take approximately a week to complete. Based on population estimates when the YPP lake was sampled from 2018 to 2019, very few Chinook salmon or steelhead are expected to be salvaged from the lake. Although the BA anticipated an abundance of no more than five of either species (BA Table 4.1-38), fish sampling from 2018 to 2019 caught 52 Chinook and 4 *O. mykiss*, although they were not able to complete a population estimate (Brown and Caldwell, Rio ASE, and BioAnalysts 2021). Therefore, to make sure we do not underestimate the number of Chinook and steelhead present, NMFS assumed up to 85 Chinook and 25 steelhead could be present in the lake when fish salvage begins.

The box culvert on the EFSFSR and enhancement of the EFSFSR upstream from YPP will also take place in the construction period, completed in MY -1.

Combined, NMFS estimates that fish salvage for the construction period (MYs -3 to -1) will: handle approximately 2,729 Chinook salmon, with 819 subject to electrofishing, injuring 82, and stranding or killing another 82; and will handle approximately 24 steelhead, injuring one, and stranding or killing another one (Table 62). These effects will all occur to the EFSFSR Chinook salmon population and the SFSR steelhead population. However, the injuries and mortalities will be spread across the three-year period, and will not be realized all at once to a single year class of either species.

2.10.4.7.2. Operations and Closure.

Fish salvage will also be required during operations and closure, beginning with stream enhancement in Lower Meadow Creek in MY 3, decommissioning the tunnel around MY 17, and wrapping up around MY 18 when lower Meadow Creek is restored from the toe of the TSF buttress. Although additional fish salvage may be required upon closure of the Burntlog Route beginning in MY 23+, the segments of the Burntlog Route where Chinook and steelhead are expected to be present will not be decommissioned and these stream crossings are expected to remain in place. Therefore, no additional fish salvage of ESA-listed Chinook salmon or steelhead is anticipated at mine closure for decommissioning of this route.

Combined, NMFS estimates that fish salvage for the operations and closure period (MYs 0 to 23+) will: handle approximately 4,374 Chinook salmon, with 1,312 subject to electrofishing, injuring 131, and stranding or killing another 131; and will handle approximately 438 steelhead, 131 of which will be subject to electrofishing, injuring 13, and stranding or killing another 13. These effects will all occur to the EFSFSR Chinook salmon population and the SFSR steelhead population. However, the injuries and mortalities will be spread across different years of mine operation, and will not be realized all at once to a single year class of either species.

2.10.4.7.3. Trap and Haul.

Trap and haul are an alternative that will only be used if fish arrive volitionally at the downstream end of the tunnel, but do not ascend the fishway (see FOMP Appendix C Table 1). Trap and haul could occur each year the EFSFSR tunnel fishway is operational (from MY -1 to 11), but would only occur when deemed necessary to avoid delay of adult passage near or during the spawning period. Migration periods (i.e., Chinook salmon: Jul. 7 – Sep. 15; steelhead: Apr 1. – May 31) will be monitored via fishway video and Passive Integrated Transponders (PIT) tag detections in the fishway. The period that trap and haul would occur coincides with 1-week prior to the spawning period (all species). If necessary, trap and haul frequency each year is only expected to occur 1-2 times per day depending on multi-species presence.

As described in the FOMP (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021), the trap and haul facility has been designed to handle up to 100 Chinook and 100 steelhead annually. Given the short transport distance (i.e., to pool habitat upstream of the tunnel), and if managed correctly, NMFS expects mortality associated with trap and haul to be low (0.1 to 1%) (R. Graves, NMFS Branch Chief, pers. comm., June 2024). If handling up to 100 Chinook or steelhead per year, no more than one adult Chinook salmon or steelhead are expected to be killed by trap and haul in any given year. Because it is not known how effective the tunnel will be at providing unassisted fish passage, it is not clear if this trap and haul mortality will take place, or how frequently. However, if required each year, it will only be required through MY 11, when unimpaired fish passage is restored across the YPP backfill.

2.10.5. Effects to Species - Lemhi

This component of the proposed action could potentially affect SR spring/summer Chinook salmon and SR Basin steelhead. This portion of the project is being implemented with the intent of improving habitat conditions in the Lemhi River subbasin. As described above in the critical habitat effects analysis, anticipated beneficial effects of this project include increased bank stability, enhanced instream habitat for rearing, spawning, and migrating fish, improved floodplain access, and improved riparian conditions. Potential short-term negative effects to fish include disturbance or salvage of individuals during construction, sediment-related impacts, and possible chemical contamination.

If successfully implemented, this proposed project will immediately increase floodplain connectivity to a 7,000-ft. reach of the Lemhi River. These physical changes are anticipated to improve habitat conditions in the project reach (e.g., increased habitat complexity, reduced stream temperatures, etc.), which in turn is likely to generate improvements in distribution of spawning and rearing fish. Considered in its entirety, this proposed project is anticipated to generate a positive response to ESA-listed fish production (e.g., salmon redds) and growth. Since this segment occurs within the primary Lemhi River Chinook salmon production area, adults will likely select the restored reach for spawning within a few years of project completion, and juvenile densities are expected to increase immediately. Steelhead densities are also expected to increase immediately within this stream reach. Although improved fish production and growth may lead to better survival of Lemhi River populations, this action in itself will not likely be enough to restore either population, due to other limiting factors both in and out of the basin.

Perptua is proposing to complete all in-water work during the locally approved in-water work window (July 1 to 3rd week of August). Adult steelhead and steelhead embryos will be absent from the action area at this time and not be exposed to any project impacts. Adult Chinook salmon may be present during the proposed work window and could be affected by the work completed during this time. Chinook spawning is expected to begin in late August.

Reviewing IDFG redd survey data from 2008 to 2023, Chinook salmon redds have periodically been observed in the Lemhi project area, with one found each year in years 2008, 2012, 2015, 2017, 2019, and 2022. The higher value and more frequently used spawning areas in the Lemhi River are found upstream with some additional spawning farther downstream. Juvenile SR Basin steelhead and SR Chinook salmon may be present throughout this portion of the action area. Reach-specific juvenile linear fish density data were provided in the BA from 2015 to 2020, averaging approximately 1,166 Chinook per mi. and approximately 2,916 steelhead per mi.

2.10.5.1. **Fish Salvage**

As previously described, construction of the off-channel habitat will take place in the dry, before being connected to the mainstem Lemhi River. Fish salvage will be required in the mainstem once the cofferdam is in place and water is diverted into the newly constructed off-channel habitat.

Considering the number of fish estimated present in the BA, and the same fish salvage rates used previously for fish handling efforts on the Stibnite portion of the effects analysis, NMFS estimates that fish salvage for the construction period (MY -2) will: exposing approximately 774 Chinook salmon to handling, 224 of which will be subject to electrofishing, injuring 22, and stranding or killing another 22; and will handle approximately 1,867 steelhead, approximately 560 of which will be subject to electrofishing, injuring 56, and stranding or killing another 56

(Table 63). Fish salvage for the Lemhi portion of the proposed action will occur once, in MY -2, impacting a single year class of each species.

These effects will all occur to the Lemhi Chinook salmon Lemhi steelhead populations. Although part of the same ESU, the Lemhi Chinook salmon population is part of the Upper Salmon MPG versus the SFSR MPG impacted by the rest of the SGP. However, the Lemhi steelhead population is not only part of the same ESU, but also part of the Salmon River MPG, the same MPG affected by the SGP.

Table 63. Estimated Number of Juvenile Chinook Salmon and Steelhead Present, Handled, Injured, or Killed from Fish Salvage Efforts at the Lemhi River Restoration Project by Mine Year.

Mine Year	Activities	Est. # Present	# Post-drawdown (50%)	# Seined/ Netted (70%)	# Electro-fished	# Injured (10%)	# Killed (5%)	# Stranded (5%)	Est. Total Mortality (# Killed + Stranded)
Chinook Salmon									
-2	Lemhi R. Fish Salvage	1,494	747	523	224	22	11	11	22
Steelhead									
-2	Lemhi R. Fish Salvage	3,734	1,867	1,307	560	56	28	28	56

2.10.5.2. **Water Quality (Turbidity and Chemical Contamination)**

Juvenile fish will likely be affected by short-term turbidity pulses occurring during installation of temporary cofferdam installation and when introducing water to newly constructed channel segments. Elevated turbidity can cause lethal, sublethal, and behavioral effects in juvenile and adult salmonids depending on the duration and intensity (Newcombe and Jensen 1996). Increased turbidity levels in the action area may result in temporary displacement of all fish from preferred habitat or potential sublethal effects such as gill flaring, coughing, avoidance, and increase in blood sugar levels (Bisson and Bilby 1982; Sigler et al. 1984; Berg and Northcote 1985; Servizi and Martens 1992). However, as previously described in the critical habitat effects analysis, completing excavation in the dry and while implementing a large number of sediment control measures will limit both the frequency and the magnitude of turbidity pulses in the Lemhi River. Turbidity pulses are expected to be short-lived (a few hours) before returning to background levels. Because the Lemhi River is relatively large, the plumes are likely to be confined to one bank and many exposed fish will be able to easily move to adjacent non-turbid habitats, thereby avoiding exposure without harm. Operations will cease should turbidity monitoring show exceedances for more than two monitoring intervals.

The use of heavy machinery adjacent to the stream channel increases the risk for the potential of an accidental spill of fuel, lubricants, hydraulic fluid or similar contaminant into the riparian zone, or directly into the water where they could injure or kill aquatic food organisms, or directly impact ESA-listed species. However, as described in the critical habitat effects analysis, NMFS believes that the proposed fuel spill and equipment leak contingencies and preventions described in the proposed action are sufficient to effectively minimize the risk of negative impacts to ESA-listed fish from toxic contamination, and the risk of chemical contamination is unlikely to occur.

2.10.5.3. **Noise and Disturbance**

Noise and vibration from equipment operation have the potential to disturb or harm ESA-listed Chinook salmon and steelhead. Noise and vibration from heavy equipment operating adjacent to live water may disturb fish in the immediate vicinity causing short-term displacement.

Increased noise caused by construction vehicles will be similar to that described previously for the Stibnite mine site, except there will be no blasting associated with the Lemhi portion of the project. Specialty mufflers will be used for continuously running generators, pumps, and other stationary equipment, and most of the construction activities will occur outside the flowing channel. While construction equipment will be used to construct the channels, other than the placement of the blockage weir, the construction equipment will be used alongside channels in which fish have no access or have been salvaged. As described in the critical habitat effects analysis, the sound level for a typical construction vehicle (such as an excavator) is typically between 80 and 120 dB (FHWA 2024; Bauer and Babich 2006; Mintek 2024; Pal and Mandal 2021; and Hebbal and Kadadevaru 2017). These levels are below those that should impair fish health or behavior. Effects are therefore unlikely, but those that do occur, will be limited to localized behavioral impacts such as movement disruption or area avoidance for Chinook salmon, steelhead. NMFS does not anticipate short-term displacement caused by equipment noise will result in effects of a duration or magnitude that is expected to result in harm of ESA-listed salmon or steelhead.

2.10.6. Summary of Effects to Chinook Salmon and Steelhead

The SGP will affect SR Basin steelhead in the Salmon River MPG, specifically the SFSR population; while effects of the Lemhi Restoration portion of the project will also affect the Lemhi River steelhead population in the Salmon River MPG. Effects to steelhead are most likely to occur in the Lemhi River, SFSR, EFSFSR (downstream from YPP), Johnson Creek, Burntlog Creek, Cabin Creek, Meadow Creek, and Sugar Creek.

The SGP will affect SR Spring/summer Chinook salmon for the SFSR MPG, specifically the SFSR and EFSFSR populations; while the Lemhi Restoration portion of the proposed action will affect the Upper Salmon MPG, specifically the Lemhi River population. Effects to Chinook salmon are most likely to occur in the Lemhi River (Lemhi population); SFSR and Cabin Creek (SFSR population); and the EFSFSR, Johnson Creek, Meadow Creek, Sugar Creek, lower reaches of Burntlog Creek, Trapper Creek, Riordan Creek, and EFMC (EFSFSR population).

With the exception of disturbance and fish sampling effects, all of the action's potential effects to species are directly related to fish responses to the previously described effects on DCH. A summary of the various effects follows.

Chinook salmon and steelhead could potentially be affected by chemical contamination. We concluded that the SGP is unlikely to lead to onsite or transport-related chemical spills that reach designated critical habitats, and EDFs and BMPs for herbicide treatment are expected to ensure that weed treatment does not result in more than sublethal effects. Stormwater discharges from site facilities and roadways during construction and operations will contribute contaminants such as PAHs, tire wear particles, and metals during and immediately following storm events.

Discharge from the sanitary wastewater treatment plant is expected to contain phosphorus, nitrogen, caffeine, pharmaceuticals, personal care products, plasticizers, food additives, flame retardants, microparticles, and per and polyflouryl alkyl substances (PFAS) (Bothfeld 2021). All life stages of fish are expected to be exposed to contaminants originating in stormwater runoff from roadways and maintenance and housing facilities as well as to contaminants in sanitary wastewater treatment plant effluent. These exposures are not expected to cause outright lethality; however, some sublethal effects (e.g., altered behavior) may occur.

Discharge of mine-contact water, either through point sources or nonpoint sources is expected to alter water quality in the project area, with arsenic, antimony, copper, and mercury being the contaminants of greatest concern. These contaminants are expected to elicit sublethal effects (e.g., reduced growth, tissue damage, altered behavior, reduced olfaction) in fish that develop or rear in project area streams through either waterborne or dietary exposures. There is some risk that early life stage fish (incubation through early exogenous feeding) may experience low levels of mortality (<1 percent) if a redd is continually exposed to predicted maximum concentrations of antimony in Meadow Creek during the early years of operation. Similarly, it is possible that early life stage fish may experience some mortality (< 1 percent) if a redd is continually exposed to predicted maximum concentrations of arsenic in the EFSFSR downstream of the YPP during some years in early closure. Because the proposed action is expected to improve arsenic and antimony concentrations in these streams, the risk of mortality of early life stage fish, although not eliminated, will be reduced. The proposed action is expected to cause incremental increases in total mercury in the water column of streams inhabited by salmon and steelhead. These increases could lead to greater bioaccumulation of mercury in fish tissues. Additionally, an incremental increase in organic carbon content in the EFSFSR due to sanitary wastewater effluent could increase in methylation potential in the EFSFSR. Bioaccumulation of mercury in fish tissue is not expected to reach lethal levels; however, some fish may experience sublethal effects. The degree to which these sublethal effects may manifest to reduced survival is unknown.

Considering evidence of successful incubation and early rearing in Meadow Creek and the EFSFSR under current water quality conditions, and considering the SGP will reduce antimony and arsenic concentrations in these streams and copper concentrations will remain substantively the same, we do not believe these potential low levels of mortality or sublethal effects will reduce abundance or productivity in the population throughout the life of the project.

The SGP will alter temperatures of streams within the mine site in perpetuity. Climate change is expected to exacerbate the impacts of the proposed action; however, adherence to the performance objectives relative to stream temperatures will reduce the magnitude of thermal impacts. The degree to which temperatures are altered varies by reach. Steelhead adult migration and spawning are unlikely to be significantly impacted by the SGP since these life stages utilize the habitat in spring and early summer when thermal conditions are not expected to be impacted by the SGP. Juvenile steelhead rearing will be adversely affected by temperature changes, similar to Chinook salmon. All life stages of Chinook salmon will experience negative effects from temperature changes induced by the SGP. Meadow Creek will experience the greatest thermal impacts as a result of the SGP and will experience the greatest change between MYs 23 and 27. This is due to reactivation of the reconstructed Meadow Creek channel atop the TSF.

Meadow Creek will also be further impacted by thermal loading from the wastewater treatment plant discharge, which will exert its greatest effects in MYs 4 through 6.

Meadow Creek temperatures are predicted to reach critical levels upstream of EFMC during MYs 23 through 27, potentially causing issues such as prespawn mortality for adult Chinook salmon and reduced survival for Chinook salmon embryos and both Chinook salmon and steelhead juveniles. Temperatures in Meadow Creek downstream of EFMC will be reduced relative to existing conditions; however, temperatures will still be elevated to a level that may cause sublethal effects in some juvenile steelhead and Chinook salmon. The Meadow Creek reaches that may be used for spawning and rearing represent less than 0.1 percent of the total intrinsic potential habitat for the SFSR steelhead population and less than 1 percent of total intrinsic potential habitat for the EFSFSR Chinook salmon population. When considering: (1) the habitat represents a small fraction of the population production potential; (2) presence of nearby suitable habitat (i.e., EFSFSR, EFMC, downstream reach of Meadow Creek); and (3) only a few individuals are likely to experience lethal effects (e.g., Chinook salmon embryos; or delayed mortality of juvenile salmon or steelhead due to sublethal effects from exposure to elevated temperatures), we do not anticipate population-level impacts as a result of these localized temperature changes.

The proposed action includes measures to reduce or avoid sediment delivery and turbidity impacts, including silt fences, straw waddles, graveling and applying dust control chemicals on roads, limiting equipment stream crossings, operating in dewatered work areas, slowly re-watering work areas, etc. Therefore, turbidity levels are not expected to reach lethal levels, but are expected to reach levels that generally only elicit behavioral responses from salmonids. Vegetation clearing and the construction, use, and maintenance of access roads may increase delivery of sediment to waterways, which may increase sediment deposition. However, with the application of sediment control BMPs and stormwater treatment techniques, the impacts of sediment in surface water, interstitial spaces, etc. as well as the effects to fish, are not predicted to be measurable but not severe. GRAIP-Lite modeling suggests that the combination of restoration efforts to address chronic sources of sediment delivery in the EFMC, planned road closures, and mine site revegetation efforts, should ultimately result in an overall decrease in sediment input into Johnson Creek, Meadow Creek, and the EFSFSR.

The proposed action will reduce flow within and downstream from the project area from the construction through closure stages, and in Sugar Creek and downstream reaches for 100+ years post closure. The flow effects will be very small during the construction phase, will be largest during mine operation, and will be very small during post closure. The flow effects will peak in MY 7, resulting in approximately eight fewer returning SR Spring/Summer Chinook salmon and eight fewer returning SR Basin steelhead. The flow effects will generally decrease from MY 7 through MY 20, and will decrease to approximately 0.4 cfs during post closure. The long-term flow effects will reduce adult returns of SR Spring/summer Chinook salmon and SR Basin steelhead by an average of approximately 0.43 and 0.78, respectively.
Fish passage will be improved across the action area in both the temporary and the long term, allowing increased volitional access to stream segments not occupied since the 1930s. Both Chinook salmon and steelhead will also gain access to new spawning and rearing habitat in the EFSFSR and Meadow Creek as soon as the tunnel is complete in MY -1. Minimum flows,

stipulated in the water rights conditions, should protect fish passage within and downstream from the project area.

The quantity and quality of forage available to salmonids will be reduced in localized areas at the Stibnite site due to channel relocation, changes in water quality and quantity, sedimentation, and clearing of riparian vegetation. The quantity of forage will be reduced downstream of channels that are dewatered or relocated due to the loss of wetted habitat and loss of riparian vegetation. Revegetation efforts are expected to forage reductions in localized areas are temporary or short-term in nature. In addition, flow reductions will also cause reductions in benthic invertebrates as well as reduce the rate of benthic invertebrate drift. In the long-term, given restoration of stream channels and increased channel complexity, we expect the quantity of invertebrates to be similar to, or greater than current conditions. Short-term losses of forage are expected to increase competition among rearing juveniles. Predicted concentrations of arsenic and mercury are expected to impact prey quality. As previously described, arsenic concentrations are predicted to substantially decrease over the life of the project; therefore, we believe accumulation of arsenic in prey tissues will also decrease over time. The proposed action will result in slightly higher mercury concentrations in streams inhabited by salmonids. In addition, the SGP will produce an incremental increase in organic carbon content in the EFSFSR due to domestic sanitary wastewater effluent. Taken together, there will be an increased risk of bioaccumulation of mercury in salmonid prey items. Because mercury methylation is dependent upon a myriad of factors, it is not possible to quantify the potential decrease in prey quality associated with mercury accumulation.

Noise and vibration from blasting and heavy equipment operating adjacent to live water may disturb fish in the immediate vicinity causing short-term displacement. However, equipment operation in and around the SGP is not expected to create levels expected to reach levels known to have generated adverse effects to fish species, and is unlikely to result in injury or death. Similarly, design criteria and BMPs for blasting are expected to be protective of salmon, steelhead, and their redds.

In-water work associated with the proposed action will take place during in-water work windows, in dewatered work areas, and only after fish salvage has been conducted. Most of the project-related fish salvage will occur during the construction period (MY -3 to -1), during construction of stream crossings along the Burntlog Route and in the EFSFSR, channel reconstruction in Meadow Creek and the EFSFSR, and when draining the YPP Lake. Fish salvage will also be required during operations and closure, beginning with stream enhancement in Lower Meadow Creek in MY 3, decommissioning the tunnel around MY 17, and wrapping up around MY 18 when lower Meadow Creek is restored from the toe of the TSF buttress.

For the Stibnite portion of the project, NMFS estimates that fish salvage for the construction period (MYs -3 to -1) will handle approximately 2,729 Chinook salmon, subjecting approximately 819 Chinook salmon to electrofishing, injuring 82, and stranding or killing another 82. It will also handle approximately 24 steelhead, subjecting approximately 8 steelhead to electrofishing, injuring one, and stranding or killing another one. These effects will be split between the SFSR and EFSFSR populations for Chinook and the SFSR population for steelhead, and the effects will be spread across three-year classes for each species.

NMFS estimates that fish salvage for the operations and closure period (MYs 0 to 23+) will: handle approximately 4,374 Chinook salmon, subjecting 1,312 to electrofishing, injuring 131, and stranding or killing another 131; and will handle approximately 438 steelhead, electrofishing 131, injuring 13, and stranding or killing another 13. These effects will all occur to the EFSFSR Chinook salmon population and the SFSR steelhead population. However, the injuries and mortalities will be spread across three different years of mine operation, and will not be realized all at once to a single year class of either species.

For the Lemhi fish salvage efforts, fish will also be salvaged during the construction period (MY -2). NMFS estimates that approximately 774 Chinook salmon will be handled, 224 of which will be subject to electrofishing, injuring 22, and stranding or killing another 22; and approximately 1,867 steelhead will be handled, 560 of which will be subject to electrofishing, injuring 56, and stranding or killing another 56. Fish salvage for this portion of the proposed action will occur once, in MY -2.

For the Lemhi portion of the project, fish salvage could result in the loss of up to two returning steelhead, but is not likely to result in the loss of more than one adult equivalent Chinook salmon. These effects would only occur during a single year.

Trap and haul is an alternative that will only be used if fish arrive volitionally at the downstream end of the tunnel, but do not ascend the fishway. NMFS expects mortality associated with trap and haul to be low (0.1 to 1%), and if up to 100 Chinook or steelhead are handled in this manner each year, no more than one adult Chinook salmon or steelhead are expected to be killed by trap and haul in any given year. These effects would be realized to the EFSFSR population of Chinook salmon and to the SFSR population of steelhead.

For water quality effects, it is not possible to quantify the number of juvenile fish that may suffer sublethal effects to an extent that will reduce their survival; therefore, it is not possible to express water quality effects in terms of fish population productivity or production. However, based on available information population-level abundance or productivity reductions are not expected to occur given predicted water column concentrations. As described above, construction-related effects (e.g., fish salvage, stranding, crushing, etc.) are based on a known area that will be affected, fish population data are available, and the effects of fish salvage are well documented. Therefore, the number of SR spring/summer Chinook salmon and SR Basin steelhead killed by construction/salvage activities, can be calculated. Likewise, because population trend data and streamflow gage are available, the effects of changing streamflow on population productivity can be estimated, which can be used to calculate the effects on fish production. We used natal stream to Lower Granite Dam (LGD) survival and SAR data from the Idaho Anadromous Monitoring Annual Reports (2015-2022) to express construction/salvage and the flow-related effects as the number of juveniles migrating downstream past LGD, and as the number of adult returns. These results are summarized in Tables 64 and 65, and constitute the quantifiable take that will result from the proposed action.

Table 64. Reduction in SR spring/summer Chinook salmon juveniles migrating downstream past Lower Granite Dam (LGD), and reduction in returning adults, due to construction/salvage and flow effects of the proposed action.

Mine Year	Chinook Salmon Production Loses Due to Construction Activities		Chinook Salmon Production Loses Due to Due to Flow Reductions		Total Chinook Salmon Production Losses	
	Juveniles At LGD	Adult Returns	Juveniles At LGD	Adult Returns	Juveniles At LGD	Adult Returns
-3	0.12[1]	0.0012[1]	-	-	0.04	0.0004
-2	-	-	-40.8	-0.39	-40.7	-0.39
-1	-	-	160	1.5	160	1.5
1	-	-	373	3.5	373	3.5
2	20.4	0.19	770	7.3	790	7.5
3	27.0	0.26	556	5.3	583	5.5
4	-	-	600	5.7	600	5.7
5	-	-	267	2.5	267	2.5
6	-	-	574	5.4	574	5.4
7	-	-	829	7.8	829	7.8
8	-	-	796	7.5	796	7.5
9	-	-	495	4.7	495	4.7
10	-	-	515	4.9	515	4.9
11	-	-	556	5.3	556	5.3
12	-	-	467	4.4	467	4.4
13	-	-	502	4.8	502	4.8
14	-	-	362	3.4	362	3.4
15	-	-	275	2.6	275	2.6
16	-	-	164	1.6	164	1.6
17	0.25	0.0024	181	1.7	181	1.7
18	11.1	0.11	187	1.8	198	1.9
19	-	-	142	1.3	142	1.3
20	-	-	140	1.3	140	1.3
20+	-	-	45.9	0.43	45.9	0.43
Ave[2]	2.6	0.02	403	3.8	406	3.8

Notes: 1. Some or all of the take attributed to construction in mine year (MY) -3 could actually occur in MYs -3, -2, or -1. 2. Average for MYs -3 through 20, flow effects described for 20+ will persists for approximately 57 years.

Table 65. Reduction in SRB steelhead juveniles migrating downstream past Lower Granite Dam, and reduction in returning adults, due to construction/salvage and flow effects of the proposed action.

Mine Year	Steelhead Production Loses Due to Construction Activities		Steelhead Production Loses Due To Flow Reductions		Total Steelhead Production Losses	
	Juveniles At LGD	Adult Returns	Juveniles At LGD	Adult Returns	Juveniles At LGD	Adult Returns
-3	0.10[1]	0.0021[1]	-	-	0.03	0.0007
-2	0.03	0.0006	-20.4	-0.42	-20.3	-0.42
-1	0.14	0.0028	61.7	1.3	61.9	1.3
1	-	-	145	3.0	145	3.0
2	-	-	289	6.0	289	6.0
3	3.3	0.07	221	4.6	224	4.7
4	-	-	255	5.3	255	5.3
5	-	-	90.2	1.9	90	1.9
6	-	-	242	5.0	242	5.0
7	-	-	370	7.7	370	7.7
8	-	-	334	6.9	334	6.9
9	-	-	190	3.9	190	3.9
10	-	-	197	4.1	197	4.1
11	-	-	211	4.4	211	4.4
12	-	-	184	3.8	184	3.8
13	-	-	202	4.2	202	4.2
14	-	-	151	3.1	151	3.1
15	-	-	118	2.5	118	2.5
16	-	-	67.1	1.4	67.1	1.4
17	0.18	0.0037	80.0	1.7	80.2	1.7
18	1.3	0.03	82.2	1.7	83.5	1.7
19	-	-	62.3	1.3	62.3	1.3
20	-	-	58.5	1.2	58.5	1.2
20+	-	-	37.5	0.78	37.5	0.78
Ave[2]	0.22	0.005	163	3.4	163	3.4

Note: 1. Some or all of the take attributed to construction in mine year (MY) -3 could actually occur in MYs -3, -2, or -1. 2. Average for MYs -3 through 20, flow effects described for 20+ will persists for approximately 57 years.

2.11. Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation [50 CFR 402.02 and 402.17(a)]. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline versus cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described earlier in the discussion of environmental baseline (Section 2.4).

The Stibnite portion of the action area is primarily managed by the BNF and PNF. A few small parcels of private property and state-administered lands are scattered throughout the action area. Uses on these non-federal lands are not expected to change in the foreseeable future. Activities in the action area include road/trail maintenance performed by non-Federal entities (e.g., Valley County, Idaho State Parks and Recreation) and recreation (e.g., camping, fishing, hiking, etc.). These activities will continue to influence water quality and habitat conditions for anadromous fish in the action area. Riparian and stream corridors have been negatively impacted by roads and trails and these impacts will continue in the future.

The Lemhi River portion of the action area is entirely privately owned, and is currently operating as a ranch. Land use at the ranch has typically revolved around agriculture and grazing. However, the LRLT is negotiating a perpetual conservation easement for the property to ensure the restoration benefits and associated mitigation credits persist for at least the length of the predicted temporal loss for the SGP. If signed, the agreement is expected to limit the property's uses in order to protect its conservation values. In conservation easements, the LRLT typically commits to a perpetual working partnership with all present and future landowners to ensure that the conservation easement is honored, and assists and encourages landowners to engage in conservation focused land management practices.

The impacts of these activities on the current condition of ESA-listed species and designated critical habitats within the action area was described in the Status of the Species, Status of Critical Habitat, and Environmental Baseline sections of this opinion. Current levels of these activities are likely to continue into the future and are unlikely to be substantially more severe than they currently are.

2.12. Integration and Synthesis

The Integration and Synthesis section is the final step assessing the risk that the proposed action poses to species and critical habitat. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.12.1. Critical Habitat

Critical habitat throughout the SR Spring/summer Chinook salmon and SR Basin steelhead designations, ranges from excellent in wilderness areas, to degraded in areas of human activity. Historical mining pollution, sediment delivery from historical logging practices, and degraded riparian conditions from past grazing were major factors in the decline of anadromous fish populations in the action area. Habitat-related limiting factors for recovery of one or more populations within the action area include excess sediment, degraded riparian conditions, passage barriers, and high-water temperatures (NMFS 2017). Climate change is likely to exacerbate several of the ongoing habitat issues, in particular, increased summer temperatures.

The impacts of federal and non-federal land use activities on critical habitat are reflected in the environmental baseline section of this document. Current levels of these uses are likely to continue into the future and are unlikely to be substantially more severe than they currently are. It is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline versus cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline.

The SGP portion of the action is located in headwater tributaries of the SFSR, with proposed mining activities to take place primarily in areas previously disturbed by mining beginning around 1919. Excavation of the YPP began in 1938, and volitional passage of Chinook salmon and steelhead to the EFSFSR and Meadow Creek was eliminated at that time. Additional mining continued at the site in the 1940s, 1970s, 1980s, and 1990s. Mining, milling, smelting, and leaching activities left behind impacts including underground mine workings, multiple open pits, development rock dumps, mill tailings deposits, cyanidation heap leach pads, neutralized (spent) heap leach ore piles, a mill and smelter site, three town sites, camp sites, a washed-out earthen dam (with its associated erosion and downstream sedimentation), haul roads, an abandoned water diversion tunnel, an airstrip, and other disturbances.

Past mining activities have resulted in ongoing releases of contaminants to surface water and groundwater at the site including elevated concentrations of antimony, arsenic, copper, lead, mercury, and cyanide. Most notable are elevated concentrations of arsenic and antimony. Past mining activities have also caused alterations to stream configurations and habitat including formation of the YPP lake, creation of a fish passage barrier immediately upstream of the YPP lake, sediment and tailings deposits, development rock dumps, and channel diversions.

Although not formally identified as a CERCLA Superfund site, some mining operators at the site conducted activities to reduce the release of hazardous substances before 2001. Notable work included diverting Meadow Creek and stabilizing the Bradley Tailings/SODA disposal area, which was completed in 1999. In addition, the USFS began using its CERCLA authorities to address legacy mining impacts at the site since 2001. In 2002, the USFS removed tailings from a pond and soils located at the former smelter stack area, and the Meadow Creek floodplain was reconstructed in the former pond area. In 2004 and 2005, the USFS reconstructed Meadow Creek directly downstream of Smelter Flats. This included the removal of tailings from the channel and depositing this material in a new containment cell located on the SODA. The new channel banks were revegetated with willow plants and the old channel was backfilled and reclaimed. In 2009, the USFS regraded and covered a portion of the remaining tailings at Smelter Flats to prevent further erosion and exposure risk. It is in these restored stream reaches, that surplus hatchery Chinook salmon have periodically been placed by the NPT and IDFG and have successfully spawned and reared for the first time in decades.

Population-specific habitat concerns for the SR Spring/summer Chinook salmon SFSR MPG, which includes the EFSFSR and SFSR populations, include: fine sediment; high stream temperatures; and passage barriers. Limiting factors for the SFSR steelhead population include fine sediment, migration barriers (of which the YPP is identified as a barrier), and degraded riparian conditions, which contribute to elevated stream temperatures. Based on NMFS' most recent 2022 5-Year Reviews (NMFS 2022b; 2022c), recommended actions specific to SR spring/summer Chinook salmon and SR Basin steelhead in the EFSFSR include improving water quality by reclaiming abandoned mine sites such as the Cinnabar Mine; continuing to conduct appropriate road maintenance, road obliteration, road relocation, and road resurfacing; improving riparian conditions in disturbed areas; eliminating passage barriers; restoring floodplains; and improving planning for potential climate change effects by continuing to monitor stream temperature and validate fish distribution in modeled cold water refugia.

Within the Lemhi River portion of the action area, fish habitat has been affected by construction and maintenance of roads, livestock grazing, channelization and straightening of stream channels, conversion of uplands and wetlands into agriculture land, construction and maintenance of water diversions, and extensive water use for irrigated agriculture. Riparian and instream habitat in the mainstem and most tributaries have been affected, with resultant increases in water temperature and sediment; reduced access to riparian wetlands, side channels, and tributary stream habitat; and reduced cold water refugia.

Important activities to advance the recovery of Chinook salmon populations in the Upper Salmon River MPG include: (1) increasing habitat complexity by creating multi-threaded channels; (2) increasing rearing habitat by increasing floodplain connectivity; (3) reducing the W:D, stabilizing streambanks, and improving willow-dominated riparian areas; and (4) maintaining and improving instream flows and tributary connectivity.

Recommended actions for the Lemhi River population of SR Basin steelhead include; (1) improving riparian conditions in disturbed areas; (2) eliminating passage barriers; (3) increasing winter juvenile rearing habitat by increasing floodplain connectivity and complex habitat structure; (4) reducing W:D; (5) increasing low- to zero-velocity pool habitat with cover; (6) providing more side channel and multi-threaded channel habitat; and (7) reducing fine sediment delivery to streams. Specifically, in the upper Lemhi River, recommended actions to improve conditions for steelhead include increasing habitat complexity by creating multi-threaded channels, narrowing the W:D, stabilizing banks, increasing willow-dominated riparian areas, maintaining and improving instream flows, and improving tributary stream connections to the to the mainstem Lemhi River.

Various habitat restoration projects have locally improved riparian and stream channel habitat and improved flow in the lower reaches of some of the tributaries and in portions of the mainstem. These improvements have resulting in localized improvements in salmonid productivity.

Streams within the action area are vitally important to the recovery of anadromous fish species. There are a number of heavily used Chinook salmon and steelhead spawning areas in the action area in Johnson Creek, the EFSFSR, and the Lemhi River. Tributary habitat will likely become even more important for thermal refugia in the face of climate change. Recreation, use of the existing road system, mining, and agriculture are the primary human activities in the action area. Roads from legacy logging remain on the landscape and are a threat to the aquatic ecosystem. In more recent times, wildfire has become the largest disturbance mechanism in the SFSR subbasin. Sediment conditions have generally been on an improving trend, likely due to restoration actions and changes to land management approaches in the action area. Water temperatures are currently warmer than optimal and will likely continue to warm into the future as a result of climate change. Riparian conditions are degraded in areas where roads are located in the RCA and in areas used for mining and agriculture. Although there are some localized areas heavily impacted habitat as described above, habitat conditions in mainstem rivers and tributary streams within the action area are good overall.

At this time, Chinook salmon only access portions of historical habitat upstream of the YPP if adults are outplanted by IDFG and the NPT. The upper reaches of Meadow Creek, above the SODA are not used by adult Chinook salmon and it is unlikely that juvenile Chinook salmon can migrate through the Meadow Creek reach adjacent to the SODA to access upstream habitat. Steelhead, on the other hand, have not had access to these upper reaches since around 1938, locally affecting overall SFSR steelhead spatial structure. Although both species currently have access to the Lemhi River portion of the action area, Chinook and steelhead abundance and productivity are both hampered due to degraded habitat conditions in the mainstem Lemhi River.

Designated critical habitat within the action area will be negatively impacted in the temporary (less than 3 years), short-term (less than 15 years), and long-term (greater than 15 years) timeframes. Negative impacts are associated with: (1) increased sediment delivery, (2) impeded passage; (3) increased water temperatures; (4) contaminant contributions; (5) reduced flows; (6) altered riparian vegetation; (7) reduced floodplain connectivity, and (8) reduced forage. The proposed action will also have some positive impacts including elimination of migration barriers, addressing chronic sources of sediment delivery in EFMC, increased channel complexity, reduced contaminant concentrations, and improved stream temperatures.

Increased sediment delivery to action area streams from activities associated with construction, stream restoration, and overall ground disturbance will have temporary and short-term effects. Increases in fine sediment deposition within stream channels have the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles, potentially impacting spawning/incubation and rearing/feeding life stages of Chinook salmon and steelhead. However, spawning substrates are generally FA in action area streams, and GRAIP-Lite modeling suggests that the amount of sediment delivered to action area streams will decrease in comparison to the baseline condition. With application of proposed sediment control BMPs, the deposition of sediment in action area waters is not expected to degrade habitat in the temporary or short-term; and following closure of the mine, obliteration of access roads, and restoration efforts in the EFMC to address chronic sources of sediment delivery, the proposed action is expected to result in a substantial decrease in annual sediment delivery into Meadow Creek and the EFSFSR. Therefore, we anticipate that spawning and rearing habitat will be negatively impacted in small, localized areas immediately following instream and ground-disturbing activities as a result of turbidity pulses and subsequent sediment deposition.

Passage will be impaired for short periods of time at discrete locations (i.e., where channels are being dewatered to facilitate stream crossing construction or channel relocation), but will be locally restored across most of the SGP portion of the action area as early as MY-1. Construction of the fish tunnel, providing passage to habitat in the EFSFSR and lower Meadow Creek, will restore access to spawning and rearing habitat not volitionally accessible to Chinook salmon or steelhead since 1938. This will locally restore lost spatial structure to the EFSFSR Chinook and SFSR steelhead populations. Similarly, new off-channel habitat created in the Lemhi River portion of the project in MY-2 will immediately restore habitat complexity, locally improving abundance and productivity by creating new migration, spawning, and rearing habitat for both populations Chinook salmon and steelhead in the Lemhi River mainstem.

At the SGP site, stream temperature will be negatively impacted in Meadow Creek and the EFSFSR at different spatial and temporal scales. These impacts are primarily due to channel relocation because it takes years for riparian vegetation to grow to a height that will provide sufficient shade and cooler microclimates adjacent to streams. In addition, draining of the YPP and pit dewatering also impact stream temperature by removing the cooling influences of groundwater recharge. Modeled negative impacts will primarily occur during early closure, following reintroduction of flow into the newly constructed Meadow Creek channel on the TSF. Increased solar radiation along this long reach of Meadow Creek will contribute to warm downstream temperatures. Meadow Creek, below the TSF, will experience the most severe effects. In order to support adult migration and spawning, incubation, and juvenile rearing, we believe 7DADM water temperatures should be below 18, 13, and 16°C, respectively. Some embryo mortality may occur in redds constructed early in the spawning season for up to 32 years due to average weekly maximum temperatures being greater than 13°C in Meadow Creek below the TSF. Similarly, elevated summer temperatures in Meadow Creek during this extended time period may cause rearing juveniles to experience sublethal effects such as reduced growth or increased susceptibility to disease due to average weekly maximum temperatures being greater than 16°C. Over the longer term (beyond MY 52), average weekly maximum temperatures are expected to be below the applicable temperature thresholds for summer and fall. Meadow Creek, below the TSF, represents a small fraction of the overall habitat available for spawning and rearing and juvenile fish and potential spawning adults are able to utilize nearby suitable habitat if conditions in Meadow Creek are not favorable. Temperature impacts will lessen with distance downstream considering colder water contributions from tributary streams. For example, the EFSFSR upstream of Meadow Creek is cold and will dampen the temperature impacts downstream of its confluence with Meadow Creek. In the EFSFSR, below Meadow Creek, there will be a couple of years where summer and fall stream temperatures will be slightly higher than 16°C and 13°C, causing some individual fish to experience sublethal effects and potentially some embryo mortality in redds constructed early in the season. Modeled stream temperatures in the EFSFSR below Sugar Creek will be below protective temperature thresholds and are expected to support spawning, rearing, and migratory life stages of salmon and steelhead. In the Lemhi River, allowing the River to better interact with its floodplain, in addition to revegetation efforts associated with this restoration project, will address local habitat restoration priorities, locally buffering solar inputs along this reach of the Lemhi River.

Removal of the historical, unlined mine waste disposal material will have an early, positive impact on water quality; however, placement of permanent mine facilities (e.g., TSF embankment and buttress, and waste rock backfill into the pits) and discharge of treated mine contact water will negatively impact water quality during operations and early closure. During late closure, mine contact water is not expected to require treatment in perpetuity because seepage from the TSF and TSF embankment and buttress is predicted to meet water quality criteria. The net effect of these actions will be an overall reduction in antimony, arsenic, and copper concentrations in Meadow Creek and the EFSFSR. Yet, concentrations of one or more these contaminants are predicted to be at levels that may cause some mortality of embryos and sublethal effects in adult and juvenile fish. Mercury concentrations will slightly increase in Meadow Creek, EFSFSR, and Sugar Creek. Total mercury contributions from West End Creek will increase by at least an order of magnitude. Mercury concentrations will be above levels that have been associated with sublethal effects caused by bioaccumulation of mercury (NMFS 2014). Whether harmful bioaccumulation occurs in the action area will depend on methylation potential. Overall, although there is risk of harmful effects to individuals from contaminant exposures, we believe the water quality PBF will continue to support spawning, incubation, rearing, and migration for salmon and steelhead.

The proposed action will reduce flow in SR spring/summer Chinook salmon and SR Basin steelhead DCH during MYs -2 – 20, with smaller reductions in MYs 21 – 78. These reductions in flow will reduce average productivity of DCH by 1.1%, 0.007%, and 0.36%, respectively, for DCH in the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead population areas, for MYs -2 – 20. For MYs 21 – 78, flow reductions will reduce productivity of DCH by 0.13%, 0.001% and 0.082%, respectively, in the SFSR Chinook salmon, and in the SFSR steelhead population areas.

The quantity and quality of forage available to salmonids will be reduced in localized areas at the Stibnite site due to channel relocation, changes in water quality and quantity, sedimentation, and clearing of riparian vegetation. The quantity of forage will be reduced downstream of channels that are dewatered or relocated due to the loss of wetted habitat and loss of riparian vegetation. Revegetation efforts are expected to forage reductions in localized areas are temporary or short-term in nature. In addition, flow reductions will also cause reductions in benthic invertebrates as well as reduce the rate of benthic invertebrate drift. In the long-term, given restoration of stream channels and increased channel complexity, we expect the quantity of invertebrates to be similar to, or greater than current conditions. Predicted concentrations of arsenic and mercury are expected to impact prey quality. As previously described, arsenic concentrations are predicted to substantially decrease over the life of the project; therefore, we believe accumulation of arsenic in prey tissues will also decrease over time. The proposed action will result in slightly higher mercury concentrations in streams inhabited by salmonids. In addition, the SGP will produce an incremental increase in organic carbon content in the EFSFSR due to domestic sanitary wastewater effluent. Taken together, there will be an increased risk of bioaccumulation of mercury in salmonid prey items. Because mercury methylation is dependent upon a myriad of factors, it is not possible to quantify the potential decrease in prey quality associated with mercury accumulation.

While the proposed action will negatively impact some PBFs, as summarized above, implementation of the proposed action is expected to positively impact many physical aspects of DCH in the long term, including eliminating chronic sources of sediment delivery, removing fish passage barriers, increasing habitat complexity, restoring floodplain connectivity and function, and improving RCA conditions. These actions directly address the passage barrier, elevated sediment, and degraded riparian condition limiting factors identified in the recovery plans.

The Stibnite portion of the project will address the road maintenance, road resurfacing, and elimination of passage barriers called for in NMFS' most recent 5-Year Review (NMFS 2022c) for SR Basin steelhead in the EFSFSR, benefits realized during the pre-construction phase of the SGP. Other recommendations, including improving water quality by reclaiming abandoned mine sites; access road obliteration; improving riparian conditions in disturbed areas; and restoring floodplains will begin early in the pre-construction phase but will not be fully realized until closure and restoration elements of the project have been fully implemented. The SGP will similarly address population-specific habitat concerns (i.e., fine sediment, water quality, and passage barriers) for the SR Spring/summer Chinook salmon SFSR MPG, specifically the EFSFSR and SFSR populations. Addressing chronic sources of chemical contamination and fine sediment, while restoring historical access to complex, instream habitat where streams interact with a fully functioning floodplain, is expected to lead to localized, long-term improvements to spawning, incubation, and rearing habitat for the EFSFSR Chinook salmon population and the SFSR populations of Chinook salmon and steelhead. These improvements will locally benefit DCH PBFs long term, but will not be at the scale to fully address habitat issues and threats at the designation scale.

In the Lemhi River, the restoration project has been designed to specifically address degraded habitat conditions, limiting factors, and threats identified for this stream reach. This element of the proposed action will reestablish connectivity with the river's floodplain, creating multi-thread channels, reducing width-to-depth ratios, stabilizing streambanks, and will include a vegetation plan to restore riparian habitat in the long term. Floodplain connectivity will be restored across a 7,000 linear ft. section of the Lemhi River, locally restoring DCH in this stream reach by MY -1. Although these activities will not address these limiting factors and threats to DCH at the designation scale, they will locally benefit DCH for Lemhi River populations by improving habitat conditions locally at the river reach scale.

The SGP project will occur at a previously disturbed mine site where anadromous fish access has been anthropogenically blocked for almost 80 years. The upper EFSFSR subwatershed is currently degraded as a result of past mining activities. The proposed action will both positively and negatively impact PBFs of DCH as previously described, and the Lemhi restoration effort was incorporated into the proposed action as a means for offsetting the unavoidable adverse effects that will occur in the upper EFSFSR. When considering the status of the critical habitat, environmental baseline, effects of the action, and cumulative effects as discussed above, NMFS concludes that implementation of this proposed action will not appreciably diminish the value of DCH as a whole for the conservation of both species.

2.12.2. Species

As described in Section 2.2, individuals belonging to two MPGs (i.e., SFSR and Upper Salmon) and three populations (i.e., SFSR, EFSFSR, and Lemhi) within the SR Spring/summer Chinook salmon ESU; and individuals belonging to two populations (i.e., SFSR and Lemhi) within the Salmon River MPG of the SR Basin steelhead DPS use the action area to fully complete the migration, spawning, and rearing parts of their life cycle. The SR Spring/summer Chinook salmon ESU is currently at a high risk of extinction. Similarly, the SR Basin steelhead DPS is not currently meeting its VSP criteria and is at a moderate risk of extinction. Since the last 5-year review, there has been a substantial downturn in adult abundance for both species. This downturn is thought to be driven primarily by marine environmental conditions and a decline in ocean productivity. Very large improvements in abundance will be needed to bridge the gap between the current status and proposed status for recovery for many of the ESU/DPS component populations.

The regional tributary habitat strategy set forth in the final recovery plans (NMFS 2017) is to protect, conserve, and restore natural ecological processes at the watershed scale that support population viability. Ongoing actions to support recovery of these two species include, but are not limited to, conserving existing high-quality habitat and restoring degraded (and maintaining properly functioning) upland processes to minimize unnatural rates of erosion and runoff. Natal habitat recovery strategies and actions for populations within the action area include: (1) reduce road-related impacts (e.g., sediment delivery) on streams; (2) inventory stream crossings and replace any that are barriers to passage; (3) reduce floodplain and channel encroachment; and (4) restore floodplain function.

The environmental baseline incorporates effects of restoration actions implemented to date. It also reflects impacts that have occurred as a result of land management and implementation of various programmatic activities. In addition, impacts from existing state and private actions are reflected in the environmental baseline. Cumulative effects from state and private actions in the action area are expected to continue into the future and are unlikely to be substantially more severe than they currently are. The environmental baseline also incorporates the impacts of climate change on both the species and the habitat they depend on. Several of the ongoing habitat issues that impact VSP parameters, in particular, increased summer temperatures and decreased summer flows, will continue to be affected by climate change.

All three populations of SR spring/summer Chinook salmon occupying the action area are at a high risk of extinction. NMFS' preferred recovery scenario for the SR spring/summer Chinook salmon ESU targets the SFSR and Lemhi populations to achieve viable status, and the EFSFSR population to be maintained. Both populations of SR Basin steelhead are at a moderate risk of extinction. The preferred recovery scenario for the SR Basin steelhead DPS targets both the SFSR population and the Lemhi population be viable. Within the action area, the most heavily used Chinook salmon and steelhead spawning/rearing habitat occurs in Johnson Creek, Burntlog Creek, the EFSFSR, Sugar Creek, and the Lemhi River. Meadow Creek is also used for Chinook spawning and rearing, but only in years in which surplus hatchery fish are stocked above YPP Lake. SR Basin steelhead have not had access to historical spawning and rearing in the upper EFSFSR or Meadow Creek since around 1938. In order to achieve these preferred recovery scenario goals, it is vitally important to preserve habitat conditions that are FA and improve habitat conditions that are FAR or FUR.

Implementation of the Stibnite portion of the proposed action is expected to adversely impact Chinook salmon and steelhead as a result of fish salvage efforts and impacts to their habitat (i.e., reduced water quantity, chemical contamination, increased water temperature, increased sediment delivery, and reduced forage. It will also improve fish habitat in the long term, through localized improvements to water quality, chronic sediment delivery, fish passage, floodplain connectivity, riparian vegetation, and instream habitat complexity.

The proposed action includes construction activities, with fish salvage employed to reduce effects on ESA listed fishes. The effects associated with construction, and the resultant fish salvage, will lead to mortality of ESA-listed salmonids in the action area. Given the inwater work window and application of the NMFS electrofishing guidelines under which electrofishing will not be done in the vicinity of redds or spawning adults, these effects will be on rearing juveniles. Additionally, these effects will be confined to the project area and will mostly occur in MYs – 3 to 3. Based on our estimates of the number of juvenile fish that will be killed and considering these effects will be spread across multiple years, fish salvage is unlikely to reduce the number of returning adult SR spring/summer Chinook salmon or SR Basin steelhead.

Flow-related effects are likely to impact fish production and population productivity while the mine is in operation, with smaller impacts for approximately 57 years after mining ceases. The proposed action will reduce flow in the occupied SR spring/summer Chinook salmon and SR Basin steelhead habitat for MYs -2 - 20, with smaller reductions during MYs 21 – 78. These reductions in flow will reduce productivity by an average of 1.1%, 0.007%, and 0.36%, respectively, for the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead populations, for MYs -2 – 20. From MYs 21 - 78, the reduction in flow will reduce productivity of the EFSFSR Chinook salmon, SFSR Chinook salmon, and in the SFSR steelhead populations by 0.13%, 0.001% and 0.082%, respectively.

Discharge of mine-contact water, either through point sources or nonpoint sources is expected to alter water quality in the project area, with arsenic, antimony, copper, and mercury being the contaminants of greatest concern. These contaminants are expected to elicit sublethal effects (e.g., reduced growth, tissue damage, altered behavior, reduced olfaction) in fish that develop or rear in project area streams through either waterborne or dietary exposures. There is some risk that early life stage fish (incubation through early exogenous feeding) may experience low levels of mortality (<1 percent) if a redd is continually exposed to predicted maximum concentrations of antimony in Meadow Creek during the early years of operation. Similarly, it is possible that early life stage fish may experience some mortality (< 1 percent) if a redd is continually exposed to predicted maximum concentrations of arsenic in the EFSFSR downstream of the YPP during some years in early closure. It is reasonable to conclude that implementation of the proposed action is reducing the risk of mortality of early life stage fish (though not eliminating that risk) because arsenic and antimony concentrations will be reduced relative to baseline conditions. The proposed action is expected to cause incremental increases in total mercury in the water column of streams inhabited by salmon and steelhead. These increases could lead to greater bioaccumulation of mercury in fish tissues. Additionally, an incremental increase in organic carbon content in the EFSFSR due to sanitary wastewater effluent could increase in methylation potential in the EFSFSR. Bioaccumulation of mercury in fish tissue is not expected to reach lethal levels; however, some fish may experience sublethal effects. The degree to which these sublethal effects may manifest to reduced survival is unknown. Baseline data (presence of redds, juvenile Chinook salmon, and juvenile steelhead) in the EFSFSR, Sugar Creek, and Meadow Creek (Chinook salmon only due to outplanting efforts) indicates spawning, rearing, and migration currently occurs in streams with elevated arsenic and detectable, and in some cases elevated, concentrations of total mercury. When considering this, coupled with the projected incremental increases in mercury in habitat that is or will be occupied and the predicted decreases in antimony and arsenic concentrations in these streams, we do not believe these potential low levels of mortality or sublethal effects will reduce abundance or productivity in the population throughout the life of the project.

Stream temperature will be negatively impacted in Meadow Creek and the EFSFSR at different spatial and temporal scales. In order to support adult migration and spawning, incubation, and juvenile rearing, we believe 7DADM water temperatures should be below 18, 13, and 16°C, respectively. These temperature thresholds are predicted to be exceeded in Meadow Creek and the EFSFSR above the Sugar Creek confluence. Meadow Creek will experience the greatest temperature increase for the greatest amount of time. In this reach (from its mouth to the TSF), anadromous salmonids may be impacted as follows: (1) some Chinook salmon embryo mortality is expected to occur in redds that are constructed early in the season; (2) some adult Chinook salmon, may experience pre-spawn mortality or reduced gamete viability if they hold in water temperatures exceeding 18°C; (3) and some rearing juvenile Chinook salmon and steelhead may experience sublethal effects such as reduced growth or increased disease risk. In the EFSFSR, there may be a few years where some Chinook salmon embryo mortality occurs in redds that are constructed early in the season, and some rearing juvenile Chinook salmon and steelhead may experience sublethal effects. Taken together, these reaches of Meadow Creek and the EFSFSR represent a small fraction of the overall habitat available for spawning and rearing. Both juvenile and adult fish may seek alternative, nearby habitats with more suitable thermal conditions. For these reasons, any impacts to individuals from exposure to elevated temperatures are not expected to cause population-level reductions in productivity nor will it diminish spatial structure.

Sediment generating activities will include frequent, sporadic turbidity effects to water quality across action area streams, with those increases occurring most frequently occurring during runoff events and resulting in localized deposition of fine sediment in action area stream channels. Although these effects will likely temporarily affect fish behavior (particularly during runoff events), they are unlikely to reach levels severe enough to result in harm. Localized deposition of fine sediment in action area streams has the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles, potentially impacting spawning/incubation and rearing/feeding life stages of Chinook salmon and steelhead. However, spawning substrates are generally FA in action area streams, and GRAIP-Lite modeling suggests that the amount of sediment delivered to action area streams will decrease in comparison to the baseline condition. With application of proposed sediment control BMPs, the deposition of sediment in action area waters is predicted to be measurable but not severe. It is not expected to affect spawning success in the temporary or short-term; and following closure of the mine, obliteration of access roads, and restoration efforts in the EFMC to address chronic sources of sediment delivery, the proposed action is expected to result in a substantial decrease in improved spawning conditions in Meadow Creek and the EFSFSR.

The quantity and quality of forage available to salmonids will be reduced in localized areas at the Stibnite site due to channel relocation, changes in water quality and quantity, and clearing of riparian vegetation. The quantity of forage will be reduced downstream of channels that are dewatered or relocated due to the loss of wetted habitat and loss of riparian vegetation. Revegetation efforts are expected to forage reductions in localized areas are temporary or short-term in nature. In addition, flow reductions will also cause reductions in benthic invertebrates as well as reduce the rate of benthic invertebrate drift. In the long-term, given restoration of stream channels and increased channel complexity, we expect the quantity of invertebrates to be similar to, or greater than current conditions. Short-term losses of forage are expected to increase competition among rearing juveniles. Predicted concentrations of arsenic and mercury are expected to impact prey quality. As previously described, arsenic concentrations are predicted to substantially decrease over the life of the project; therefore, we believe accumulation of arsenic in prey tissues will also decrease over time. The proposed action will result in slightly higher mercury concentrations in streams inhabited by salmonids. In addition, the SGP will produce an incremental increase in organic carbon content in the EFSFSR due to domestic sanitary wastewater effluent. Taken together, there will be an increased risk of bioaccumulation of mercury in salmonid prey items. Because mercury methylation is dependent upon a myriad of factors, it is not possible to quantify the potential decrease in prey quality associated with mercury accumulation.

The Lemhi Restoration portion of the proposed action is proposed as compensatory mitigation for stream and wetland impacts of the SGP, with the intent of improving habitat conditions in the Lemhi River basin. The project will enhance habitat conditions across approximately 7,000 ft. of the Lemhi River channel; increasing habitat quality and complexity; reducing channel W:D; enhancing floodplain connectivity; improving instream structure and velocity; increasing pool quantity and complexity; facilitating surface/groundwater interchange for temperature moderation; providing instream cover for fish; and establishing a riparian corridor for shade, cover, and bank stability. These largely beneficial effects will begin to take effect by MY-2, benefitting the Lemhi populations of SR spring/summer Chinook and SR Basin steelhead before active mining begins at the SGP. The potential adverse effects of this element of the proposed action on ESA-listed salmon and steelhead and their critical habitat can be broadly categorized into effects from fish salvage, and temporary habitat-related effects to water quality (i.e., turbidity, chemical contamination) and habitat (i.e., sedimentation of spawning gravels). In the long term, reconnecting the Lemhi River to its floodplain is expected to improve habitat complexity and will improve habitat conditions across the reach, likely leading to localized improvements in Lemhi River Chinook salmon and steelhead population abundance and productivity.

NMFS expects that Perpetua and their and contractors will implement the proposed action as proposed, with full adherence to the design criteria and the EDFs. NMFS also expects that we will be involved in the IARB process to review project elements with potential effects to ESA-listed species or critical habitat to ensure that: (1) no changes to the proposed action occur that will result in effects not previously considered in the BA or this opinion; and (2) the assumptions underlying the analysis of this opinion remain valid. Given this, we expect that adverse effects to ESA-listed species will be avoided or minimized and that unavoidable adverse effects are appropriately addressed. As described in the Effects of the Action (Section 2.5), potential impacts to water quality, food/forage, sedimentation, and effects from dewatering and fish handling/salvage all have the potential to harm individual SR Spring/summer Chinook salmon and SR Basin steelhead. The majority of these effects are expected to be sublethal. A few individual embryos may experience mortality if exposed to elevated concentrations of arsenic or antimony or if redds are constructed early in the spawning season when temperatures are elevated. Mortality within the project area is expected to primarily occur as a result of fish salvage activities during dewatering events associated with stream crossing structures and stream channel restoration efforts.

NMFS quantified the effects of flow alterations and fish salvage. These quantified effects, expressed as adult returns, will range from slightly positive during MY 2 (due to increased flow from discharge of treated contact water) to a reduction of approximately eight returning adult SR spring/summer Chinook salmon, and eight returning adult SR Basin steelhead, in MY 7. After MY 7, the effects steadily decrease to approximately one returning adult, for each species, in MY 19 and 20. After mine closure, long-term effects on flow, and fish, will result from the filling of the West End Pit Lake, and will reduce adult returns by less than one SR Snake River Chinook salmon and one SRB steelhead, per year.

Should trap and haul become necessary, NMFS expects that up to one more adult Chinook salmon and steelhead is expected to be killed annually through this process. These losses would most likely occur from MY -1 to MY 11, years in which the tunnel will be in operation.

For the Lemhi portion of the project, fish salvage could result in the loss of up to two returning steelhead, but is not likely to result in the loss of more than one adult equivalent Chinook salmon. These effects would occur during one year only.

We were unable to estimate the number of juveniles that might be affected by turbidity, or from disturbance associated with blasting or heavy equipment operation. However, given proposed EDFs and BMPs, we do not expect any more than behavioral responses, and do not otherwise expect any harm to ESA-listed salmonids. Other than when installing bypass structures, no inwater work will occur, with inchannel work occurring only in dewatered work areas. Turbidity pulses and plumes will occur as a result of inchannel work; road construction, reconstruction, and use; and mine and exploratory operations. But, erosion control BMPs and turbidity monitoring are expected to ensure that turbidity levels do not reach a magnitude or persist long enough to result in more than behavioral responses by salmonids. The magnitude of sediment increases and its impact on fish spawning, incubation, rearing is also difficult to predict; however, implementation of erosion control EDFs should effectively minimize the amount of sediment being delivered, and should improve conditions as project area vegetation becomes reestablished and chronic sediment sources are addressed. Considering the minimum amount of fish handling that will occur, spread across time and populations, and considering the short duration of adverse effects associated with elevated sediment delivery, we do not expect climate change to amplify any of these adverse effects. Juvenile fish passage will be temporarily impaired in discrete locations; however, long-standing fish barriers will be removed, which should locally improve overall conditions and population spatial structure. We are unable to estimate the number of juvenile salmonids that may experience sublethal effects as a result of waterborne or dietary exposures to contaminants or elevated temperatures. Implementation of the EDFs, monitoring water quality and biological conditions, and adaptively managing the project in response to monitoring data will avoid and minimize future reductions of water quality and associated adverse effects to ESA-listed species.

Sediment introduced into and subsequently deposited in the EFSFSR, Johnson Creek, their tributaries; or the Lemhi River, as a result of project implementation, is not expected to reduce the current productivity of the EFSFSR, SFSR, and Lemhi River Chinook salmon populations; or the SFSR and Lemhi River steelhead populations. This is primarily because: (1) turbidity pulses are expected to be short-lived (lasting only a matter of minutes to hours) and small in both magnitude and their downstream extent; (2) sediment will not be delivered to streams simultaneously, rather sediment will be delivered over discrete periods of time (e.g., during rainstorms following ground-disturbing activities or during channel re-watering; and (3) sources of sediment will be dispersed along the stream network so not all of the sediment will end up in a single location within the stream channel. Our assessment assumes the USFS, USACE, and any applicant or contractor will properly implement appropriate EDFs and BMPs during project implementation.

The effects of construction, fish salvage, and reduced flow, due to the proposed action, will result in the annual loss of one to eight adult EFSFSR Chinook salmon equivalents and one to eight adult SFSR steelhead equivalents, during MY -1 through 20. These losses will reduce abundance and productivity of these two populations by 1.1% and 0.36%, slightly increasing extinction risk through MY 20. Facilitating passage past the YPP will slightly improve spatial structure, slightly reducing risk for both populations. Overall, the proposed action will have a negligible effect on extinction risk of the EFSFSR Chinook salmon and the SFSR steelhead populations during MY -1 through 20. After MY 20, average annual losses will be less than one half of a returning adult EFSFSR Chinook salmon and less than one returning adult SFSR steelhead, which will not appreciably reduce population abundance or productivity of either population. The flow effects of the proposed action will reduce size and productivity of the SFSR Chinook salmon population by less than 0.01% during MY -1 through 20, and by less than 0.0001% after MY 20, which will not appreciably increase the extinction risk for that population. Because these impacts will not appreciably increase the extinction risk for the affected populations, the viabilities of the MPGs and the ESU/DPS are not likely to be appreciably reduced.

The SGP project will occur at a previously disturbed mine site where anadromous fish access has been anthropogenically blocked for almost 80 years. The proposed action will locally improve spatial structure, abundance, and productivity by improving habitat in the mine area footprint, restoring floodplain connectivity, habitat complexity, improving water quality, and restoring access to new spawning and rearing habitat for both Chinook salmon and steelhead. The Lemhi restoration effort incorporated into the proposed action as a means for offsetting the unavoidable adverse effects and that will occur in the upper EFSFSR, further benefitting abundance and productivity of the SR spring/summer Chinook salmon ESU, and the Salmon River MPG of the SR Basin steelhead DPS. When considering the status of the species, and adding in the environmental baseline, and cumulative effects, implementation of the proposed action will not appreciably reduce the likelihood of survival and recovery of SR Spring/summer Chinook salmon or SR Basin steelhead.

2.13. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of SR Spring/summer Chinook salmon, SR Basin steelhead, or destroy or adversely modify their designated critical habitat.

2.14. Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Harass" is further defined by interim guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns, which include but are not limited to, breeding, feeding, or sheltering." "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

2.15. Amount or Extent of Take

The proposed action is reasonably certain to result in incidental take of ESA-listed species. NMFS is reasonably certain the incidental take described here will occur because adult and juvenile Chinook salmon and steelhead will be present in the action area during project implementation, and those fish will be exposed to effects of the proposed action. In some instances, NMFS is able to quantify the amount of take; however, where available information precludes our ability to quantify take, we use surrogates to describe the incidental take pursuant to 50 CFR 402.14 (I). The surrogates used to describe incidental take are explained in sections 2.1.5.1 through 2.5.1.3.

2.15.1. Construction and Fish Salvage

In this opinion, NMFS determined that incidental take is reasonably certain to occur due to construction and associated fish salvage activities. Disturbance associated with equipment operation (i.e., from noise), blasting and drilling (i.e., from noise and vibration) is likely to harass rearing juvenile salmonids (i.e., annoying juveniles sufficiently to disrupt normal behavioral patterns). As described in the species effects analysis, NMFS is unable to quantify the take associated with disturbance due to equipment operation in close proximity to action area streams. It is not possible to tell whether fish are present and have been disturbed, and it is not possible to determine how many, if any, juvenile fish are subject to predation as a result of these activities.

Equipment operation will produce noise and vibration at sufficient intensities to cause behavioral modifications. The degree that juvenile salmon and steelhead will be harassed is directly correlated with both the amount of work done and the proximity of that work to streams. For these reasons, we are not able to identify an amount, extent, or surrogate of take associated with general equipment operation. However, we have defined a surrogate for blasting and drilling. When working alongside streams or lakes occupied by ESA-listed Chinook salmon or steelhead, NMFS will consider take exceeded if: (1) blasting occurs closer than 239-ft. on 20-ft. benches, or closer than 419 ft. on 40-ft. benches; or (2) if drilling occurs closer than 100 ft. Although these surrogates could be considered coextensive with the proposed action, they function as effective reinitiation triggers because our analysis is based upon impacts resulting from such measures, they can be readily monitored, and thus will serve as a regular check on the proposed action.

Similarly, take caused by the increased sediment delivery into action area streams cannot be accurately quantified as number of fish for a variety of reasons. The distribution and abundance of fish within the action area is dependent upon a number of environmental factors that vary over time and space, potentially including exposure of both juvenile and adult salmon and steelhead to resulting turbidity plumes. It is not possible to monitor the number of fish that may be displaced by turbidity plumes. In these circumstances, NMFS can use the causal link established between the activity and the likely changes in habitat conditions affecting the listed species to describe the extent of take as a numerical level of habitat disturbance.

The best available indicators for the extent of take caused by increased sediment delivery is the magnitude and extent of turbidity plumes in the receiving waters during project implementation. The magnitude and extent of the turbidity plume is proportional to the amount of harm that the proposed action is likely to cause through short-term degradation of water quality and instream habitat. Sediment levels are expected to rapidly peak and then steadily decrease in intensity within 1,000 feet downstream of construction areas that are immediately adjacent to or within the stream channel. Although we recognize the limitations of using turbidity as a surrogate for suspended sediment, monitoring for turbidity is a reasonable and cost-effective measure that can be readily implemented in the field. Most of the time turbidity measurements take 30 seconds, can be done on site, and therefore allow for rapid adjustments in project activities if turbidity approaches unacceptable levels. For these reasons, we have chosen turbidity as a surrogate for incidental take from sediment-related effects.

NMFS will consider the extent of take exceeded if turbidity readings, taken approximately 1,000 feet downstream of inwater work areas, reveal turbidity concentrations greater than 50 NTU above background for more than 90 minutes, or 100 NTUs instantaneously. Literature reviewed in Rowe et al. (2003) indicated that NTU levels below 50 generally elicit only behavioral responses from salmonids thereby making this a suitable surrogate for sublethal incidental take monitoring. This take indicator functions as effective reinitiation trigger because it can be readily monitored, and thus will serve as a regular check on the proposed action.

NMFS estimated a quantity of fish potentially handled/harassed during fish salvage. NMFS will consider the amount of take exceeded if:

- At Stibnite, during the construction phase of the project (MYs -3 to -1), more than 819 juvenile Chinook salmon captured via electrofishing, or more than 82 juveniles are killed; or more than 8 juvenile steelhead are captured via electrofishing, or more than one juvenile steelhead is killed.
- At Stibnite, during the operations and closure period (MYs 0 to 23+), more than 1,312 juvenile Chinook salmon are captured via electrofishing, or more than 131 juveniles are killed.
- At Lemhi, if more than 224 juvenile Chinook salmon are captured via electrofishing, or more than 22 juveniles are killed; or more than 560 juvenile steelhead are captured via electrofishing, or more than 56 juveniles are killed.

NMFS will also consider the extent of take exceeded if trap and haul activities handle more than 100 adult Chinook salmon or 100 adult steelhead in any given year, or if more than one of either species is killed by trap and haul in any given year. These take indicators function as effective reinitiation triggers because they can be readily monitored, and thus will serve as a regular check on the proposed action.

2.15.2. Water Diversion, Use, Management, and Drainage Area Reduction

Water diversion, water use and management, and long-term reduction in drainage area available for streamflow is reasonably certain to result in incidental take of ESA-listed species. NMFS determined that incidental take is reasonably certain to occur as follows: (1) the proposed action will reduce flow, within the project area in Meadow Creek, Sugar Creek, and the EFSFSR; and downstream from the project area in the EFSFSR and SFSR; (2) the affected habitat is occupied by SR spring/summer Chinook salmon and SR Basin steelhead; (3) reducing flow in occupied SR spring/summer Chinook salmon and SR Basin steelhead habitat will reduce growth and survival of rearing Chinook salmon and steelhead; (4) juvenile SR spring/summer Chinook salmon and SR Basin steelhead will enter the EFSFSR diversion and will have to exit via the juvenile bypass system, which will delay downstream migration and increase mortality. The take exempted by this ITS is the loss of SR spring/summer Chinook salmon and SR Basin steelhead from these circumstances. NMFS has quantified an average annual reduction in production, due to the proposed action, of 416 Chinook salmon outmigrants and 168 steelhead outmigrants, for MYs -2 through MY 20, and 46 Chinook salmon outmigrants and 38 steelhead migrants after MY 20. However, changes in production cannot be monitored sufficiently to ensure that amount and extent of take is not exceeded. This is because: (1) production estimates for SR spring/summer Chinook salmon and SR Basin steelhead are based on redd count data and LGD adult return data, respectively, and therefore lack the precision needed to monitor changes of the scale anticipated due to the proposed action; (2) population density of SR spring/summer Chinook salmon and SR Basin steelhead varies greatly from year to year; (3) fish harmed due to increased environmental stress caused by the reductions in flow would be difficult to distinguish from fish harmed due to environmental stress that normally occurs or that is caused by baseline actions; and (4) counting juvenile fishes entering or exiting water diversions is not practicable. Even if take that occurred within the action area could be adequately quantified, monitoring total take due to the proposed actions would still not be feasible because some mortality due to effects of the proposed action in the action area is likely to occur during the downstream migration or in the estuary. This is because fish growth is related to streamflow (Harvey et al. 2006; Davidson et al. 2010), so reducing streamflow in rearing habitat likely reduces the size of downstream migrating smolts. Smaller smolts have higher mortality outside of the natal tributaries (Zabel and Achord 2004), which results in lower smolt-to-adult return rates.

When take cannot be adequately quantified, NMFS describes the extent of take through the use of surrogate measures of take that would define the limits anticipated in this Opinion. As established above in Section 2.10.1.2, net reduction of streamflow due to water diversion, water use and management, and reduction in drainage area, will result in most of the take due to the proposed action; and a small amount of take will occur due to entrainment in the EFSFSR surface water diversion. Presence and condition of the EFSFSR diversion fish screen is relatively easy to ascertain and, as quantifiable habitat indicators, the amount of water flowing in Meadow Creek, Sugar Creek, and the EFSFSR; the net effect of the proposed action on flow (i.e., the amount diverted minus the amount released); and the reduction in drainage area can be accurately measured. In this case, the extent of take will be described as: (1) the amount of water flowing in the EFSFSR at the POD; (2) the amount of water flowing in Meadow Creek from the confluence of Meadow Creek and Blowout Creek to the confluence of Meadow Creek and the EFSFSR; (3) the amount of water flowing in the EFSFSR below the confluence of the EFSFSR and Sugar Creek; (4) the net effect of water diversion and water discharge on streamflow; and (5) the size of the WEP Lake drainage area. The extent of take exempted by this ITS would be exceeded if: (1) flow is less than 3.0 cfs in Meadow Creek from the confluence of Meadow Creek and Blowout Creek to the confluence of Meadow Creek and the EFSFSR when flow is diverted from any of the groundwater wells in Section 15, Township 18N, Range 9E; (2) water is diverted from the EFSFSR surface water diversion when flow at that POD is less than 7.25 cfs from June 30 to September 30, or is less than 5.0 cfs from October 1 to June 29; (3) the average monthly net flow reduction (diversion – discharge) exceeds the amounts in columns 2-5 of Table 60 for any month during MYs -1 through 20; (4) net flow reduction in the EFSFSR exceeds 20% of flow present below the confluence with Sugar Creek, when unimpaired flow in the EFSFSR below the confluence with Sugar Creek is less than 25 cfs; (5) the drainage area of the WEP Lake exceeds 185 acres; (6) the EFSFSR surface water diversion is operated without a fish screen and bypass system that meets criteria in NMFS 2022a.

2.15.3. Water Quality

The new point and nonpoint sources of contaminants will impact water quality (contaminant concentrations and temperature) to a degree that is reasonably certain to result in incidental take of ESA-listed species. NMFS determined that incidental take is reasonably certain to occur as follows: (1) the proposed action will alter water quality within the mine site area in Meadow Creek, Sugar Creek, and the EFSFSR; and downstream from the mine site in the EFSFSR; (2) the affected habitat is or will be occupied by SR spring/summer Chinook salmon and SR Basin steelhead; (3) concentrations of copper, arsenic, mercury, and contaminant mixtures will be at levels associated with sublethal adverse effects for salmon and steelhead including, but not limited to: avoidance (adults and juveniles); reduced growth (juveniles); reduced ability to detect and avoid predators or capture prey; (4) mercury loads in West End Creek will substantially increase during operations, adding to the mercury load in Sugar Creek and the EFSFSR, which are already mercury-impaired; (5) stream temperatures are predicted to reach levels that could cause adult Chinook salmon to suffer pre-spawn mortality, reduced gamete viability, delayed or blocked migration; reduced survival of incubating Chinook salmon embryos; and reduced growth of juvenile Chinook salmon and steelhead rearing in Meadow Creek and the EFSFSR.

NMFS is unable to quantify the amount of take that might occur as a result of these water quality changes because: (1) future conditions are predictions based upon multiple models, each of which has its own series of predictions; (2) the number of ESA-listed fish that spawn or rear in these areas is unknown and is expected to vary annually; (3) the actual exposure of ESA-listed fish to harmful concentrations of chemicals, and the duration of such exposure, is unpredictable; and (4) there is a large degree of variability in effects that could occur if fish were exposed to chemical concentrations, depending on the magnitude and duration of exposure, condition of exposed fish, life stage of fish, and presence of other stressors (e.g., increased temperature, reduced dissolved oxygen, pathogens). Instead of quantifying the amount of take, NMFS has elected to use surrogates for take that consider the extent of potentially occupied habitat where the proposed action may cause increases in chemical concentrations or stream temperatures to levels that are harmful to ESA-listed species or where biological responses indicate take is occurring that otherwise can't be detected by water column concentrations of selected, individual contaminants.

The best available indicators for the extent of take are the magnitude and extent of water quality impacts in the receiving water and associated biological changes (i.e., fish tissue concentrations and macroinvertebrate community composition) during construction, operations, closure, and post-closure. NMFS will use magnitude, frequency, and duration of chemical concentrations and instream temperatures at specific monitoring locations as the basis for our take surrogate related to water quality impacts. In addition, because the harmful effects of individual contaminants or contaminant mixtures are indirectly experienced through bioaccumulation or alterations in the macroinvertebrate communities, NMFS will also use fish tissue concentrations and macroinvertebrate community composition measures as available indicators for the extent of take. These measures are directly related to the amount of harm or harassment that the proposed action is likely to cause. The extent of take exempted by this ITS would be exceeded if:

(1) Concentrations of arsenic exceed levels predicted at the monitoring locations specified in Table 65 where: (1) Measured, elevated concentrations are not attributable to background concentrations; (2) follow up monitoring indicates elevated concentrations are not outliers; and (3) annual trend analysis indicates increases concentrations. Follow up monitoring shall include the collection of weekly surface water samples at the location for a period of 4 weeks (i.e., 4 sample events). At a minimum, this shall be within 7 days of becoming aware of the exceedance.
(2) Concentrations of total mercury exceed levels predicted at the monitoring locations specified in Table 66 where: Measured concentrations are not attributable to background concentrations; (2) follow up monitoring indicates elevated concentrations are not outliers; and (3) annual trend analysis indicates increased concentrations. Follow up monitoring shall include the collection of weekly surface water samples at the location for a period of 4 weeks (i.e., 4 sample events). At a minimum, this shall be within 7 days of becoming aware of the exceedance.
(3) Concentrations of dissolved copper exceed the chronic criterion at the monitoring locations specified in Table 66 where: (1) the chronic criterion is calculated using site-

specific data for pH, temperature, DOC, and hardness collected on the same day and at the same time; (2) measured concentrations are not attributable to background concentrations; (3) follow up monitoring indicates elevated concentrations are not outliers; and (4) annual trend analysis indicates increased concentrations. Follow up monitoring shall include the collection of weekly surface water samples at the location for a period of 4 weeks (i.e., 4 sample events). At a minimum, this shall be within 7 days of becoming aware of the exceedance.

(4) Stream temperatures exceed predictions (MWMT for July and September) made for reaches that contain the monitoring locations specified for the EFSFSR and Meadow Creek in Table 66.

(5) Biological monitoring indicates the mine is having adverse effects on aquatic communities in Meadow Creek and the EFSFSR. At a minimum, aquatic community metrics that shall be used to evaluate potential adverse effects are listed below. In the future, alternate metrics may be developed that are more appropriate for evaluating potential impacts from mining activities. As such, NMFS recognizes that the suite of metrics may be adjusted to reflect the best available science, subject to verification by NMFS.

- Total Taxa Richness
- Ephemeroptera Taxa Richness
- Plecoptera Taxa Richness
- Percent Plecoptera
- Percent Ephemeroptera
- Trichoptera taxa Richness
- Hilsenhoff Biotic Index
- Percent 5 Dominant Taxa
- Metals Tolerance Index
- Intolerant Taxa Richness
- Percent Tolerant Individuals
- PIBO O/E

Table 66. Monitoring Locations for Evaluating Extent of Incidental Take at The Mine Site.

Stream	Prediction Node/Sample Location
Meadow Creek	YP-T-27 / SW-22
	YP-T-22 / SW-19
EFSFSR	YP-T-10 / SW-32
	YP-T-8 / SW-28
	YP-T-4 / SW-4
	YP-T-2 / SW-9
Sugar Creek	YP-T-1 / SW-8

2.16. Effect of the Take

In the opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.17. Reasonable and Prudent Measures

"Reasonable and prudent measures" refer to those actions the Director considers necessary or appropriate to minimize the impact of incidental take on the species (50 CFR 402.02). NMFS believes that full application of conservation measures included as part of the proposed action, together with use of the RPMs and terms and conditions described below, are necessary and appropriate to minimize the likelihood of incidental take of ESA-listed species due to completion of the proposed action.

The USFS and USACE shall:

1. Minimize the potential for incidental take from water quality impacts to streams.

2. Minimize the potential for incidental take from water quantity impacts to streams.

3. Minimize the potential for incidental take from fish handling and disturbance.

4. Ensure completion of a monitoring, and adaptive management reporting program to confirm that the terms and conditions in this ITS were effective in avoiding and minimizing incidental take and ensure incidental take is not exceeded.

2.18. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The USFS, USACE, or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The following terms and conditions implement RPM 1:

    a. Apply standard construction practices, including minimizing the amount of surface disturbance and clearly delineating all work zones before starting construction, to minimize the potential to deliver sediment to action area streams.
    b. Monitor turbidity as proposed, but stop construction activities if turbidity levels 1,000 feet downstream of their source begin to approach 50 NTUs above background or are visible for more than 90 minutes or begin to approach 100 NTUs above background at any time. After stopping the activities, contact NMFS to determine when work can proceed and if additional BMPs need to be employed to further minimize the intensity of remaining plumes to ensure extent of take is not exceeded.
    c. Initiate a visual turbidity monitoring program if drilling occurs in RCAs. Visual monitoring must occur at least two times during drilling activities at each location. If visible turbidity is present downstream of drilling activities, operations will cease until the source of turbidity can be identified and mitigated.
    d. Perpetua will ensure water treatment plants are designed, operated, and maintained in a manner that ensures optimal removal of contaminants and adherence to effluent limits.

e. Perpetua will request IDEQ derive effluent limits using 5th percentile hardness levels representative of the season for which effluent limits are derived, even when those levels are lower than the hardness floor identified in the Idaho Water Quality Standards.[14]
f. Perpetua will monitor the mine contact water treatment plant effluent, for the following contaminants: aluminum, arsenic, antimony, cadmium, copper, cyanide, WAD, dissolved organic carbon, TDS, hardness, iron, lead, mercury, selenium, silver, and zinc. Monitoring will be performed each month there is discharge. The effluent shall also be monitored daily for pH and continuously (15-minute intervals) for temperature and flow rate.[14]
g. Perpetua will conduct whole effluent toxicity testing (acute and chronic) for the mine contact water treatment plant. WET testing must occur quarterly; however, monitoring frequency may be reduced, with review and verification from NMFS, if tests consistently demonstrate an absence of acute or chronic toxicity.[14]
h. During operations, when West End Creek is diverted around the West End Pit, Perpetua will treat water in West End Creek prior to discharge to the existing channel below the West End Pit. The objective of treatment is to reduce total mercury concentrations to levels that currently exist as YP-T-6 and to not increase total mercury loading to Sugar Creek during operations.[14]
i. Develop, in coordination with NMFS, and implement a stream temperature monitoring plan to ensure the assumptions forming the basis of this opinion remain valid and stream temperatures do not exceed the predicted temperatures described for each affected stream reach during construction, and post-closure mine phases. At a minimum, monitoring locations will include those identified in Table 66 as well as locations above and below the sanitary wastewater treatment plant discharge in the EFSFSR.
j. Develop, in coordination with NMFS, and implement a stream water quality monitoring plan to ensure the assumptions forming the basis of this opinion remain valid and to ensure contaminants do not exceed the predicted concentrations during construction, operations, and post-closure periods at locations identified in Table 66. At a minimum, monitoring locations will include those identified in Table 66.
k. Develop, in coordination with NMFS, and implement biological monitoring plan to ensure the assumptions forming the basis of this opinion remain valid and to ensure exposures to bioaccumulative contaminants and contaminant mixtures are not having unanticipated impacts. The biological monitoring plan shall include monitoring for mercury accumulation in fish tissue, arsenic accumulation in macroinvertebrate tissues, and macroinvertebrate community composition. At a minimum, monitoring locations will include those identified in Table 66, as well as a monitoring macroinvertebrate communication composition in the Tamarack Creek reference location (MWH-017).

[14] IDEQ is responsible for issuing IPDES discharge permits and may contain more stringent or additional requirements. Ultimately, what is identified in these terms and conditions are the minimum measures NMFS deems necessary for minimizing incidental take of SR spring/summer Chinook salmon and SR Basin steelhead.

l. The monitoring required as part of 1.i, 1.j, and 1.k will continue through construction, operations, and closure and may cease only upon NMFS agreement that performance objectives are achieved and modeled predictions are not exceeded.

2. The following terms and conditions implement RPM 2:

   a. Perpetua will measure and record the amount of water diverted from all surface and groundwater PODs at the SGP site.
   b. Perpetua will measure and record the amount of water discharged from all discharge points at the SGP site.
   c. Perpetua will use data from a and b to calculate the net effect on flow in Meadow Creek, the EFSFSR upstream from Meadow Creek, the EFSFSR between Meadow Creek and the YPP, and the EFSFSR between the YPP and Sugar Creek.
   d. Perpetua will measure and record flows in Meadow Creek immediately upstream of the confluence of Meadow and Blowout Creeks, in Meadow Creek just upstream from the confluence of Meadow Creek and the EFSFSR, in the EFSFSR at the EFSFSR diversion, in the EFSFSR just upstream from the confluence of the EFSFSR and Sugar Creek, and in Sugar Creek just upstream from the EFSFSR.
   e. Perpetua will manage water diversion, use, and discharge such that:
      i. Flow in Meadow Creek will not be reduced below 3.0 cfs between the confluence of Meadow and Blowout Creeks and the confluence of Meadow Creek and the EFSFSR.
      ii. Flow in the EFSFSR at the POD will not be reduced below 7.25 cfs from June 30 to September 30, or less than 5.0 cfs from October 1 to June 29.
      iii. Flow in the EFSFSR below the confluence with Sugar Creek will not be reduced by more than 20% whenever unimpaired flows are less than 25 cfs.
      iv. The diversion of water directly from the EFSFSR shall not exceed 4.5 cfs.
      v. Recognizing that actual flow reduction may differ from that modeled and presented in Table 60, Perpetua and the USFS shall work with the IARB to review annual water quantity monitoring results to ensure that operations are adjusted, as needed, to be consistent with the effects analysis and extent of take provided in this opinion.
   f. Perpetua will ensure that a fish screen(s) and bypass system(s) are present on the EFSFSR diversion and meet NMFS (2022a) criteria (or NMFS more recent criteria).
   g. Perpetua will ensure that the WEP Lake drainage does not exceed 185 acres.

3. The following terms and conditions implement RPM 3:

   a. If trap and haul procedures are used:

      i. Ensure that personnel responsible for conducting trap and haul operations are trained in the event that if something breaks down, they have the knowledge to know what to do in response to make quick decisions to prevent fish losses.

ii. Ensure water temperatures and dissolved oxygen are within desired parameters (NMFS 2000) at all stages of fish capture and handling.

b. To minimize impingement in block nets left in place for more than one day in Chinook salmon and steelhead spawning and rearing habitat, monitor nets every four hours for fish impingement.

c. Ensure that the fish tunnel, and all bridges and culverts accessible to ESA-listed Chinook salmon and steelhead meet NMFS most recent design and fish passage guidelines (currently NMFS 2022a), including considerations for climate change.

d. Ensure all charge limitations, controlled blasting techniques, and blasting setbacks proposed for use in the proposed action are followed for all blasting activities. Any modifications to blasting setback distances based on monitoring at the mine site shall be reviewed and verified by NMFS prior to implementation. Fish salvage will not be used in lieu of charge limitations, controlled blasting techniques, or blasting setbacks.

4. The following terms and conditions implement RPM 4:

a. Regarding adaptive management, ensure that NMFS is involved in all IARB communications, correspondence, and meetings. NMFS expects that at a minimum, the IARB will be engaged in the review of all documents referenced in section 1.11.1, and those listed below. Furthermore, Perpetua will obtain NMFS' verification prior to finalization and implementation of plans and designs that may affect ESA-listed species.[15] NMFS verification will be subject to its confirmation that effects remain consistent with the effects analysis and extent of take provided in this opinion.

i. Water quality and water quantity monitoring reports;
ii. Final SPPC and the Hazardous Materials Handling and Emergency Response Plan;
iii. SGP Road Maintenance Agreement with Valley County;
iv. Annual USFS summary of the implemented and planned road maintenance activities;
v. Road maintenance activities requiring more substantial efforts than typical maintenance (e.g., landslide or avalanche recovery), or outside the current road footprint (e.g., instream fill, LWD removal from streams, etc.);
vi. Explosives and Blasting Management Plan;
vii. Final Design Drawings for stream reaches at the mine site.
viii. Final Design Drawings Lemhi River Restoration Project.

[15] At a minimum, these include the FMP, WRMP, FOMP, Adaptive Management Plans, Closure and Reclamation Plans, atypical road maintenance/repair activities within RCAs, stream designs, surface water diversion intake design, and EFSFSR diversion tunnel design.

b. Submit an annual project status/completion report to NMFS by March 15 following each year of the proposed action. At a minimum, reports shall identify:

   i. Inwater work completed, including starting and ending dates for completed work. Site photos taken before and after work should be included and labeled.
   ii. Records of all fish salvage completed, including the locations and dates of salvage, environmental conditions, equipment settings, number of fish captured, handled, moved, and killed by species.
   iii. Results and summaries of the effluent quality (including WET testing results), surface water quality, surface water temperature, and biological monitoring performed that year. The annual report shall confirm the extent of incidental take exempted by this opinion was not exceeded.
   iv. A summary of pollution and erosion control inspection results, including description of any erosion control failure, contaminant release, and efforts to correct such incidences.
   v. Results of turbidity monitoring to demonstrate the authorized extent of take was not exceeded.
   vi. Identification of blasting and exploratory drilling locations, including their distance from waters occupied by ESA-listed salmon or steelhead, and time needed to complete drilling at each location.
   vii. Details of all closure, restoration, and reclamation work completed in previous year.
   viii. Specific to revegetation efforts, annually submit post-construction revegetation reports documenting progress toward achieving the targeted goals for riparian vegetation and ground cover for other ground disturbing activities within three years of planting. Considering difficulties establishing vegetation in the project area in past rehabilitation efforts, ground cover monitoring and annual updates shall continue until desired targets are reached, and for 5 years thereafter.
   ix. The report shall provide the above identified information and confirm the project's proposed BMPs and that this opinion's terms and conditions were successfully implemented.

c. Exceedances of effluent limits or exceedance of predicted instream contaminant concentrations and temperature predictions will be reported to NMFS quarterly.

d. Reports must be submitted electronically to NMFSWCR.SRBO@noaa.gov.

2.19. Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, "conservation recommendations" are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

1. The USFS and the applicant should consider developing redundancy as a safety factor for the liner (e.g., a thickening of the clay layer) used on the YPP backfill to better protect against bedload scour and potential failure, better ensuring that surface flows do not go subsurface. The safety factor should be based on a maximum scour depth of the 100-year flood event, factoring in necessary considerations for climate change.
2. Considering the proposed action is expected to contribute additional mercury loading to Sugar Creek and the EFSFSR, the USFS should find opportunities and implement actions on USFS land that can reduce mercury loadings from other sources of contamination (e.g., Cinnabar Mine Site or other historic sources of mercury in the EFSFSR watershed).
3. Considering the proposed action will increase traffic on roads, the USFS and applicant should consider implementing BMPs to ensure stormwater runoff from roads does not directly drain to stream channels, but rather is directed to vegetated ground where it can infiltrate.

2.20. Reinitiation of Consultation

This concludes formal consultation for the SGP.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the federal agency where discretionary federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of incidental taking specified in the ITS is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

2.21. "Not Likely to Adversely Affect" Determinations

The Southern Resident killer whale DPS, composed of J, K and L pods, was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). A 5-year review under the ESA completed in 2021 concluded that Southern Residents continue to face a high risk of extinction and should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2021a).

The limiting factors described in the final recovery plan included reduced prey availability and quality, high levels of contaminants from pollution, and disturbances from vessels and sound (NMFS 2008). This section summarizes the status of SRKWs throughout their range. This section summarizes information taken largely from the recovery plan (NMFS 2008), recent 5-year review (NMFS 2021a), as well as new data that became available more recently.

Critical habitat for the SRKW DPS was first designated on November 29, 2006 (71 FR 69054) in inland waters of Washington State. NMFS published a final rule to revise SRKW critical habitat in 2021 (86 FR 41668; August 2, 2021). This rule, which became effective on September 1, 2021, maintains the previously designated critical habitat in inland waters of Washington (Puget Sound, see 71 FR 69054; November 29, 2006) and expands it to include six additional coastal critical habitat areas off the coast of Washington, Oregon, and California (about 15,910 mi^2). Critical habitat includes approximately 2,560 mi^2 of inland waters of Washington in three specific areas: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca. It also includes 15,910 mi^2 of marine waters along the U.S. west coast between the 20-ft. depth contour and the 656.2-ft. depth contour from the U.S. international border with Canada south to Point Sur, California.

Based on the natural history of SRKWs and their habitat needs, NMFS identified the following PBFs essential to conservation for critical habitat: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging. A brief summary of the prey PBFs is presented below. Detailed information on all the PBFs essential to conservation can be found in the 2006 critical habitat final rule (71 FR 69054, November 29, 2006) and the recent 2021 critical habitat expansion final rule (86 FR 41668, August 2, 2021), and the Final Biological Report that supports the 2021 critical habitat rule (NMFS 2021b), which are incorporated here by reference.

Prey species of sufficient quantity, quality and availability are essential to conservation as SRKWs need to maintain their energy balance all year long to support daily activities (foraging, traveling, resting, socializing), as well as gestation, lactation, and growth. Reduced prey availability has been strongly associated with killer whale mortality and to a lesser degree with low fecundity (Ford et al. 2010; Nelson et al. 2024; Ward et al. 2009; Wasser et al. 2017). Most wild salmon stocks throughout the whales' geographic range are at fractions of their historic levels and 28 ESUs and DPSs of salmon and steelhead are listed as threatened or endangered under the ESA, with the Chinook salmon ESUs and DPSs being most important to the SRKW diet. Historically, overfishing, habitat losses, and hatchery practices were major causes of decline for salmonids. Poor ocean conditions over the past two decades have reduced salmon and salmonid populations already weakened by the degradation and loss of freshwater and estuary habitat, fishing, hydropower system management, and hatchery practices. In addition to sufficient quantity of prey, fish need to be accessible and of sufficient quality and size to support SRKW. Contaminants affect the quality of SRKW prey in Puget Sound and in coastal waters of Washington, Oregon, and California. The size of Chinook salmon is also an important aspect of prey quality (i.e., SRKWs primarily consume large Chinook), so changes in Chinook salmon size (for instance as shown by Ohlberger et al. [2018]) may affect the quality of this feature of critical habitat. This shift may be largely due to direct effects from size-selective removal by marine mammals and fisheries, followed by evolutionary changes toward these smaller sizes and early maturation (Ohlberger et al. 2018). Smaller fish have a lower total energy value than larger ones (O'Neill et al. 2014). Therefore, SRKWs need to consume more fish salmon in order to meet their caloric needs as a result of a decrease in average size of older Chinook salmon.

Human activities managed under a variety of legal mandates have the potential to affect SRKW critical habitat PBFs, including those that could increase water contamination and/or chemical exposure, decrease the quantity, quality, or availability of prey, or inhibit safe, unrestricted passage between important habitat areas to find prey and fulfill other life history requirements. Examples of these types of activities include (but are not limited to), in no particular order: (1)

salmon fisheries and bycatch; (2) salmon hatcheries; (3) offshore aquaculture/mariculture; (4) alternative energy development; (5) oil spills and response; (6) military activities; (7) vessel traffic; (8) dredging and dredge material disposal; (9) oil and gas exploration and production; (10) mineral mining (including sand and gravel mining); (11) geologic surveys (including seismic surveys); and (12) activities occurring adjacent to or upstream of critical habitat that may affect essential features, labeled "upstream activities" (including activities contributing to point-source water pollution, power plant operations, liquefied natural gas terminals, desalinization plants) (NMFS 2021b).

SRKWs have been repeatedly observed feeding off the Columbia River plume in March and April during peak spring Chinook salmon runs (Krahn et al. 2004; Zamon et al. 2007; Hanson et al. 2008; and Hanson et al. 2010). For this reason, the eastern Pacific Ocean, where SRKW overlap with Chinook salmon from the Columbia River basin is included in the action area due to potential impacts on the whale's prey base.

Southern Resident killer whales consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016), but salmon are identified as their primary prey. Southern Residents are the subject of ongoing research, including direct observation, scale and tissue sampling of prey remains, and fecal sampling. Scale and tissue sampling from May to September indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90 percent) (Hanson et al. 2010; Ford et al. 2016). The diet data also indicate that the whales are consuming mostly larger (i.e., older) Chinook salmon. Deoxyribonucleic acid (DNA) quantification methods are also used to estimate the proportion of different prey species in the diet from fecal samples (Deagle et al. 2005). Ford et al. (2016) confirmed the importance of Chinook salmon to the Southern Residents in the summer months using DNA sequencing from whale feces. Salmon and steelhead made up to 98 percent of the inferred diet, of which almost 80 percent were Chinook salmon. Coho salmon and steelhead are also found in the diet in spring and fall months when Chinook salmon are less abundant. Specifically, coho salmon contribute to over 40 percent of the diet in late summer, which is evidence of prey shifting at the end of summer towards coho salmon (Ford et al. 1998; Ford and Ellis 2006; Hanson et al. 2010; Ford et al. 2016). Less than 3 percent each of chum salmon (*O. keta*), sockeye salmon (*O. nerka*), and steelhead were observed in fecal DNA samples collected in the summer months (May through September). Prey remains and fecal samples collected in inland waters during October through December indicate that Chinook and chum salmon are primarily contributors to the whales' diet (Hanson et al. 2021). Observations of whales overlapping with salmon runs (Wiles 2004; Zamon et al. 2007; Krahn et al. 2009), and collections of prey and fecal samples have occurred in the winter months. Preliminary analysis of prey remains and fecal samples sampled during the winter and spring in coastal waters indicated that the majority of prey samples were Chinook salmon (80 percent of prey remains and 67 percent of fecal samples were Chinook salmon), with a smaller number of steelhead, chum salmon, and halibut (Hanson et al. 2021). The occurrence of K and L pods off the Columbia River in March suggests the importance of Columbia River spring-run stocks of Chinook salmon in their diet (Hanson et al. 2013) at that time of year. Chinook salmon genetic stock identification from samples collected in winter and spring in coastal waters included 12 U.S. west coast stocks, and over half of the Chinook salmon consumed originated in the Columbia River (Hanson et al. 2021) for the K and L pods (primarily fall-run stocks). Based on genetic analysis of feces and scale samples, Chinook salmon from Fraser River stocks dominate the diet of Southern Residents in the summer (Hanson 2010).

The proposed action will not have any direct effects on SRKW; however, it may indirectly affect the quantity of prey available to them. As described in the above Opinion and ITS, the proposed action may result in the loss of an average of four adult SR spring/summer Chinook salmon each year for up to 21 years. The ocean range of Snake River spring/summer Chinook salmon (Weitkamp 2010) overlaps with the known range and designated critical habitat of SRKW. The loss of four Chinook salmon each year would minimally reduce the SRKW's available prey base in the Pacific Ocean for up to 21 years.

Given the total quantity of prey available to SRKWs, the reduction in prey due to the proposed action will be extremely small. The above Opinion did not identify any potential for the proposed action to influence the quality (size) and/or quality (contaminant levels) of Chinook salmon to an extent that would cause sublethal effects should SRKW eat prey originating within the action area. NMFS finds that the proposed action will not have anything more than minimal effects on abundance, diversity, or distribution of ESA-listed Chinook salmon, and therefore the effects to the quantity of prey available to the whales in the long term across their vast range is expected to be very small. For these reasons, the proposed action will have an insignificant effect on SRKW, and therefore, NMFS concurs with the action agencies' NLAA determination for SRKW. Likewise, because so few of the SRKW prey will be affected by the action, the effect to the prey base PBF is insignificant, and NMFS concurs with the action agencies' NLAA determination for SRKW DCH.

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity," and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [CFR 600.905(b)].

This analysis is based, in part, on the EFH assessment provided by the USFS and USACE, and descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The action area, as described in Section 2.3 of the above opinion, except for areas above natural barriers to fish passage, is also EFH for Pacific Coast Chinook salmon (PFMC 2014). The PFMC designated the following five habitat types as habitat areas of particular concern (HAPCs) for salmon: complex channel and floodplain habitat, spawning habitat, thermal refugia, estuaries, and submerged aquatic vegetation (PFMC 2014). The proposed action may adversely affect the following HAPCs: complex channel and floodplain habitat, spawning habitat, and thermal refugia.

Proper function of complex channels and floodplain habitat could be affected in the EFSFSR and Meadow Creek; spawning habitat could be affected in the EFSFSR, Meadow Creek, and Sugar Creek; and thermal refugia could be affected in the EFSFSR, Meadow Creek, Sugar Creek, Johnson Creek, Burntlog Creek, and East Fork Burntlog Creek.

3.2. Adverse Effects on Essential Fish Habitat

Based on information provided in the BA and the analysis of effects presented in the ESA portion of this document, NMFS determined the proposed action would adversely affect EFH as follows:

1. The proposed action will result in ground-disturbing activities, which may adversely affect riparian and instream habitat in Meadow Creek, EFSFSR, and Johnson Creek and its tributaries.
2. The proposed action will affect water quality, which may adversely affect the temperature and chemical properties of instream habitat in Meadow Creek, EFSFSR, SFSR, and Johnson Creek and its tributaries.
3. The proposed action will reduce streamflow in portions of and tributaries to the EFSFSR; which will increase summer water temperature; reduce amount of habitat available for adult Chinook salmon; reduce food for juvenile Chinook salmon; reduce access to escape cover for juvenile Chinook salmon; reduce movement of sediment in the affected tributaries; and reduce cold water refugia habitat for juvenile rearing and adult holding Chinook salmon.

3.3. Essential Fish Habitat Conservation Recommendations

NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the adverse effects of the proposed action on EFH.

1. To address ground disturbing habitat effects to the spawning habitat, and complex channel and floodplain habitat HAPCs:
    a. Standard construction practices, including minimizing the amount of surface disturbance and clearly delineating all work zones before starting construction,

should be applied to minimize the potential to deliver sediment to action area streams.

b. Turbidity should be monitored as proposed, but construction activities should stop if turbidity levels 1,000 feet downstream of their source begin to approach 50 NTUs above background or are visible for more than 90 minutes or begin to approach 100 NTUs above background at any time. After stopping the activities, NMFS should be contacted to determine when work can proceed and if additional BMPs need to be employed to further minimize the intensity of remaining plumes to ensure extent of take is not exceeded.
c. A visual turbidity monitoring program should be initiated if drilling occurs in RCAs. Visual monitoring should occur at least two times during drilling activities at each location. If visible turbidity is present downstream of drilling activities, operations should cease until the source of turbidity can be identified and mitigated.
d. The USFS and the applicant should consider developing redundancy as a safety factor for the liner (e.g., a thickening of the clay layer) used on the YPP backfill to better protect against bedload scour and potential failure, better ensuring that surface flows do not go subsurface. The safety factor should be based on a maximum scour depth of the 100-year flood event, factoring in necessary considerations for climate change.
e. The USFS should obtain NMFS review and verification of the following plans and design prior to their finalization and implementation: FMP, WRMP, FOMP, Adaptive Management Plans, Closure and Reclamation Plans, atypical road maintenance/repair activities within RCAs, stream designs, surface water diversion intake design, and EFSFSR diversion tunnel design.

2. To address water quality effects to the thermal refugia, spawning habitat, and complex channel and floodplain habitat HAPCs:
    a. Perpetua should ensure water treatment plants are designed, operated, and maintained in a manner that ensures optimal removal of contaminants and adherence to effluent limits.
    b. Perpetua should request IDEQ derive effluent limits using 5th percentile hardness levels representative of the season for which effluent limits are derived, even when those levels are lower than the hardness floor identified in the Idaho Water Quality Standards. [16]
    p. During operations, when West End Creek is diverted around the West End Pit, Perpetua should treat water in West End Creek prior to discharge to the existing channel below the West End Pit. The objective of treatment is to reduce total mercury concentrations to levels that currently exist as YP-T-6 and to not increase total mercury loading to Sugar Creek during operations.[16]
    q. Considering the proposed action will increase traffic on roads, the USFS and applicant should consider implementing BMPs to ensure stormwater runoff from

[16] IDEQ is responsible for issuing IPDES discharge permits and may contain more stringent or additional requirements. Ultimately, what is identified in these terms and conditions are the minimum measures NMFS deems necessary for minimizing incidental take of SR spring/summer Chinook salmon and SR Basin steelhead.

roads does not directly drain to stream channels. Instead stormwater runoff from roads should be directed to vegetated ground where it can infiltrate.

3. To address streamflow effects to the thermal refugia, spawning habitat, and complex channel and floodplain habitat HAPCs:
   a. The permittees should manage water diversion, use, and discharge such that:
      i. Flow in Meadow Creek will not be reduced below 3.0 cfs between the confluence of Meadow and Blowout Creeks and the confluence of Meadow Creek and the EFSFSR.
      ii. Flow in the EFSFSR at the POD will not be reduced below 7.25 cfs from June 30 to September 30, or less than 5.0 cfs from October 1 to June 29.
      iii. Flow in the EFSFSR below the confluence with Sugar Creek will not be reduced by more than 20% whenever unimpaired flows are less than 25 cfs.
      iv. The diversion of water directly from the EFSFSR should not exceed 4.5 cfs.
      v. Recognizing that actual flow reduction may differ from that modeled and presented in Table 60, Perpetua and the USFS should work with the IARB to review annual water quantity monitoring results to ensure that operations are adjusted, as needed, to be consistent with the effects analysis in this opinion.
   b. The permittees should ensure that a fish screen(s) and bypass system(s) are present on the EFSFSR diversion and meet NMFS (2022a) criteria.
   c. The permittees will ensure that the WEP Lake drainage does not exceed 185 acres.

Fully implementing these EFH Conservation Recommendations would protect, by avoiding or minimizing the adverse effects described in Section 3.2, above, for Pacific Coast salmon.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the USFS or USACE must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the Federal agency have agreed to use alternative timeframes for the Federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects [50 CFR 600.920(k)(1)].

3.5. Supplemental Consultation

The USFS or USACE must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH Conservation Recommendations [50 CFR 600.920(l)].

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The DQA specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the USFS and USACE. Other interested users could include Perpetua and the agencies of the State of Idaho. Individual copies of this opinion were provided to the USFS and USACE. The document will be available within 2 weeks at the NOAA Library Institutional Repository (https://repository.library.noaa.gov/welcome). The format and naming adhere to conventional standards for style.

4.2. Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3. Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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6. APPENDICES

APPENDIX A

Summary of Environmental Design Features and Protection Measures

(Relevant Excerpts from BA Appendix B, Stantec 2024)

Table A-1. Summary of Environmental Design Features and Protection Measures: Fish - General

Description	Reference
To protect fish residing in, using, or potentially using the Yellow Pine Pit (YPP) lake (Chinook salmon, steelhead trout, bull trout, westslope cutthroat trout, mountain whitefish), Perpetua has developed a Fish Salvage and Release Plan (Section 5.4.7 within Brown and Caldwell, Rio ASE, and BioAnalysts 2021) to isolate the lake from upstream movement into the lake and salvage and release fish. The Fish Salvage and Release Plan will be refined in coordination with federal, state, and tribal agencies. Perpetua will, in consultation with the USFWS and the NMFS (the Services), design, install, and operate a fish trap and one or two weirs designed to allow fish to leave the YPP lake but not allow fish to migrate upstream past the trap to ensure that the fewest number of individual ESA-listed fish species are present in the pit lake when the draining process begins. The timing for providing the upstream barrier to fish movement will be designed to minimize the number of fish in the YPP lake, particularly larger bull trout (i.e., installed in the spring when streamflow conditions allow). Fish captured in the YPP lake will be immediately released downstream of the upstream fish movement barrier or in another location determined by the appropriate regulatory agencies. The YPP lake will be partially drained to recover the remaining fish and relocate them prior to final draining of the pit lake.	2021 Modified Mine Plan
A fishway has been designed and will be operated within the East Fork South Fork Salmon River (EFSFSR) tunnel to provide upstream and downstream volitional fish passage throughout mine operations (see EFSFSR Temporary Diversion Tunnel portion of Section 1.7.10.2). The EFSFSR diversion tunnel will be approximately 0.9 miles long and 15 feet high by 15 feet wide. The tunnel will include a parallel accessway to allow equipment and personnel access for monitoring, inspection, and maintenance. The accessway will function as a floodway for high flows, limiting the operating flow range within the fishway while river and thus total tunnel flows vary more widely.	2021 Modified Mine Plan
As an alternative to the fishway in the EFSFSR tunnel, Perpetua will provide adult passage by trap and haul if needed. Criteria may be put in place so that if any unusual or unexpected events occur that result in adverse impacts to fish during operations, fish passage through the fishway will be switched to trap and haul operations (e.g., per the Fishway Operations Management Plan (FOMP), BA Appendix C (Stantec 2024), at one week prior to the spawning period, if adults present in the resting pool below the fishway have not entered the fishway over a 48-hour period, they will be collected for transport).	2021 Modified Mine Plan
Low-energy lighting will be provided in the fishway to determine if it aids in fish passage and to provide light for tunnel and fishway inspections. The system will be configured so that it mimics the photoperiod of the region, run manually on a dimming system, or be completely turned off at the option of the operator.	2021 Modified Mine Plan
Fish salvage and relocation operations will be conducted any time the facility needs repair within the fishway, potentially during sediment removal, and potentially when streamflows recede from the accessway.	2021 Modified Mine Plan
Post mining, the EFSFSR stream channel will be reestablished across the backfilled YPP with a channel design that will provide for upstream and downstream fish passage.	2021 Modified Mine Plan
Perpetua will reestablish fish passage at the location of the existing box culvert on the EFSFSR just downstream of the confluence with Meadow Creek at the McCall-Stibnite Road (CR 50-412) crossing.	2021 Modified Mine Plan
Perpetua will improve fish passage along the Burntlog Route within the Stibnite Gold Project (SGP) area by identifying and replacing existing collapsed, undersized, or otherwise degraded or poorly designed culverts at road crossings and committing appropriate resources to fix and improve these structures.	2021 Modified Mine Plan
Perpetua will install side-ditching, culverts, guardrails, and bridges, where necessary along the Burntlog Route, with design features to provide fish passage and limit potential sediment delivery to streams.	2021 Modified Mine Plan

Description	Reference
Perpetua will employ blasting setback distances and other controlled blasting techniques following industry best management practices (BMPs) (modifying blasting variables including charge size, and vibration and overpressure monitoring) to minimize impacts to fish from blasting. Perpetua will follow up with monitoring in early stages of operation to evaluate effectiveness and refine blasting protocols in coordination with federal, state, and tribal agencies, if needed. Blasting setbacks are described in the Fish and Aquatic Resources Mitigation Plan (FMP). Blasting for the YPP will be in proximity to the EFSFSR while blasting for the Hangar Flats Pit (HFP) will be in proximity to the Meadow Creek diversion, above its confluence with the EFSFSR.	2021 Modified Mine Plan
Dewatering of the YPP lake or stream segments will generally be conducted during low-flow periods to facilitate stream segment isolation and fish salvage. When practicable, dewatering also will be timed to avoid or minimize impacts during known spawning periods for Chinook salmon, steelhead, and bull trout.	2021 Modified Mine Plan
To protect fish, Perpetua will develop a standard procedure for channel segment isolation, dewatering, fish salvage, and fish relocation to appropriate receiving streams during dewatering or maintenance of natural stream and diversion channels, based on the USFWS Recommended Fish Exclusion, Capture, Handling, and Electroshocking Protocols and Standards (USFWS 2012) and refined in coordination with federal, state, and tribal agencies.	2021 Modified Mine Plan
The FOMP defines the monitoring and evaluation plan elements and describes how the hydraulic conditions, fish use, and performance of the tunnel fishway will be measured and evaluated, and the design of the adaptive management component of the plan including the option of using trap and haul.	2021 Modified Mine Plan
Access and SGP haul road crossings of fish bearing streams will be designed such that structures installed or constructed allow fish passage.	2021 Modified Mine Plan
Perpetua will implement measures to limit stream baseflow effects during active operations, including a combination of lining key reaches of streams potentially impacted by pit dewatering, and treating and discharging pit dewatering water that is not used for ore processing or other industrial uses. Maintain instream flows for fish species and other aquatic resources: flows within natural stream channels affected by SGP operations will be maintained to meet seasonally appropriate and stream-specific low-flow needs to the maximum extent practicable. Perpetua will continue to evaluate options and measures to further avoid and minimize the magnitude and duration of effects of the SGP through other measures in consultation with federal, state, and tribal agencies.	2021 Modified Mine Plan
Following permanent cessation of mining activities at the YPP, Perpetua will backfill the pit and route the EFSFSR over the backfilled pit with a longer, lower-gradient channel with higher intrinsic potential for Chinook salmon and steelhead spawning and rearing than the channel that exists presently. The floodplain area along the constructed channel will include side-channels and other off-channel features and will be revegetated to restore wetland and riparian habitat providing long-term shade/cover favorable to fish.	2021 Modified Mine Plan
To address stream temperature, riparian planting widths along restored and enhanced stream reaches will be 18 feet wide on each streambank where possible. Taller and denser vegetation such as spruce trees will be planted. Further, the creation of the lined Stibnite Lake, a feature similar in size to the present YPP lake, will replace the function of the existing YPP lake in buffering stream temperature extremes and reduce maximum stream temperatures in EFSFSR in and downstream of the SGP. The 18-foot planting area provided sufficient shading so that predicted solar radiation did not increase stream temperatures above existing conditions upon the reestablishment of the vegetation based on temperature modeling results from the SPLNT Model (Brown and Caldwell 2021).	2021 Modified Mine Plan
During mine operations, summer low flows in perennial diversion channels around the tailings storage facility (TSF) impoundment and buttress (Meadow Creek), YPP (Hennessy Creek and EFSFSR tunnel), and West End Pit (West End Creek) will be piped underground as a mitigation measure to maintain cold stream temperatures.	2021 Modified Mine Plan
A liner will be installed under the Meadow Creek stream/floodplain corridor to minimize water seepage into the HFP or the pit dewatering well system, and to avoid potential pit wall instability or loss of stream habitat as a result of stream dewatering.	2021 Modified Mine Plan

Description	Reference
In fish-bearing waters, intake hoses shall be screened with the most appropriate mesh size (generally 3/32 of an inch), or in compliance with NMFS guidelines.	2021 Modified Mine Plan
In intermittent and perennial non-fish bearing waters, new surface diversions will not be authorized unless they provide passage and habitat for native and desired non-native aquatic species other than fish.	2021 Modified Mine Plan
For watersheds with listed aquatic species, essential fish habitat, or designated critical habitat, transportation system design criteria for fish passage will be coordinated with NMFS or USFWS, as appropriate.	2021 Modified Mine Plan
Employees and staff will receive training and direction to avoid spawning adult Chinook salmon, bull trout and steelhead.	2021 Modified Mine Plan
Provide trap and haul passage for adult ESA-listed species (Spring/summer Chinook, steelhead, and bull trout) when necessary, between April 1 - September 15 at the north portal to the fish passage.	2021 Modified Mine Plan
Blasting peak particle velocity will be < 7.3 psi (50 kPa) where fish are present.	2021 Modified Mine Plan
Blasting airblast overpressure will be < 2.0 in/s (51 mm/s) during sensitive stage (embryo incubation before epiboly is complete).	2021 Modified Mine Plan
Water infrastructure will be managed to protect fish and minimize harm by implementing best practices for diversions, dewatering, isolation, and fish salvage.	2021 Modified Mine Plan
Efforts to increase spring/summer Chinook salmon production in the upper EFSFSR have been actively pursued since 2009 with the transport and release of mature adults upstream from YPP.	2021 Modified Mine Plan
Required setbacks for blasting are set to meet maximum overpressure and maximum peak particle velocity and that a 239-ft blasting setback on 20-ft benches and 419 ft on 40-ft benches from the closest point the blast field to stream and lake habitats should be protective.	2021 Modified Mine Plan
Perpetua will develop an Explosives and Blasting Plan that will ensure compliance with the blasting requirements of the Mine Safety and Health Administration, 30 CFR Part 56, Subpart E – Explosives and Part 57, Subpart E – Explosives. The blasting plan will include the setback distances and options for other mitigative measures and BMPs.	2021 Modified Mine Plan
Design and maintain diversion channels and restored channels to avoid the risk of stranding fish including juvenile and adult salmonids.	2021 Modified Mine Plan
Maintain appropriate streamflows and water quality conditions in natural or restored channels where fish are present.	2021 Modified Mine Plan
Protect stream segments not directly impacted by mining to protect fish species from indirect physical or chemical impacts (i.e., applying road construction and maintenance BMPs to control sedimentation and water quality effects from mine and access routes).	2021 Modified Mine Plan
Provide fish passage enabling volitional or managed movement of migratory species around blockages that may currently exist in high-gradient stream sections or at existing road crossings or other drainage culverts to areas not currently accessible (i.e., removal the current barriers of the Yellow Pine Pit and the box culvert on the EFSFSR downstream of the confluence with Meadow Creek plus relocation of the gradient barrier on Meadow Creek to a location further upstream) .	2021 Modified Mine Plan
Exclusion and fish handling, using a trap, seine, electrofishing, or other method designed to minimize injury risk, will be supervised by a qualified fish biologist per guidance provided in NOAA 2000 Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act.	2021 Modified Mine Plan

Description	Reference
Avoid capture and handling stress by excluding fish from entering the YPP lake prior to draining; migratory adult salmonids (i.e., Chinook salmon and bull trout) will be prevented from moving upstream into the lake by installing and operating a fish trap and one or two weirs designed to allow fish to leave the YPP lake but not allow fish to migrate upstream past the trap.	2021 Modified Mine Plan
Design of the restored EFSFSR stream channel over the backfilled YPP to allow for volitional upstream passage by all salmonid species present.	2021 Modified Mine Plan
During operations, Perpetua will implement measures to monitor streamflows and water quality conditions at key locations as defined in Table 4-1 of the Water Resources Monitoring Plan (Brown and Caldwell. 2021c).	2021 Modified Mine Plan
East Fork Meadow Creek (EFMC) - Stabilize and restore EFMC to improve watershed conditions, enhance concurrent restoration efforts and improve habitat near the Project site, restore the water table and long-term function of the upper reach that was historically a low-gradient meadow with broad riparian wetlands, stabilize the steep, confined, erosive middle reach to address the significant fine sediment load currently produced from this reach, restore the downstream, relatively low-gradient reach will be restored to provide rearing habitat for Chinook salmon and other salmonids.	2021 Modified Mine Plan
Passive integrated transponder (PIT) tag arrays will be positioned at key monitoring points within the tunnel for assessing travel times and migration rates of both juvenile and adult salmonids that have been previously PIT-tagged.	2021 Modified Mine Plan
Establishing an adult fishway during operations proactively results in a 14-year head start on reestablishing volitional passage prior to restoring the EFSFSR stream channel across the YPP.	2021 Modified Mine Plan
There will be an annual decision point about how the fishway should be operated each year (operate fishway, trap and haul, or no operation of fishway) and for the relationship to Chinook salmon stocking in the EFSFSR to be considered.	2021 Modified Mine Plan
No net loss of function of wetlands and streams resulting from construction, operation, and reclamation of the Project after providing compensatory mitigation for unavoidable impacts to jurisdictional streams and wetlands.	2021 Modified Mine Plan
Provide net benefit to wetlands, streams, water quality, and fisheries in the Project area following mining and closure by repair and rehabilitation of habitats adversely affected by historical mining impacts in the Project area.	2021 Modified Mine Plan
Observe setback distances for each blasting activity, wherever possible. In the event a blasting activity will not meet the required setback distance, Perpetua will attempt to adjust the bench height or blast intensity to minimize potential adverse effects to fish communities in the nearby stream. Where the setback distance cannot be met and alterations to the blasting protocol will not adequately mitigate potential harm to fish communities, Perpetua will implement measures to isolate, capture, and relocate ESA-listed fish species from the stream segment where potential for impact exists.	2021 Modified Mine Plan
As Perpetua works through the permitting and Endangered Species Act (ESA) consultation processes with the agencies, if further concerns arise regarding the effects of the projected incremental increase in winter water temperatures in the diverted reach of the EFSFSR, Perpetua will explore opportunities to use cold ambient air temperatures to lower discharge temperatures to minimize this localized effect, if deemed necessary to support salmonid incubation and emergence conditions. The additional temperature mitigation measures being considered include the following: • Increasing the restoration planting width from 7 to 18 feet on all restored stream reaches; Streambank planting of the enhanced EFSFSR reach that is currently disturbed to the width allowable by site constraints; • Revised planting prescriptions that include more spruce and willow trees than prescribed in the Conceptual Mitigation Plan; Constructing a lake near the location of the present YPP lake to mimic its temperature-moderating effects; and • Maintaining low-flow pipes within stream diversions until restoration plantings have matured to provide adequate shade. Implementing water treatment plant design refinements to lower effluent temperature prior to discharge to streams during the winter, as necessary.	2021 Modified Mine Plan

Description	Reference
Where mine facilities or practices have been identified as potentially contributing to degradation of water quality, aquatic species, or occupied sensitive and watch plant habitat, facilities and practices causing degradation will be considered for relocation, closure, changes in management strategy, alteration, or discontinuance.	2021 Modified Mine Plan
Improvements to fish passage will be made along the Burntlog Route within the Project area in streams of fish-bearing size. This will be completed by identifying and replacing collapsed, undersized, or otherwise degraded or poorly designed culverts at road crossings and committing appropriate resources to fix and improve these structures that have not already been replaced for fish passage. The same dewatering and fish salvage techniques used at the SGP will be used at these locations as well before constructing a replacement culvert if work isolation methods alone will not suffice. The 21 crossings are on Burntlog Creek, East Fork Burntlog Creek, EFSFSR, Johnson Creek, Landmark Creek, Peanut Creek, Rabbit Creek, Riordan Creek, Trapper Creek, and 12 unnamed creeks. Based on eDNA data collected as part of the road design the crossings with fish passage are: • 1 Johnson Creek crossing; • 1 Burntlog Creek crossing; • 6 crossings of East Fork Burntlog Creek and its tributaries; • 2 crossings of Trapper Creek and its tributaries; • 2 Peanut Creek crossings; • 1 Riordan Creek crossing; • 1 Rabbit Creek crossing; and, • 3 EFSFSR crossings. See Table 3.4-4 in the FMP for more details.	Fish and Aquatic Resources Mitigation Plan, Section 5.5.3
Designs will be consistent with NMFS 2022 design criteria and consultation with the USFWS. Perpetua will complete this work using the Forest Service Stream Simulation approach on fish bearing streams (Forest Service Stream Simulation Working Group) (USFS 2008). Stream simulation was adopted by the USDA, Forest Service as a pragmatic approach and sustainable long-term solution to maintain passage for all aquatic organisms at all life stages at road-stream crossings while meeting vehicle transportation needs and objectives. Larger crossings along the Burntlog Route will feature channel-spanning bridges or arches rather than culverts. These improvements are expected to benefit salmonid species access to productive habitats and increase watershed connectivity.	Fish and Aquatic Resources Mitigation Plan, Table 5-1 Fish and Aquatic Resources Mitigation Plan, Section 5.5.3
The instream work windows provided in this section are based on our current understanding of fish use and periodicity for Chinook salmon, steelhead, bull trout, and westslope cutthroat trout. The instream work windows will be updated as information and timing of migratory salmonids is acquired through monitoring of the EFSFSR tunnel fishway. Instream work windows have been developed for each species because not all streams contain all target species. For example, Fiddle Creek and EFMC only contain westslope cutthroat trout and *O. mykiss* only occur in the EFSFSR downstream from the YPP passage barrier. The information presented is intended to establish appropriate instream work windows for each species and stream in the SGP area and to assist with avoidance and minimization measures. Thus, instream work windows avoid potential impacts to spawning adults an protect developing eggs within the gravel. As a conservation measure, no in-water work will occur within 300 feet of spawning areas during anadromous fish spawning and incubation times, which will be dictated by the approved work window.	Fish and Aquatic Resources Mitigation Plan, Section 5.2
Perpetua developed a spreadsheet tool to compute the required setback distances from fish-bearing streams and lakes. The spreadsheet tool was developed using the following steps: 1. The equations used in the spreadsheet were taken from Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998), including equating the peak particle velocity to charge weight and distance. 2. The standards used came from the Alaska Blasting Standard for the Proper Protection of Fish (TR 13-03) described above—the blast overpressure threshold limit was set at 7.3 psi and peak particle velocity threshold was set at 2.0 in/s).	Fish and Aquatic Resources Mitigation Plan, Section 5.6

Description	Reference
3. The spreadsheet tool was then populated with the anticipated drill and blast assumptions (bench height, drill hole diameter, stemming length, powder column height, powder volume and charge per hole [weight]). The spreadsheet tool calculates the resulting minimum setback distance to achieve enough setback to meet the threshold limits, namely 239 feet for blasting a 20-foot-deep bench and 419 feet for blasting a 40-foot-deep bench (i.e., there are more explosives used for the deeper bench). Perpetua used these required setback distances to do a high-level review of streams and lakes in closest proximity to areas where blasting may be required. This review identified areas where the blasting may be within the 239-foot and 419-foot setbacks. These include some stream segments adjacent to the EFSFSR diversion tunnel, YPP, West End Pit (WEP), the TSF and HFP where Meadow Creek is closest to the pit. This analysis does not definitively identify areas where impacts will occur but points to areas where adjustments to blasting methods may be needed to reduce the required blasting buffer (bench heights, charge size, and detonation pattern, etc.). According to the proposed implementation, such areas will be the locations at which initial calculation and testing of blast effects (instantaneous pressure and peak particle velocity) will be conducted. It is also noteworthy that blasting in some of the areas identified may not occur until non-consolidated materials are removed without blasting, such that the distance between blast sites and streams will have increased. During ESA informal consultation meetings with the participating agencies and tribes in 2019, Perpetua reviewed and summarized elements of the blasting analysis for review and comment. In advance of those meetings, Perpetua provided the literature used in determining protective setback distances needed for fish protection, the spreadsheet tool to compute the required setback distances and the Excel spreadsheet analysis, and geographic information system (GIS) maps of the mine pits and other areas where blasting will likely be required. The agencies reviewed the materials provided and there was a general concurrence within the agency group on the following: (1) the Alaska blasting standards for air overpressure and ground vibration were appropriate; (2) that the spreadsheet tool was a useful and appropriate tool for calculating required protective buffer distance; (3) that careful blasting operations using standards based setbacks designed to be protective of fish and fish embryos will likely result in little or no adverse effects to fish life stages from blasting; and (4) that the approach and standards to be used were sound and that the plan will be refined and included in a future revision of the FMP. The agencies indicated that they expected monitoring validation of the estimated and actual blast intensities early in the construction and mining period to verify accuracy the estimates provided by the spreadsheet tool. The predicted setback distances will be verified via blast monitoring instrumentation (blast seismographs and pressure transducers) utilized for test blasts at three sites with different physical conditions.	
The purpose of the FMP is to describe the measures proposed by Perpetua to protect fish and aquatic resources during mine operation, site reclamation, closure, and post-closure for the Proposed Action (2021 MMP). The FMP provides information on how Perpetua plans to: • Implement measures to avoid and minimize impacts to fish species and aquatic resources during Project construction and operation. • Implement ongoing protection and mitigation measures such as stream habitat enhancement, fishway operations, fish protection during mining, and stream diversions, stream restoration, water quality management, and other protective BMPs. • Monitor mitigation actions to ensure they are implemented correctly and have met established success criteria, applying an adaptive management approach as needed. The specific areas where infrastructure is developed to minimize harm include: • Protection of water quality • Protection of fish individuals via avoidance and handling procedures • Fish passage improvements • Blasting procedures to manage vibration • Effects monitoring • Stream restoration	Fish and Aquatic Resources Mitigation Plan, Section 1

Description	Reference
The following fish protection or exclusion methods will be utilized in the project: • Fish screening to prevent entry of adult and juvenile fish into Meadow Creek diversion canals and low-flow pipes around the TSF. • New Meadow Creek stream channel diversion around the HFP will be constructed dry then watered to become the permanent stream channel. • EFSFSR tunnel designed to receive the entire EFSFSR flow to allow for safe upstream and downstream fish passage. • Raw water intakes will include fish screens designed in accordance with NMFS guidelines. • Diversion of streams encountering historic mining facilities into relocated channels. To protect ESA-listed fish species, Perpetua will utilize a standard procedure for channel segment isolation, dewatering, fish salvage, and fish relocation during dewatering or maintenance of natural stream and diversion channels, based on the USFWS Recommended Fish Exclusion, Capture, Handling, and Electroshocking Protocols and Standards (USFWS 2012). This procedure was developed for the approved 2022 – 2024 Administrative Settlement Agreement and Order of Consent (ASAOC) removal work on site and will be adapted for use by the Project. Additional sources of information on fish protection protocols may be considered in developing the program. For example, the Bonneville Power Administration (BPA) Habitat Improvement Program (HIP) III provides a series of conservation measures intended to protect and restore fish and wildlife habitat affected by construction activities. The elements of the standard procedure are described below. For channel isolation and dewatering, to minimize impacts to fish, cofferdams will isolate portions of the proposed channel within the existing ordinary high-water mark (OHWM) to keep water and fish out of a channel until construction is completed. Once construction of a channel is completed (including prewashing the substrate), water will be slowly reintroduced into the new channel (one-third of the flow initially), with seine block nets keeping fish from entering the new channel. Seine block nets will be placed in the upstream end of the channel with fish salvage steps described in the next paragraph. Next, two-thirds of the flow will be released into the new channel until flows and turbidity stabilize, and then ultimately all flow will be released into the new channel and the seine block net to the new channel removed. Fish salvage steps before stream dewatering will be: • Identify stream reach that may require fish salvage operations and/or instream water work associated with the SGP, and which salvage methods are most applicable, as outlined in the fish salvage plan. • Secure necessary fish handling permits to conduct instream water work and fish handling. • Secure and stage all necessary fish capture, isolation, holding, and transportation equipment to execute fish salvage operations. This includes but is not limited to pumps, generators, fuel, fuel spill containers, sanctuary nets, block nets, electrofishing units, seines, transport vehicles, radio communications, buckets (smaller vessel to move fish from to tank to release location) and tanks (if fish are relocated), back up aeration and pumps for staging area fish handling and transportation, backpack for transporting fish, hoses, thermometers, turbidity meter, field data notebooks. • Isolate stream channel via weirs, block nets, sandbags, straw bales, and tarps to prevent fish movement into the fish salvage area. Isolation may occur well in advance of fish salvage operations to prevent adult salmonids from entering the stream or lake. • Partially dewater isolated stream section to improve fish capture efficiency (if needed). Some diverted water should be conveyed through diversion channel(s) to prevent increased turbidity downstream. Isolate water used to pre-wet and clean diversion channel. Use pumps to extract turbid water for land application until diverted water reaches ambient turbidity levels in undisturbed stream. Work area isolation provide a means to limit potential effects to fish by preventing movement into the work area with the goal of safely removing as many fish outside of the work area as practicable. Protocols established in BPA's HIP Program will be followed for work area isolation and fish salvage, which include: • When work area isolation is required, design plans will include all isolation elements, fish release areas, a pump to be used to dewater the isolation area, and, when fish are present, a fish screen that meets NMFS's fish screen criteria. Wider mesh screens may be used after all fish have been removed from the isolated area.	Fish and Aquatic Resources Mitigation Plan, Table 5-1 Fish and Aquatic Resources Mitigation Plan, Section 5.3 Fish and Aquatic Resources Mitigation Plan, Table 5-7 Fish and Aquatic Resources Mitigation Plan, Section 5.4.7.2

Description	Reference
Salvage activities will take place during conditions to minimize stress to fish species, typically periods of the coolest air and water temperatures which occur in the morning versus late in the day. A fish biologist will determine an operational plan to remove ESA-listed fish, with the least amount of harm to the fish, before in-water work begins. This will involve either passive movement of fish out of the Project reach through slow dewatering, or actively removing the fish from the Project reach. Should active removal be warranted, a fish biologist will clear the area of fish before the site is dewatered using one or more of a variety of methods including seining, dipping, or electrofishing, depending on specific site conditions. Salvage operations will follow the ordering, methods, and conservation measures specified as follows: • Slowly reduce water from the work area to allow some fish to leave the work area volitionally. • Block nets will be installed at upstream and downstream locations and maintained in a secured position to exclude fish from entering the Project area. Block nets will be secured to the stream channel bed and banks until fish capture and transport activities are complete. Block nets may be left in place for the duration of the Project to exclude fish as long as passage requirements are met. • Nets will be monitored hourly anytime there is instream disturbance. • If block nets remain in place more than one day, the nets will be monitored at least daily to ensure they are secured to the banks and free of organic accumulation. If the Project is within bull trout spawning and rearing habitat, the block nets must be checked every 4 hours for fish impingement on the net, per BPA (2019) requirements unless a variance can be granted. • Capture fish through seining and relocate to streams. • While dewatering, any remaining fish will be collected by hand or dip nets. • Seines with a mesh size to ensure capture of the residing ESA-listed fish will be used. • Minnow traps may be left in place overnight and used in conjunction with seining. • Electrofish to capture and relocate fish not caught during seining. This step is to be used as a last resort; after all passive techniques have been exhausted. • Continue to slowly dewater the stream reach. • Collect any remaining fish in transport buckets with cold water and relocate to the stream. • Limit the time fish will be held in a bucket and release them as quickly as possible. • The number of fish within a bucket will be limited, and fish will be of relatively comparable size to minimize predation. • Aerators for buckets will be used, or the bucket's water will be frequently changed with cold, clear, water at 15-minute, or more-frequent, intervals. • Buckets will be kept in shaded areas; or if in exposed areas, covered by a canopy. • Dead fish will not be stored in buckets used to transport fish but will be left on the streambank to avoid mortality counting errors. Fish capture methods that will be employed during fish salvage operations include both active and passive capture techniques. Brennan-Dubbs (2012) and NOAA (2000) provide guidance on several fish capture techniques. Active capture techniques may include electrofishing, dip netting, seining, minnow traps, and fish herding and/or crowding. Passive capture techniques will include fish traps associated with weirs to exclude juvenile and adult fish from instream work areas. A weir and fish trap will be placed downstream of YPP lake to prevent adult salmonids from entering or reentering the lake thus avoiding the possibility of fish salvage for those migratory fish. The trap will be checked at least once a day and debris accumulation will be removed from the picket panels. Fish will be removed from the trap and immediately released downstream. As with all fish salvage operations, the date, number, and species of fish handled will be documented and provided in a post-salvage operations report.	
The top-level parameters: • biological community observations; • instream habitat conditions; • riparian conditions; • wetland condition, functions, and values;	Fish and Aquatic Resources Mitigation Plan, Section 7.3

Description	Reference
• fish access; and, • channel conditions and dynamics will be monitored as part of the SGP Fisheries and Aquatic Habitat Monitoring program. Most parameters provide a continuation of baseline monitoring (i.e., fisheries, instream habitat, and macroinvertebrates) while others are new to assess the implementation and performance of stream habitat restoration and enhancement. Each parameter is classified by the type of monitoring that it will support along with the methods used to establish baseline data and metrics. Biological community observations will include monitoring of fish assemblages and stream macroinvertebrate communities via continued fish and macroinvertebrate surveys based on the baseline aquatic surveys completed. Condition monitoring for habitat will occur annually during low-flow periods through completion of habitat restoration activities and then for an additional five-years. Condition monitoring will be based on the baseline habitat information and will record observations of substrate, wood debris, pool frequency and quality, width-depth ratios, streambank conditions, off-channel habitat and other parameters specified in the FMP (Section 7.3) along with their proposed monitoring methodology. Other short-term monitoring will be conducted in association with specific Project activities (e.g., blasting management, water diversion, fish handling, and salvage). In addition, there is some uncertainty regarding the number and precise timing of juvenile and adult fish that will use the EFSFSR tunnel and fishway (Brown and Caldwell, Rio ASE, and BioAnalysts, Inc. 2021). As part of the adaptive management program, initial monitoring and evaluation will be key to understanding those uncertainties. Monitoring elements established for EFSFSR tunnel will include: • Monitor adult approach (downstream - PIT tag station). • Monitor adult fishway entrance (North portal - video). • Monitor adult fishway exit (South portal - video). • Monitor adult entrance and exit times via adult entrance and exit times (video) and PIT-tagged juvenile and adult entrance and exit times. • Document trap and haul passage, date, and time. • Monitor adult resting pool and entrance behavior. • Document adult passage success. • Document fish health. A number of metrics and indices or indicators are available and appropriate for evaluating the status, trends, and condition (or health) of aquatic communities based on monitoring results. Some have been previously described such as the metrics in Table 7-1 of the FMP, and others, such are the Stream Macroinvertebrate Index are widely used in biological monitoring in Idaho. Some biological metrics such as redd counts and distribution, fish abundance, species composition, may not have expected values or standards based on literature but can be compared to baseline biological conditions and trends. Other metrics that describe instream habitat and channel condition and dynamics will be compared to Watershed Condition Indicator (WCI) functional conditions (i.e., pool frequency, large woody debris, etc.) to evaluate habitat and channel conditions in restored stream reaches compared to baseline while some parameters will also be compared initially to stream enhancement/restoration designs (Rio ASE 2021a) as part of implementation and compliance monitoring. Other indicators are multi-metric indices that provide more robust and provide greater insight into stream and watershed condition, including WCI, Stream Functional Assessment, SMI. These multi-metric indices generally are scored or rated based on scoring criteria that are based on expectations generated from streams of similar size in the same geographic region. Individual metrics or subgroups of metrics can be used alone, or the entire set of metrics can be combined into an overall score indicative of stream condition, health, or biological integrity. The results of stream habitat, riparian, and biological monitoring will be analyzed and presented in tables, figures, and text and interpreted in a manner consistent with the data and sampling design. Summary analysis will provide a comparison of metrics to certain published standards, comparison to baseline and degree of change, and when sufficient data have been collected, the analysis of trends. Specific requirements for certain physical or	Fish and Aquatic Resources Mitigation Plan, Section 5.5.1

Description	Reference
biological monitoring may be required by permits (e.g., Idaho Pollutant Discharge Elimination System [IPDES], 401 Water Quality Certification) and the reports will be adapted to meet those requirements through consultation with the Forest Service and permitting agencies. Perpetua will create annual summary reports of the results of stream habitat and biological monitoring for submittal to the Forest Service, permitting agencies, and other stakeholders. The monitoring data will then be utilized for adaptive management of the Project and site restoration as warranted. Adaptive management is the process of adjusting management actions and/or directions based on new information as it becomes available. Adaptive management is an approach that recognizes and prepares for uncertainty (e.g., in simulated outcomes, restoration effectiveness, etc.) and natural events or disturbance (climate change, flooding, fire, etc.). It couples the decision-making process with monitoring, performance criteria, and ongoing evaluation, and is typically implemented with explicit process steps and needed adjustments when monitoring indicates that performance objectives are not being met. That is, if the results of the monitoring program indicate that mitigation measures are failing to achieve the ecological performance standards as anticipated, reasons for failure will be evaluated and corrective actions will be proposed to correct shortcomings. There is inherent uncertainty in elements of forecasted impacts and the anticipated effectiveness of management measures and mitigation plans. Certain monitoring elements described above, such as monitoring of specific stream functional assessment (SFA) habitat elements, water quality monitoring, streamflows, and fish and aquatic community monitoring are examples of monitoring that will be implemented in an adaptive management framework once performance expectations are established. Three elements are needed for an adaptive management strategy: (1) a clear statement of the metrics and indicators by which progress toward achieving goals will be tracked; (2) a monitoring and evaluation plan for tracking such metrics and indicators; and (3) a decision framework through which new information from monitoring and evaluation is used to adjust strategies or actions aimed at achieving recovery goals.	
Surface water monitoring components of the Water Resources Monitoring Plan (WRMP) (Brown and Caldwell. 2021c.) includes measurement streamflow, water temperature, pH, specific conductance, oxidation-reduction potential, dissolved oxygen (DO), and turbidity at various locations through the mine site, as well as collection of water samples for laboratory analysis of multiple constituents including metals. Thirty-three surface water monitoring locations proposed in the WRMP are located upstream and downstream of Project activities and facilities such as the worker housing area, the TSF, open pit mining operations, the ore processing area, and the downstream boundary of the mine operations area on the EFSFSR.	Fish and Aquatic Resources Mitigation Plan, Section 7.3 Water Resources Monitoring Plan, Section 4.2.1
Meeting Project water consumption needs for mining and ore processing depends on diversion of surface water from the EFSFSR during times when groundwater production is insufficient to meet consumptive use needs. When operating the surface water diversion from the EFSFSR, Perpetua will follow one of two approaches: 1. When make-up water is required from the river, the EFSFSR intake pumps will be operated at or near the full 4.5 cfs to fill the Midnight Pond booster tank to a high-water level, at which point level sensors in the Midnight Pond booster tank will shut off the pumps. The booster pumps will then drain the tank at whatever demand is required from the process plant to a low-water level, at which point the EFSFSR intake pumps will start up again and fill the tank. For this method, the Midnight Pond booster tank will need to be sized to limit the number of starts and stops on the EFSFSR intake pumps, such that there are no more than six pump starts per hour. 2. When make-up water is required from the river, the EFSFSR intake pumps will be turned on and the variable frequency drive (VFD) on the pumps will target a particular water surface elevation in the Midnight Pond booster tank, based on input from a level sensor in the tank. If the demand is less than 50% of the duty point of the intake pumps, the pump will fill the tank to a high-water level and will shut off. When the booster pumps drain the tank, the intake pumps will again turn on and target the same water surface elevation. In this case, likewise, the Midnight Pond booster tank will need to be sized to limit the number of starts and stops on the EFSFSR intake pumps to no more than six pump starts per hour. A safety measure will be employed at the intake to ensure that fish passage and downstream ecological requirements are met in the EFSFSR diversion, if the pump demand is greater than the flows in the EFSFSR or greater than some allowable reduction in EFSFSR flows (i.e., 20% diversion of EFSFSR flow as measured below the Sugar Creek confluence). A low-level float switch will be provided in the wet well, such that if the water level	Fishway Operations and Management Plan, Appendix G, Section 5.7 Fishway Operations and Management Plan, Appendix G, Table 3-2

Description	Reference
drops below a defined level the pumps will turn off and no water will be withdrawn, and a low-level alarm will alert operators of the pump shutoff. The level of this float switch will need to be coordinated with the downstream minimum flow requirements but should be easily located due to the controlled water surface in the Fish Tunnel's south portal forebay. This float switch will also protect the pumps from drawing the wet well down below the minimum submergence level and entraining air in the pipeline which could cause damage to the pumps. The screen design for the stream water intake utilizes a brushed cone screen that adheres to criteria set by the 2011 NMFS Anadromous Salmonid Passage Facility Design guidelines for maximum approach velocity (0.4 ft/s, NMFS 11.6.1.1), flow distribution (near uniform, NMFS 11.6.1.4), screen inclination (45 degrees, NMFS 11.6.1.6), maximum circular screen opening diameter (3/32 inch, NMFS 11.7.1.1), maximum rectangular screen opening width (1/16 inch, NMFS 11.7.1.2), maximum square screen opening dimension (3/32 inch, NMFS 11.7.1.3), corrosion resistant screen material (NMFS 11.7.1.4), minimum screen open area (27%, NMFS 11.7.1.6), flush screen surfaces (NMFS 11.8.1.1), structural features to protect screen integrity (NMFS 11.8.1.2), and associated civil works to prevent eddies and stagnant zones around the screen (NMFS 11.8.1.3).	
There will be three potential sources of turbidity associated with an IPDES outfall. The first is any that will come out with the treated wastewater. The proposed water treatment plant (WTP) will remove nearly all of the total suspended solids (TSS) prior to discharge from the WTP. There is not necessarily a direct correlation between TSS and turbidity; however, with minimal TSS in the water, it can be expected that the turbidity in the WTP discharge will also be very low. The second potential source is any turbidity on the stream bottom that will be disturbed when the outfall enters the stream and may have the potential to stir up any bottom sediment in the immediate vicinity. The area surrounding and downstream of the discharge location will have cobble-gravel-boulder substrates. Therefore, the operating outfalls will create very little if any turbidity and any such minor turbidity will be quickly dissipated. The third potential turbidity source will be erosion of the outfall channel itself; this will be prevented by designing and constructing the outfall channel and transition to the receiving water to resist erosion, which is readily accomplished given the water treatment outfall flow is both known and small (peaking at 2,000 gallons per minute [gpm]). The outfall channel will have riprap to dissipate energy as flow is transitioned to the creek channel. In addition, any discharge from the underdrains will not be turbid since it will originate from seeps beneath the TSF and Buttress and will not have the potential to pick up sediment within the drainpipes.	Perpetua communication 9/20/22
Trap and haul is not the preferred method of passage at the EFSFSR tunnel. Volitional passage through the fishway is the preferred passage method. Trap and haul will only be used when it is deemed necessary to avoid further delay of adult passage near or during the spawning period. At one week prior to the spawning period, if adults present in the resting pool below the fishway have not entered the fishway over a 48-hour period and proceeded up the fishway they will be collected and transported upstream without further delay. Fish that arrive at the EFSFSR tunnel several weeks prior to the spawning period will be given full opportunity to pass volitionally through the fishway. This approach will be reassessed and modified as needed annually with the Fisheries Technical Team. Chinook Salmon, steelhead, and bull trout are the target fish species. Adult westslope cutthroat trout may be transported opportunistically with final approval of this plan. Chinook Salmon: (July 7 to September 15); Steelhead: (April 1 to May 31); Bull Trout: (June 15 to September 15) - The migration period will be monitored via fishway video and PIT tag detections in the fishway. In addition, environmental staff will also provide input on visual observations of adults near the fishway entrance. Arrivals at the fishway and redd surveys will be conducted to refine migration and spawning periods of fish passing the EFSFSR tunnel. Information will be presented annually to the Fisheries Technical Team and periods of migration and spawning will be adjusted as needed. Staff and facility will be prepared and ready for trap and haul transport from April 1 to September 15. The operational period may be adjusted as needed based on monitoring of migration and spawning behaviors and recommendations provided by the Fisheries Technical Team.	Fishway Operations and Management Plan, Appendix C, Table 1

Description	Reference
Based on annual aquatic resources survey results, the range in the number of adults estimate at the fishway annually is: o Chinook salmon: 4 – 94 o Steelhead: 3 – 93 o Bull Trout: 100 The trap and haul facility will be sized to handle 100 Chinook salmon, 100 steelhead, and 100 bull trout annually. Trap and haul transport tanks will be sized to handle at least 20% of the expected annual return for each species within a single day with two trap and haul transports. Capture pool volumes will be 840 cubic feet (ft^3) at a streamflow of 8.2 cubic feet per second (cfs), 946 ft^3 at a streamflow of 54 cfs, and 1,372 ft^3 at a streamflow of 239 cfs. Fish will be crowded within the first fishway pool with removable picket panels and netted with a large sanctuary dip net. Once in the sanctuary dip net, fish will be removed and placed into a wetted transfer boot to move fish from the capture pool to the transport tank. Water-to-water transfer is the goal with loading density at or below 0.06 kg/L (0.5 lb./gal). Tank(s) volume will be 1,100-1,900 L (300-500 gal) that will have the capacity to hold from 13-31 fish depending on tank volume and fish species transported. Trap and haul is only expected to occur once per day but may occur twice if target species need to be separated (i.e., bull trout and Chinook salmon) or there is sufficient fish onsite that require more than one transport. There are three proposed release sites that are at least 1.5 miles upstream from the EFSFSR Tunnel: • EFSFSR – Just upstream from the NF-375 road crossing but below the confluence of the EFSFSR with Meadow Creek (transport time 6 to 10-minutes). • EFSFSR – Release fish near the confluence of Fern Creek where there is road access to the stream and Chinook salmon were released in 2001 (transport time 11 to 19- minutes). • Meadow Creek - Release fish in Meadow Creek where they have been outplanted in the past. The Meadow Creek outplant location is at the west end of the Stibnite airstrip at the old bridge location to access the EFMC area (44 53’ 46” N, 115 20’ 17.3” W). This site might not be available depending on year and mine site activity (transport time 8 to 13-minutes).	
The EFSFSR tunnel is divided into a fishway and accessway. The fishway consists of an elevated fishway channel with a concrete partition/divider wall along the length of the tunnel with intermittent weirs that provide depth and velocity control. The channel is designed to accommodate a one-foot hydraulic drop between pools with a streaming flow over the weirs (submerged weir flow). Computational Fluid Dynamics (CFD) modeling was developed to aid in weir sizing/spacing and to confirm hydraulic performance of the proposed fish channel configuration. CFD modeling estimates that the velocities over each weir are maintained below 6.5 feet per second (fps) in all cases (i.e., throughout the fishway design flow range of 8 to 239 cfs total river flow) and the average velocity in the pool sections between the weirs is maintained below 2.0 fps. The partition/divider wall will be five feet high and extend the length of the tunnel. The wall confines streamflow below 25 cfs within the fishway channel, and the flow control weir regulates the partitioning of streamflow above 25 cfs between the fishway and accessway. Concrete weirs will be installed within the fishway to maintain the 1-foot hydraulic drop, with weir spacing dependent upon the slope of the tunnel -22 feet at 4.5 percent, and 66 feet at 1.5 percent. A nine-foot wide accessway will run the length of the tunnel parallel with the fishway. The accessway (or access road) will allow for inspection and maintenance of the tunnel as well as the fishway. Muck bays within the accessway are alcoves built into the side of the tunnel utilized during tunnel construction to aid in efficient removal of blasted rock. These bays will be sloped to drain towards the accessway upon tunnel completion to prevent the formation of pools that may potentially delay or strand juvenile fish that enter the accessway during high-water events. The accessway itself will follow the gradient of the tunnel floor at a slope of 1.5 percent or steeper from south (upstream) to north (downstream), thereby avoiding pools or sections of adverse gradient that could delay or strand out-migrating juveniles.	Fishway Operations and Management Plan, Section 2.4 Fishway Operations and Management Plan, Section 4

Description	Reference
Tunnel lighting will be included along the length of the tunnel ceiling, consisting of LED lights on a dimming system. From research of existing data on fish passage in tunnels, it is unclear if lighting is a benefit or not; however, there is strong evidence that abrupt lighting transitions should be avoided. Lighting will be provided to determine if it aids in fish passage and to provide light for tunnel and fishway inspections. The system will be configured so that it mimics the photoperiod of the region, runs manually on an auto-dimming system, or can be completely or partially turned off at the option of the operator. Fish passage will be monitored relative to the effectiveness of the lighting, and lighting may be adjusted or eliminated if found most functional during certain periods of the day/year. There is some uncertainty regarding the number and precise timing of juvenile and adult fish that will use the EFSFSR tunnel and fishway (Brown and Caldwell, McMillen Jacobs Associates, and BioAnalysts 2021). As part of the adaptive management program, initial monitoring and evaluation will be key to understanding those uncertainties. Monitoring elements established for EFSFSR tunnel will include: • Monitor adult approach (downstream - PIT tag station). • Monitor adult fishway entrance (North portal - video). • Monitor adult fishway exit (South portal - video). • Monitor adult entrance and exit times via adult entrance and exit times (video) and PIT-tagged juvenile and adult entrance and exit times. • Document trap and haul passage, date, and time. • Monitor adult resting pool and entrance behavior. • Document adult passage success. • Document fish health. The adaptive management proposed relies on monitoring and evaluation to determine if fishway objectives are being met, determine if corrective actions are required, and establish a timeline for completion for adaptive management actions. An element of the FOMP is a framework for reporting, feedback, and decisions on adjustments to fishway operations. Perpetua will develop, in coordination with the Services, an acceptable reporting format and content to address objectives established for fish monitoring and evaluation of the EFSFSR diversion tunnel. The report will organize and assess the physical and biological monitoring results relative to the agreed-upon criteria. The results of monitoring will provide the basis for learning about fishway operations performance and fish passage performance, serving as the basis for further evaluation and adjustments. Perpetua envisions phased decision points that will be based on monitoring results and coordination with the Services. First, decisions about operating the fishway and whether trap and haul operation is appropriate in any given year might be appropriate. Second, decisions about specific adjustments to fishway operations based on performance. However, some learning must occur first before such decisions can be made, and learning will require the operation of the fishway for some period before adaptive adjustments can be made. Formation of a Fisheries Technical Team with representatives from various resources agencies will be advantageous in the adaptive management process and will likely include the Forest Service, USFWS, NOAA and the tribal nations. The initial implementation check point will be an annual review how the fishway is operating and how it will be operated each year (operation of fishway, trap and haul, or no operation of fishway) and with consideration for its relationship to Chinook salmon stocking in the EFSFSR. The second is a check point about specific detailed adjustments to the fishway operation involving criteria so that if any unusual or unexpected events occur that result in adverse impacts to the species during operations, fish passage through the fishway will be switched to trap and haul operations. Perpetua will review with the Services annual operations after the first year of operations, and after the second year for determination of necessary fishway operational adjustments. This approach allows monitoring and performance to be addressed and decisions made with new information. Other options may be considered, including the timing of information sharing and operations decisions. If it is determined that established performance standards may not be attainable, new standards may be developed. Perpetua will work with regulatory agencies and other project partners to refine the details of this adaptive management.	

Table A-2. Summary of Environmental Design Features and Protection Measures: Fish – Sediment.

Description	Reference
Erosion and sediment runoff will be reduced to improve water quality and fish habitat by placing growth media to encourage healthy vegetative growth and reforesting select legacy impacted and burned areas in and around the Project areas with appropriate native species.	2021 Modified Mine Plan
Stormwater runoff from undisturbed areas upslope of mine features in the major drainages will be captured in the stream diversion channels described above or in other channels that will direct runoff away from disturbed areas. Smaller-scale diversion channels or earthen berms will be used, where necessary, to divert stormwater around other mine infrastructure.	2021 Modified Mine Plan
Stormwater drains, ditches, and stream channels will be protected against erosion through a combination of adequate dimension, appropriate gradient, riprap, fabric- encapsulated soil lifts, or other stabilization materials. Diversions will be sized for a peak flow recurrence interval appropriate to the risk level of the facility, in recognition of other water management measures and fail-safes in place (excess flood storage and freeboard in the Tailings Storage Facility [TSF], etc.), and in accordance with regulatory standards.	2021 Modified Mine Plan
Existing streams that run through areas proposed for mining related disturbance will be diverted to prevent generation of contact water or commingling of contact and non-contact water, keeping clean water clean; and to prevent flooding of mine facilities by runoff generated off site (e.g., Meadow Creek diversions are in segments where bull trout have been detected. The East Fork South Fork Salmon River (EFSFSR) tunnel will modify access for bull trout in the EFSFSR below its confluence with Meadow Creek. Bull trout have not been detected in Fiddle, Garnet, or Midnight Creeks).	2021 Modified Mine Plan
Crushed rock will be placed on Stibnite Gold Project (SGP) access roads as needed to provide a durable surface and limit sediment transport.	2021 Modified Mine Plan
Road surfaces throughout the SGP will be stabilized and managed to minimize transport of sediment, dust, and other materials, especially near watercourses through appropriate road engineering, surface drainage, watering, and application of dust control binding agents (magnesium chloride, lignin sulfonate, etc.), roadside ditching, road-cut stabilization, road surface maintenance, appropriate speed limits, and by limiting traffic (e.g., via the standard practices of busing, vanpooling, consolidating deliveries at the Stibnite Gold Logistics Facility (SGLF) plus public access restrictions to Project roads).	2021 Modified Mine Plan
During Burntlog Route and SGP haul road construction and use, Perpetua will install and maintain sediment control measures and devices, such as culverts, culvert inlet protection devices, ditching, silt fencing, straw wattles, straw bales, and sediment catch basins.	2021 Modified Mine Plan
Erodible cut and fill slopes along roads will be mulched, hydro-seeded or have durable rock inlay material to minimize the potential for sediment generation.	2021 Modified Mine Plan
During winter road maintenance, Perpetua will remove snow from the Burntlog Route and haul roads at the SGP and the temporary construction access Yellow Pine Route. Perpetua will avoid disposal of snow in riparian areas, wetlands, or areas where snowmelt might cause road damage or erosion during spring melt. Care will also be taken to dispose of collected snow, which may contain sand or gravel, in a manner that avoids impacts to nearby streams and rivers. Measures developed for winter road maintenance for the Golden Meadows Exploration Project will be extended to Project access roads namely: • Except snow and ice, all debris that is removed from the road surface and ditches will be deposited away from stream channels at approved locations. • During snow removal, banks will not be undercut and gravel or other surfacing material will not be bladed off the roadway surface. An appropriate snow depth will be maintained on gravel/native access road surface to protect the roadway. Internal mine haul roads utilized by heavy equipment will be plowed to their gravel running surface. • Ditches and culverts will be kept functioning during and following plowing. Berms left on the shoulder of the road will be removed and/or drainage openings will be created and maintained. Drainage openings will be spaced to maintain satisfactory surface drainage without discharge on erodible fills. • Damage of roads from, or as a result of snow removal will be repaired in a timely manner.	2021 Modified Mine Plan

Description	Reference
• Culverts and stream crossing swill be clearly marked before snow removal begins to avoid placing berm openings in locations that will allow runoff to enter drainages directly at the culvert or stream crossings. • Excessive snow will not be plowed into locations that will impact operation of the culverts or prevent positive drainage from drainage areas. No chemicals will be used.	
Perpetua will use coarse sand (with less than 20% fines) for winter sanding of the main access road and SGP haul roads in combination with a fine to medium gravel as needed, (approximately 1/4 - 5/8-inch sizing).	2021 Modified Mine Plan
Site-specific analysis using calculated risk tools, or another method will be documented in the project record for stream crossings designed to accommodate <100-year flood recurrence interval.	2021 Modified Mine Plan
To provide protection to the EFSFSR, snow removal for Stibnite Road will be accomplished in accordance with the following standards of performance: Except snow and ice, all debris that is removed from the road surface and ditches will be deposited away from stream channels at approved locations.	2021 Modified Mine Plan
Select areas within and immediately adjacent to the Project site that have been severely impacted by forest fires will be replanted to reduce soil erosion, landslides, debris flows, and sediment run-off, which contribute to sediment levels in local drainages and degrade water quality and fish habitat. Perpetua will coordinate with Forest Service to identify restoration opportunities.	2021 Modified Mine Plan
When taking water from fish-bearing waters for road and facility construction and maintenance activities, intake hoses shall be screened with the most appropriate mesh size (generally 3/32 of an inch), or as determined through coordination with NOAA Fisheries and/or the U.S. Fish and Wildlife Service.	BNF and PNF: FRST01 TEST32
Fish passage shall be provided at all proposed and reconstructed stream crossings of existing and potential fish-bearing streams.	BNF and PNF: SWST08
Surface water withdrawal intake hoses will be situated so as to prevent generation of turbidity in bottom sediments during pumping.	2021 Modified Mine Plan
Where settlement ponds, tailing dams, or impoundments are planned, each will be located, designed, constructed, and inspected under the supervision of a professional engineer.	BNF and PNF:MIGU03

Table A-3. Summary of Environmental Design Features and Protection Measures: Vegetation – General.

Description	Reference
Disturbed areas will be returned to self-sustaining perennial vegetation by establishing persistent native vegetation cover in the reclaimed areas, creating dry to wet shrub and grassland vegetation community structure with some areas that are composed of tree species, and planting and seeding shrub, grass, and tree species that are present in the existing dominant vegetation communities within and adjacent to the Project area.	2021 Modified Mine Plan
A vegetative community will be established on disturbed area that is reflective of species native to the area and that will encourage and support the development of healthy wildlife populations.	2021 Modified Mine Plan
Prior to site preparation and construction of surface facilities, vegetation will be removed from operating areas. Merchantable timber on National Forest System (NFS) surface lands could be purchased from the Forest Service (USFS). Non-merchantable trees, deadwood, shrubs, and slash will be removed, and any remaining vegetation will be grubbed using a bulldozer. The resulting material will be saved for future use in reclamation activities. Specifically, the organic matter will be chipped and stockpiled for use as mulch or blended to create a growth media additive. After vegetation removal, growth media will be salvaged and stockpiled. Stockpiles will be stabilized, seeded, and mulched to protect the stockpiles from wind and water erosion.	2021 Modified Mine Plan
Perpetua will inspect and remove vegetation material (including noxious weeds) from mechanical equipment and properly dispose to minimize the spread of unwanted vegetation.	2021 Modified Mine Plan
Wood wastes and wood mulch are the two primary sources of compost. Food waste produced from on-site meal preparation and wastes may provide another source. Combined and properly managed during composting, these materials will provide a source of organic matter to be blended into substrate materials suitable for mitigation.	2021 Modified Mine Plan
Develop and employ planting plans for wildlife benefits (cover, forage, etc.) using approved seed mixes.	2021 Modified Mine Plan
Perpetua will use aquatic safe herbicides during vegetation management activities and noxious weed control. Adhere to chemical label restrictions, federal/state rules on usage. Use proper equipment for chemical application by trained personnel.	2021 Modified Mine Plan
Erosion control techniques at the Stibnite Gold Project (SGP) will include mulching, wetland sodding; planting of vegetation to stabilize slopes; and use of silt fences, biofilters, brush mats, erosion control fabric, and/or fiber rolls along temporary swales, perimeter dikes, and stream banks. In addition, to minimize human disturbance, permanent signage will be posted around the perimeter of individual project sites to prohibit unauthorized foot traffic and the use of all-terrain vehicles and motorbikes, dumping, draining, and cutting and/or removal of plant materials.	2021 Modified Mine Plan
Perpetua will employ vegetation maintenance for safety along roads, removal of hazard trees, and riparian conservation areas, etc. – coordinate such that wildlife protection and restoration are incorporated during maintenance.	2021 Modified Mine Plan
Historically and newly impacted sites will be re-contoured to reduce sediment run off and enhance vegetative growth and habitat development.	2021 Modified Mine Plan
If disturbance cannot be avoided, the plant should be dug up and set aside in a protected area with the topsoil until it can be used in reclamation. The plants should then be replaced at their original site if possible before the end of the field season or as soon as possible to avoid desiccation.	2021 Modified Mine Plan
If straw mulch is used, it will be certified as weed-free, applied at a rate of about 3,000 pounds per acre, and applied over a raked seedbed.	2021 Modified Mine Plan
In areas where construction or early interim reclamation is implemented, the sites will be seeded with species and at amounts specified. The ultimate species selection will be based on a USFS recommended listing of reclamation plants, seed and tree availability, and cost.	2021 Modified Mine Plan

Description	Reference
In Project areas where sensitive plant species are documented or there is potential habitat for it, no seeding or mulching will be conducted, and duff will be raked onto the disturbed area with minimal application of large woody material.	2021 Modified Mine Plan
Perpetua plans to plant approximately 3,600 trees annually on burnt-over land and un-reclaimed legacy disturbance adjacent to the Project.	2021 Modified Mine Plan
Perpetua will plant tree seedlings on hill slopes; the species variety will depend on slope, aspect, and elevation and planting spacing will vary but will be approximately 12 feet by 12 feet.	2021 Modified Mine Plan
Legacy impacted and newly disturbed and burned areas in and around the Project area will be reforested with appropriate native species, which will help reduce erosion, sediment run-off, and risks of debris flows and avalanches.	2021 Modified Mine Plan
Perpetua will use either a wood, straw, or fabric mulch. Fabric mulches include jute netting and Excelsior erosion control blankets (or their equivalent) and fabric mulches will be tacked, crimped, or otherwise secured to withstand windy conditions common in the mountainous areas of Idaho.	2021 Modified Mine Plan
Minimizing the overall disturbance of the Project and impacts to undisturbed areas by siting, to the extent practicable, proposed facilities and roads on previously disturbed ground.	2021 Modified Mine Plan
On disturbed slopes greater than 30% in grade, Perpetua will apply mulch to aid in stabilizing the area to minimize or prevent erosion, as well as to promote revegetation.	2021 Modified Mine Plan
Project-related impact to soils will be minimized to the extent practicable.	2021 Modified Mine Plan
Removal or disturbance of vegetation will be kept to a minimum by limiting the area of disturbance, to the extent practicable, to maintain safe and efficient operations.	2021 Modified Mine Plan
Vegetation and soil removal will occur in a manner that minimizes erosion and sedimentation.	2021 Modified Mine Plan
In revegetation and seeding projects in occupied Threatened, Endangered, Proposed, or Candidate plant habitat, a Forest botanist shall be consulted to ensure appropriate species are used.	BNF and PNF: TEST09
When available and not cost-prohibitive, seeds and plants used for seedings and plantings in revegetation projects should originate from genetically local sources of native species. When project objectives justify the use of non-native plant materials, documentation explaining why non-natives are preferred should be part of the project planning process.	BNF and PNF: BTGU03
Trees or snags that are felled in riparian conservation areas will be left unless determined not to be necessary for achieving soil, water, riparian, and aquatic desired conditions. Felled trees or snags left in RCAs will be left intact unless resource protection (e.g., the risk of insect infestation is unacceptable) or public safety requires bucking them into smaller pieces.	BNF and PNF: SWST10

Table A-4. Summary of Environmental Design Features and Protection Measures: Vegetation – Noxious Weeds.

Description	Reference
Establishment and spread of noxious weeds and invasive plant species on Project areas will be prevented.	2021 Modified Mine Plan
Perpetua will be responsible for noxious weed control within areas disturbed by Stibnite Gold Project (SGP) activities.	2021 Modified Mine Plan
All access routes, drill platforms, pad locations, and sump construction sites will be inspected prior to Project-related activities and if they are found to be weed-infested, then the weed infestation will be treated prior to ground disturbing activity per the Forest Service's (USFS) weed management program.	2021 Modified Mine Plan
Any pulled weed will be burned in a secure site (with a burn permit) or bagged and removed and disposed of as per County Extension Service recommendations.	2021 Modified Mine Plan
Noxious weeds may be removed from the Project area by hand pulling and/or hand digging and herbicide methods described below.	2021 Modified Mine Plan
Prior to construction disturbance, known weed populations in the specific disturbance area will be flagged so that they may be avoided.	2021 Modified Mine Plan
Herbicide use, where prescribed, will be in accordance with the South Fork Salmon River Sub Basin Noxious and Invasive Weed Management Program (Forest Service 2010b). Infestations within 100 feet of live water will be controlled by hand pulling. Disposal of weeds will also be in accordance with the above plan.	2021 Modified Mine Plan
In areas of extensive weed infestations, designated wash sites for equipment should be established. Wash sites should be located: (1) where they are easily accessible and useable; (2) on gravelly or well-drained soils; (3) where wash water runoff will not carry seeds away from site; (4) where wash water runoff will not directly enter streams; and (5) where they may be used repeatedly for several projects or activities within the area.	2021 Modified Mine Plan
In areas with sensitive plant species present, noxious weeds should be removed from the Project area by hand pulling and/or hand digging.	2021 Modified Mine Plan
Limit preconstruction weed treatments, such as mechanical control and herbicide application, to areas expected to have unavoidable ground-disturbing activities.	2021 Modified Mine Plan
Noxious weeds may be removed from the Project area by applying herbicide in a controlled fashion per the labeled instructions.	2021 Modified Mine Plan
USFS and/or Valley County-approved herbicides (Forest Service 2010b) will be used to prevent and restrict the spread of noxious and invasive weeds.	2021 Modified Mine Plan
Vegetation removal and maintenance work should be conducted in accordance with the Weed Management Plan.	2021 Modified Mine Plan
Where feasible and practical, weed-free locations should be selected for incident camps, staging, cargo loading, drop points, helibases, and parking areas.	2021 Modified Mine Plan
Noxious weeds and undesirable non-native plants will be eradicated in the Operations Area boundary, within permitted use areas, and the cut/fill slopes of roads and trails used by mine and mine facility related traffic. Where it is not practical to eradicate existing infestations, infestations will be managed to prevent seed production and spread. In areas of existing extensive infestation, mitigation for noxious weed prevention will be incorporated into road layout, design, and Project evaluation.	Design Feature developed for compliance with BNF and PNF: FRGU02, TEST10
Clean borrow and gravel sources on Forest should be maintained as noxious weed free through an inspection and treatment program. Off-Forest inspections and treatments should be coordinated with county weed agents.	BNF and PNF: NPGU02
All seed used on National Forest System (NFS) lands will be certified to be free of seeds from noxious weeds listed on the current All States Noxious Weeds List.	BNF and PNF: NPST02

Description	Reference
Materials such as hay, straw, or mulch that are used for rehabilitation and reclamation activities shall be free of noxious weed seed and shall comply with the 1995 weed-free forage special order against use of non-certified hay, straw, or mulch. Materials that are not covered under a weed seed free certification, and that have the potential to contain noxious weed seed, shall be inspected and determined to be free of weed seed before purchase and use.	BNF and PNF: NPST01, NPST06
Source sites for gravel and borrow materials shall be inspected for noxious weeds before materials are processed, used, or transported from the source site into the Project area or onto the National Forest.	BNF and PNF: NPST07
Gravel or borrow material source sites with noxious weed species present shall not be used unless effective treatment or other mitigation measures are implemented.	BNF and PNF: NPST08
To prevent invasion/expansion of noxious weeds, the following provisions will be included in the plan of operating where land-disturbing activities are associated with the authorized land use: a) Re-vegetate areas, as designated by the USFS, where the soil has been exposed by ground-disturbing activity. Implement other measures, as designated by the USFS, to supplement the influence of re-vegetation in preventing the invasion or expansion of noxious weeds. Potential areas will include: construction and development sites, underground utility corridors, skid trails, landings, firebreaks, slides, slumps, temporary roads, cut and fill slopes, and travel ways of specified roads. b) Earth-disturbing equipment used on NFS lands--such as cats, graders, and front-loaders--shall be cleaned to remove all visible plant parts, soil, and material that may carry noxious weed seeds. Cleaning shall occur prior to entry onto the Project area and again upon leaving the Project area if the Project area has noxious weed infestations. This also applies to fire suppression earth-disturbing equipment contracted after a Wildland Fire Situation Analysis/Wildland Fire Implementation Plan has been completed.	BNF and PNF: NPST03
Integrated weed management shall be used to maintain or restore habitats for sensitive plants and other native species of concern where they are threatened by noxious weeds or non-native invasive plants. Specific measures to reduce the potential for spread and establishment of noxious weed infestations could include, but are not limited to, determining the presence, location, and amount of noxious weed infestations in the Operations Area, developing management strategies such as, methods and frequency for treating infestations, treatment procedures and restrictions, reporting requirements, and follow-up or monitoring requirements. Herbicide applications will be by or under the direct supervision of licensed Idaho professional herbicide applicators with Aquatic Pest Control certifications and will be consistent with the Boise National Forest Invasive Species Management Plan and Payette National Forest guidance.	Design Feature developed for compliance with BNF and PNF: NPST11

Table A-5. Summary of Environmental Design Features and Protection Measures: General Road Use and Maintenance.

Description	Reference
Minor surface improvements (e.g., ditch and culvert repair, adding gravel, winter snow removal, and summer dust suppression) will occur on the Yellow Pine Route to reduce sediment runoff and dust generation.	2021 Modified Mine Plan
Once all final mine closure/reclamation work has been completed, Perpetua will reduce the 21-foot-wide travel way of 19.8 miles of Burntlog Road (FR 447), 1.3 mile of Meadow Creek Lookout Road (FR 51290), and 2.0 miles along Thunder Mountain Road (FR 375) of Burntlog Route to their approximate pre-mining width.	2021 Modified Mine Plan
The approximately 15 miles of Burntlog Route connecting to Meadow Creek Lookout Road (FR 51290) and Thunder Mountain Road (FR 50375) will be decommissioned.	2021 Modified Mine Plan
Following mining and ore processing operations, unless they are taken over by a third-party for ongoing use and maintenance, the Burntlog Maintenance Facility buildings will be removed. The sewer system and septic tanks for the facility will be decommissioned. Soil/rock beneath fuel storage areas and chemical storage buildings will be tested for contamination. All reagents, petroleum products, solvents, and other hazardous or toxic materials will be removed from the site and disposed of according to applicable state and federal regulations. After demolition of the buildings and facilities, the site will be graded, and drainage restored.	2021 Modified Mine Plan
A new 12-foot-wide gravel road will be constructed to provide public access from Stibnite Road (FR 50412) to Thunder Mountain Road (FR 50375) through the Stibnite Gold Project (SGP). During operations, the public access road will be used to travel through the SGP and will provide seasonal use, open to all vehicles. Vehicles passing through the SGP will be required to check-in with mine personnel at the North or South SGP entry points.	2021 Modified Mine Plan
Post reclamation, a road will be established over the backfilled Yellow Pine Pit (YPP) to allow public access through the reclaimed site and connect Stibnite Road (FR 50412) to Thunder Mountain Road (FR 50375). This will replace the operational phase public access route.	2021 Modified Mine Plan
New roads constructed for the Project on National Forest System (NFS) lands will be closed and reclaimed, as required by Forest Service (USFS), once they are no longer needed to support Project construction and operations.	2021 Modified Mine Plan
Project-related traffic will be restricted to existing roadways and Project areas. Off-road travel in previously undisturbed areas will be forbidden.	2021 Modified Mine Plan
Road rutting from operations, outside the mine site, will be minimized by construction and maintenance of surface drainage structures, application of surfacing material, and by restricting road use when conditions are unacceptable due to moisture that is leading to the onset of rutting and concentrated turbid flow (Note typical guidance is ‘no use’ if ruts deeper than 4” are created.). This design feature does not apply to the mine site.	Developed to lessen impacts under BNF and PNF: SWST02, SWST03
Handling of road waste material (e.g., slough, rocks) will avoid or minimize delivery of waste material to streams that will result in degradation of soil, water, riparian, and aquatic resources.	Developed to lessen impacts under BNF and PNF: FRST05
Mitigate degrading effects from locatable mine operations situated within riparian conservation areas (RCAs) by identifying reasonable locations for access, processing, and disposal facilities outside of RCAs, wherever possible.	BNF and PNF: MIST04, LSST07, MIST08, FRGU06
To minimize the degradation of watershed resource conditions, prior to expected water runoff, water management features will be constructed, installed, and/or maintained. Activities and features include, but are not limited to, water bars, rolling dips, seeding, grading, slump removal, barriers/berms, distribution of slash, and culvert/ditch cleaning in all applicable areas.	BNF and PNF: MIST04, LSST07, MIST08, FRGU05

Description	Reference
To accommodate floods, including associated bedload and debris, new culverts, replacement culverts, and other stream crossings will be designed to accommodate a 100-year flood recurrence interval unless site-specific analysis using calculated risk tools or another method, determines a more appropriate recurrence interval.	Developed to lessen impacts under BNF and PNF: SWST01, SWST04
To minimize sediment runoff from the temporary roads and roadbeds, water management features will be constructed, installed, and/or maintained on authorized temporary roads and roadbeds, on completion of use, before expected water runoff, or before seasonal shutdown. Activities and features could include, but will not be limited to, water bars, silt fencing, certified weed-free wattles, and/or weed-free straw bales, rolling dips, seeding, grading, slump removal, barriers/berms, distribution of slash, and culvert/ditch cleaning. These features will be installed in strategic downslope areas and in RCAs, where and when appropriate.	BNF and PNF: FRST02
Snow removal will be accomplished in accordance with the following standards of performance: All debris, except snow and ice, that is removed from the road surface and ditches will be deposited away from stream channels at approved locations. During snow removal operations, banks will not be undercut, and gravel or other surfacing material will not be bladed off the roadway surface. Ditches and culverts will be kept functioning during and following plowing. Berms left on the shoulder of the road will be removed and/or drainage openings will be created and maintained. Drainage openings will be spaced to maintain satisfactory surface drainage without discharge on erodible fills. Dozers will be used on an as-needed basis for plowing snow. The dozer operator will maintain an adequate snow floor over the gravel road surface. Snow will not be totally removed to the gravel road surface. Appropriate snow floor depth will be maintained to protect the roadway. Damage of roads from, or as a result of, snow removal will be repaired in a timely manner. Culverts and stream crossings will be clearly marked before snow removal begins to avoid placing berm openings in locations that will allow runoff to enter drainages directly at the culverts or stream crossings. Excessive snow will not be plowed into locations that will impact operation of the culverts or prevent positive drainage from drainage areas. Some snow is necessary around culvert openings and in the bar ditches as this will insulate the ditch and culvert and will prevent the water in the ditch and culvert from freezing. No ice and snow removal chemicals will be used on roads. Traction material will be 3/8-inch	Developed to lessen impacts under BNF and PNF: SWST01, SWST04

Table A-6. Summary of Environmental Design Features and Protection Measures: General – Reclamation and Restoration.

Description	Reference
Facilities will be located on previously impacted lands when that location fits into mine operations.	2021 Modified Mine Plan
Productive lands that support wildlife and fisheries habitat and dispersed recreation will be established on Project-related surface disturbance.	2021 Modified Mine Plan
Approximately 37% of the reclamation will be done concurrent to mining and ore processing; the remaining 63% will be accomplished during closure. Annual reclamation activities are described in a schedule provided in Table 3-1 of the Reclamation Closure Plan (RCP). Concurrent reclamation areas will focus on construction period restoration efforts (e.g., East Fork Meadow Creek [EFMC], aka Blowout Creek) and laydown yards, Yellow Pine Pit (YPP) area facilities, and HFP area facilities. Closure period activities are focused on the WEP area, tailings storage facility (TSF) area, Fiddle growth media stockpile, and process plant area. This information is also presented graphically in Appendix C to the CMP.	2021 Modified Mine Plan
The YPP will be backfilled with WEP development rock during operations.	2021 Modified Mine Plan
A sinuous channel will be constructed through the backfilled area for the reconstructed East Fork South Fork Salmon River (EFSFSR) with an average valley gradient approximating the historical, pre-disturbance river gradient.	2021 Modified Mine Plan
The backfill will be placed to achieve a mounded final reclamation surface to promote drainage away from the WEP and prevent formation of a pit lake within Midnight Pit.	2021 Modified Mine Plan
The floor of the sidehill pit southwest of the main WEP will be graded to drain, covered with growth media, and revegetated.	2021 Modified Mine Plan
Perpetua will begin with placement of soil/rock cover material, then construct wetlands and restore Meadow Creek and its tributaries within appropriately sized lined floodplain corridors, place growth media, and revegetate the area.	2021 Modified Mine Plan
HFP will be fully backfilled with development rock to the valley bottom elevation or slightly higher during mine operations. There will be no HFP lake.	2021 Modified Mine Plan
Perpetua will manufacture growth media material using fines from glacial till sources mined from the YPP, available mulched vegetation, and off-site composted material.	2021 Modified Mine Plan
Planting, seeding, and mulching will be conducted in the fall and early winter to take advantage of snowpack and springtime moisture. Where cover crops are used in lieu of mulch, seeding will occur in the spring or fall followed by seeding of the permanent mixture.	2021 Modified Mine Plan
Reclamation monitoring will begin during concurrent reclamation at SGP facilities. Quantitative and qualitative monitoring of reclamation success will begin the first growing season after final reclamation is completed and will continue until success criteria are satisfied.	2021 Modified Mine Plan
Soil stability will be estimated for all reclaimed areas using qualitative descriptors.	2021 Modified Mine Plan
Slope stability will be monitored during the erosion inspections.	2021 Modified Mine Plan

If the performance of reclaimed areas is not satisfactory, appropriate maintenance activities will be implemented. Maintenance activities may include one or more of the following: • Sediment removal from sediment basins, stormwater drainage channels, and diversions as necessary to maintain their design capacity; • Diverting surface water away from reclaimed areas where erosion jeopardizes attainment of reclamation standards; • Stabilizing rills, gullies, and other erosion features or slope failures that have exposed development rock; • Noxious weed and invasive plant species control; and, • Re-seeding or re-applying reclamation treatments in areas where it is determined through monitoring and agency consultation that reclamation will not meet standards.	2021 Modified Mine Plan
Perpetua will submit an annual report to the Forest Service (USFS) and the other federal and state agencies that are responsible for issuing authorizations applicable to reclamation for the preceding calendar year. The annual report will contain descriptions of the reclamation activities completed during the previous year, a summary of areas reclaimed, a discussion of the results of the reclamation monitoring conducted, and corrective actions implemented.	2021 Modified Mine Plan
Perpetua or its designated contractor(s) will perform long-term maintenance as necessary, including maintaining and monitoring the Mitigation Area (including stream and wetlands) in perpetuity once the final performance standards are met or until such responsibility is relinquished to an appropriate third party (USFS, etc.) as approved by the U.S. Army Corps of Engineers (COE).	2021 Modified Mine Plan
Perpetua will plant stream reclamation reaches and wetland reclamation areas with native plant species that are present in PAB (palustrine aquatic bed), PEM (palustrine emergent marsh), PSS (palustrine scrub-shrub), and palustrine forested wetlands and riparian areas along streams throughout the Mitigation Area.	2021 Modified Mine Plan
Riparian fringe and floodplain wetlands will be established on the broad, gently sloping floodplains on both sides of the reclaimed stream channels.	2021 Modified Mine Plan
Valley margin wetlands will only be established where there is an upgradient water source sufficient to produce enough saturation and near surface water tables for wetland conditions.	2021 Modified Mine Plan
Wetland reclamation will begin after the end of mine construction, with the first reclaimed wetlands occurring in the EFMC drainage. Additional reclamation will occur in and after operational year 3 and continue through operations to closure year 25.	2021 Modified Mine Plan
Salvaged O and A horizon soils from wetland or hydric soils (seed bank materials over or in combination with mineral soils uplands and wetland subsoils (growth media) will be used to create wetland soil conditions.	2021 Modified Mine Plan
Perpetua will salvage and preserve the growth media and seedbank materials of wetlands and riparian areas that will be impacted by the Stibnite Gold Project (SGP). These salvaged soils, containing native seed banks, will be used to aid in establishment of wetland and riparian vegetation in the stream and wetland reclamation areas (i.e., stockpiled materials to be utilized for concurrent reclamation will reside in stockpiles for a shorter period of time, but the majority of the stockpiled material will be stored for approximately 15 years during the period between mine construction and mine closure. The viability of the stockpiled material will decrease due to stockpiling. Therefore, the Reclamation Closure Plan (RCP) incorporates use of soil amendments to increase viability when appropriate).	2021 Modified Mine Plan
Soil will be amended with additional compost and other sources of organic matter necessary to successfully reclaim wetlands at the SGP (i.e., the material will be sourced on site from sources such as food compost from the Worker Housing Facility).	2021 Modified Mine Plan
A qualified landscape biologist, botanist, forester, or ecologist will make recommendations to Perpetua related to the need for soil treatments and other maintenance, based on site observations and monitoring studies. Recommendations for maintenance will be included in the monitoring reports submitted to the responsible agencies (COE and the U.S. Environmental Protection Agency [EPA]). Perpetua or their contractors will perform required maintenance.	2021 Modified Mine Plan

Perpetua will conduct monitoring annually for at least 5 years to determine the progress of each restoration area in meeting the ecological performance standards. If, after 5 years, it is determined that the performance standards have not been met, monitoring will continue every other year until the performance standards have been achieved. The monitoring schedule will coincide with the appropriate season relative to the field data to be gathered. Perpetua proposes to lead annual site visits for COE, EPA, Idaho Department of Lands (IDL), Idaho Department of Fish and Game (IDFG), and other interested agency personnel to facilitate agency review of restoration areas.	2021 Modified Mine Plan
Valley margin wetlands will only be established where there is an upgradient water source sufficient to produce enough saturation and near surface water tables for wetland conditions.	2021 Modified Mine Plan
Riparian fringe and floodplain wetlands are proposed to be restored adjacent to the major streams within the Mitigation Area. Major streams within the Mitigation Area include Meadow Creek, EFSFSR, Midnight Creek, Hennessy Creek, East Fork Meadow Creek (EFMC), Fiddle Creek, and West End Creek. Riparian fringe and floodplain wetlands will be established on the broad, gently sloping floodplains on both sides of the restored stream channels.	2021 Modified Mine Plan
Wetland restoration will begin after the end of mine construction (after mine life year -1), with the first restored wetlands occurring in the EFMC drainage. Additional restoration will occur in and after operational year 3 and continue through operational year 25.	2021 Modified Mine Plan
If feasible, Perpetua may develop a restoration nursery to facilitate propagation of plant species that will be installed in stream and wetland restoration areas.	2021 Modified Mine Plan
Revegetation with a variety of native herbaceous and woody species to improve functions and values, including providing terrestrial and wildlife habitat, improving stream bank stability, and reducing sediment delivery, stream restoration reaches, and wetland restoration areas.	2021 Modified Mine Plan
Both historically and newly disturbed areas will be stabilized and seeded and/or replanted in accordance with USFS and IDL approved guidelines and standards as final landforms are available for reseeding.	2021 Modified Mine Plan
Due to the limited growth media material at the Project site, Perpetua will implement a composting program to create soil for use in reclamation activities at the Project site.	2021 Modified Mine Plan
For vegetation in areas to be disturbed by mining operations, Perpetua will cut and push vegetation into windrows where it will be slashed and burned or chipped and used in growth medium amendment generation (e.g., compost) for use in future reclamation.	2021 Modified Mine Plan
Graded and contoured areas will be seeded or planted using broadcast, drill, or hydro-seeding methods, or hand planting applicable to the specific conditions.	2021 Modified Mine Plan
Growth medium will be placed to encourage healthy vegetative growth, which will reduce erosion, sediment run-off, and risks of debris flows and avalanches.	2021 Modified Mine Plan
Reclamation seeding will be done with native seed mixtures appropriate for the elevation and habitat. Prior to installation, types, locations, and amounts of seed will be approved by the USFS. No seeding or mulching will be conducted at any area where there is a population of bent-flowered milkvetch. The soil will be scarified.	2021 Modified Mine Plan
Seed mixtures will be adjusted to fit elevation and aspect ranges of the Project, along with availability of any plant seeds.	2021 Modified Mine Plan
Of the 340.5 acres disturbed along the Burntlog route, it is assumed that 216.1 acres will be reclaimed assuming: all of the staging areas and borrow sources will be reclaimed; new portions of the route will be decommissioned and reclaimed; and portions of the route that are existing roads proposed for improvement will not be reclaimed to their original dimensions.	2021 Modified Mine Plan

The transmission line disturbances will be reclaimed during interim reclamation (temporarily disturbed areas of the new portion of transmission line that are revegetated for operations), concurrent reclamation (temporarily disturbed areas of the existing revegetated), and final closure and reclamation (decommission of the entire new portion of the transmission line permanently transmission line).	2021 Modified Mine Plan
Of the 325.3 acres of upland habitat disturbed along the transmission line, 297.9 acres will be reclaimed. Perpetua assumes that the entire new portion of transmission line (121.7 acres) and the existing line's construction impact areas (all temporary disturbances outside of the structure work area, 66.4 acres) will be reclaimed. Perpetua assumes that the structure work areas for the existing line (137.2 acres) will be 80% reclaimed (or 109.7 acres) with the area not being reclaimed classified as barren.	2021 Modified Mine Plan
EFMC (Blowout Creek) was impacted by the failure of a water storage dam in 1965 creating the steep, eroding chute that conveys the streamflow. As part of the Compensatory Mitigation Plan (CMP), Perpetua proposes to stabilize and repair the failed area of EFMC in the actively eroding chute and raise groundwater levels in the meadow upstream of the former dam site to restore wetland hydrology. A retention structure will raise groundwater levels in the meadow and a coarse rock drain will address ongoing erosion of the channel side slopes that currently deliver sediment directly to the creek, while facilitating construction of a permanent surface channel. This will be a voluntary mitigation and restoration effort, as the EFMC chute and upper meadow are unrelated to and unaffected by the proposed mine features. The lower portion of the EFMC alluvial fan will be an important borrow area for this and other restoration projects and is included in Project disturbance. During construction and early mining, grade control and water retention features will be constructed near the old reservoir water retention dam location to elevate the groundwater level and stream water surface sufficiently to restore wetland hydrology in the surrounding meadow. The retention structure will impound portions of the meadow channel, which will fill with sediment over time. A coarse rock drain will be constructed within the chute downstream of the failed dam site to isolate the flow of EFMC from the actively eroding chute side slopes and to prevent further erosion of the gully bottom, facilitating subsequent restoration of a surface channel on top of the drain. As the rock drain fills with sediment, it will become closed off from the stream channel. If the rock drain has not silted-in at the end of mine operations, the rock drain will be disconnected from surface inflow at the upstream end through excavation and replacement with less-permeable materials, or by grouting. The existing alluvial fan in lower EFMC, located adjacent to Meadow Creek, will be partially removed, mostly during mine operations for borrow materials, and the area restored. A surface diversion will be constructed at the margin of the lower alluvial fan to facilitate borrow excavation, and this stream reach subsequently restored.	2021 MMP
Each stream within the Project site was divided into design reaches based on proposed valley gradient, fish use, and hydrology. Reference sites were identified and evaluated (Rio ASE 2021). Design criteria, including proposed channel geometries, were developed for each reach based on evidence derived from: (1) geographic information system and field measurements from reference sites; (2) empirical formulae developed from local and regional data; and (3) published design guidelines available in the scientific literature (e.g., NMFS Anadromous Salmonid Passage Facility Design). Refinements to post-mining-topography (primarily changes to valley slope and width) were made to improve the intrinsic potential and associated habitat conditions within select reaches where possible. The channel geometry and reach-specific design criteria were revised then evaluated using standard at-a-station hydraulic calculations to ensure appropriate sediment transport and physical habitat conditions will be achieved. The reach-specific design criteria were then applied to a design template illustrating the reach plan view, a representative meander plan and profile, and representative cross sections. From these plans, design quantities were calculated to quantify construction costs as well as proposed habitat functional value using watershed condition indicators (WCIs) for comparison with baseline conditions (Rio ASE 2021). Typical bank treatments and in-channel features (i.e., large woody debris [LWD], log jams, boulder clusters, and pools) were developed to support the design criteria, provide habitat diversity, and facilitate bank stabilization until riparian vegetation becomes established. Finally, a generalized revegetation and planting plan was developed for specific riparian, wetland, and upland zones to improve long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity. Wetland and riparian vegetation provide surface roughness to slow floodwaters, which reduces erosion and encourages sediment deposition. It also provides habitat for wildlife, birds, and insects, and shade that moderates stream water temperatures. In addition, wetland and riparian vegetation can provide a sediment- and pollutant-filtering buffer as well as diverse native wetland and riparian plant communities. These communities, consisting of	Conceptual Mitigation Plan, Section 9 and Appendix D

graminoids, forbs, woody shrubs, and trees, provide a large variety of habitat features including food sources, LWD, and various rooting depths that provide streambank stability. In general, species composition and percent cover of wetland and riparian vegetation profoundly affect wetland ecosystem functions and habitat quality for wildlife.

Stream restoration reaches and wetland restoration areas will be revegetated with a variety of native herbaceous and woody species. Seed mixes, live stakes, and nursery-grown container plants and plugs of native graminoids, forbs, shrubs, and trees will be utilized for revegetation. Plant species for revegetation were chosen based on existing riparian and wetland vegetation observed during surveys of the Project area and reference sites.

Around streams, the width of riparian plantings will be 18 feet. The inner two feet of plantings will consist of riparian species typical to area streambanks and wetlands. These species include waterweed (*Elodea candesis* and *Elodea Nuttalii*), Bolander's quillwort (*Isoetes bolanderi*), alpine pondweed (*Potomogeton alpinus*), ribbonleaf pondweed (*Potomogeton epihydrus*), white water crowfoot (*Ranunculus aquatilis*), and common bladderwort (*Utricularia macrohiza*). These plantings will occur on approximately two-foot centers. The outer 16 feet of plantings will consist of forested wetland vegetation species due to their ability to generate shade for surface water. These species include thinleaf alder (*Alnus incana*), bluejoint reedgrass (*Calamagrostis canadensis*), redosier dogwood (*Cornus sericea*), largeleaf avens (*Geum macrophyllium*), twinberry honeysuckle (*Lonicera involucrate*), Engelmann's spruce (*Picea engelmannii*), prickly currant (*Ribes lacustre*), Drummond's willow (*Salix drummondiana*), Pacific willow (*Salix lasiandra*), slender hairgrass (*Deschampsia elongata*), slender wheatgrass (*Elymus trachycaulus*), and slender cinquefoil (*Potentialla gracilis*). Tree planting will occur on approximately six-foot centers.

The stream design has been developed to approximate a geomorphically appropriate quasi-equilibrium state, while enabling each stream reach to evolve naturally over time in response to changing environmental drivers and potential future disturbances (i.e., fire, climate change, etc.). Built into the SGP stream design are a diversity of treatments and channel prescriptions allowing a certain amount of variability and associated uncertainty in the channel response over time. For example, by using appropriate streambed, bank, and floodplain materials; allowing channels to migrate across appropriately sized floodplains; incorporating horizontal and vertical control at strategic locations; and incorporating bioengineered bank stabilization treatments and revegetation, the design mimics the stability and diversity observed in natural reference streams. This approach provides some amount of resilience to disturbances and sets the Project up for long-term resiliency and sustainability.

Design stream reach EF3 (parts A-D) is the portion of the restored EFSFSR that crosses the backfilled Yellow Pine Pit (YPP). The entirety of the pit backfill will be covered with a geosynthetic liner and the restored stream channel will be constructed in soil cover materials placed on top of another geosynthetic liner that underlies the stream corridor.

Objectives for the channel design will be restoration of fish passage, improvement of spawning and rearing habitat, and improvement of wetland function. The stream channel design parameters were based on four reference sites and were calculated to be:

Parameter	**Channel**	**Bankfull**	**Floodplain**
Slope (ft/ft)	0.0457	0.0457	0.0564
Discharge (cfs)	7.2	215	636
Max Water Depth (ft)	0.75	2.3	0.6
Top Width (ft)	22.55	27.1	235.8
Bottom Width (ft)	-	22.55	230.0
Cross-Section Area (sq. ft)	8.47	45.75	179.83
Wetted Perimeter (ft)	22.60	28.01	236.83
Hydraulic Radius (ft)	0.37	1.63	0.76
Channel Velocity (ft/s)	0.48	4.74	5.77
Floodplain Velocity (ft/s)	-	-	2.43

Stream Design Report, Appendix D.2

<table><tr><td>Channel Shear Stress (lbs./sq. ft)</td><td>1.07</td><td>4.66</td><td>6.25</td></tr><tr><td>Floodplain Shear Stress (lbs./sq. ft)</td><td>-</td><td>-</td><td>2.00</td></tr><tr><td>Width-to-Depth Ratio (ft/ft)</td><td>-</td><td>16.0</td><td>-</td></tr><tr><td>D50 Mobile Sediment (mm)</td><td>89</td><td>276</td><td>370</td></tr></table>	
The Stibnite Lake feature is designed to mimic the effects of the existing YPP lake on moderating maximum daily water temperatures. The Stibnite Lake feature will have a surface area of 10,400 meters (approximately 850 feet long by 130 feet wide) with a volume of 62,000 cubic meters (17 million gallons). The residence time for water in the Stibnite Lake feature will be between approximately 1.4 days in the summer when flowthrough will be approximately 17.8 cfs and 2.0 days in the fall when flowthrough will be approximately 12.8 cfs.	SPLNT Model Report
The restored channel designs define enhancements as the manipulation of physical, chemical or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function. Enhancement of streams as part of the SGP stream design will include improvements to physical channel processes and habitat largely within the existing stream channel. This will be accomplished by selectively installing LWD and rock structures, eliminating fish passage barriers, creating pools, enabling improved sediment sorting, and generally increasing hydraulic and habitat diversity. Enhancement efforts also include floodplain reconnection and reestablishment of riparian vegetation, achieved by excavation of legacy fill material down to bankfull level.	Stream Design Report, Section 1
The current CMP describes a plan to locate the compensatory wetland and stream mitigation sites within the same subbasins as the associated wetland and stream impact sites. However, although the proposed compensatory mitigation sites will be within the subbasins where impacts occur, they will all be located around the mine site where the majority of wetland impacts will occur, with no mitigation sites proposed outside the mine site area (i.e., along the access roads, the transmission line, etc.). The current location and configuration of mitigation sites identified in the CMP were selected based on suitable hydrology and compatibility with watershed-scale features and on the likelihood that compensatory mitigation wetlands will be sustainable within five years (Tetra Tech 2021a). The anticipated need for wetland and stream credits was based on the wetland and stream debits that will occur under the proposed mine plan. Final wetland impacts will be assessed based on the Proposed Action and any agreed upon off-site compensatory mitigation projects will be finalized at a later day, and a final mitigation plan will be prepared, including a final assessment of functional units lost and created, and then the final credits/debits will be documented in an application for CWA Section 404 permit.	Conceptual Mitigation Plan
Reclamation cover material (e.g., growth media) used in places including but not limited to the TSF and TSF Buttress will be evaluated for contaminants prior to use during reclamation. Acceptable metal/contaminant concentrations and sampling and testing methodology will be documented in a sampling and analysis plan developed prior to reclamation.	2021 Modified Mine Plan
Topsoil and any brush removed will be stockpiled separate from fill material and used in reclamation.	2021 Modified Mine Plan
Measures such as, but not limited to, segregating and stockpiling topsoil, implementing stormwater and sediment best management practices (BMP), backfilling, revegetation and concurrent reclamation will be conducted, where possible and practical, for areas where the soil has been exposed by ground-disturbing activities. These areas/sites include, but are not limited, to burrow sites, utility corridors, skid trails, firebreaks, temporary roads, cut and fill slopes, and areas where construction activities have occurred.	Developed to lessen impacts under BNF and PNF: SWST03, SWGU05
Applicable road obliteration for all roads proposed for obliteration including temporary roads and applicable sections of the Burntlog route will be fully recontoured, including full bench constructed road segments. Road obliteration through recontouring is the reclamation of a road template through the following: • Deep decompaction (36”) of the inside half of the road surface; • Excavate road fill down to the natural ground level and then place on top of the decompacted inside half of the road surface on the cut slope side of road;	Forest Service requirement

• Reestablish the natural slope profile; and, • Vegetation clump planting. **Decompaction:** All compacted road surfaces that will be covered with excavated material, for example the inside half of the road surface, shall be decompacted to a depth of 36 inches or to a restrictive layer (bedrock). This is to promote water infiltration, breakup any potential landslide slip surface between the road surface and excavated and placed fill material and allow deep root vegetation establishment. **Excavation:** After decompaction of the roadway, the outside road fill material shall be excavated and placed on roadbed between the top of cut and natural ground, forming a slope approximating natural contours. No ditches, water traps, or berms shall remain. Finished product should blend in with the surrounding terrain. **Soil-Vegetation Plug Transplanting:** Excavate soil-vegetation plugs from adjacent natural and undisturbed ground having a minimum surface area of 9 square feet to a depth beyond the vegetation rooting zone (plug size is dictated by excavator bucket size). The plug transplant shall be of sufficient depth that will maintain the root system and contain adequate soil to enhance favorable growth. Soil-vegetation plug transplanting will be done at a minimum rate of 15 plantings per 100 lineal feet evenly distributed along the width and length of the recontoured surface. The plugs will be transplanted to a depth even with the surrounding recontoured ground level. This work will be accomplished with an excavator. **Surface Ground Cover:** Ground cover across the entire recontoured or disturbed surface (this will include all scarified ground, de-compacted roads and skid trials), by order of priority, shall be achieved using a combination of clump planting, native mulch, coarse woody debris and certified weed free agriculture straw to reach a minimum of 50 percent to the maximum 80% coverage of the recontoured surface or disturbed area. Apply native seed mix, hydromulch or organic fertilizer. This order or priority shall be given to vegetation plug planting, native mulch, coarse woody debris, and straw. When applying coarse woody debris, use various size classes at levels similar to surrounding undisturbed ground and placed at various orientations. The desired result of road obliteration through recontouring is to restore slope contours the natural slope profile, improve soil productivity, improve soil-water infiltration, and reestablish ground water flow paths and hydrologic function.	
<u>On-Site Stream Channel Restoration and Enhancement: Meadow Creek and Tributaries</u> Stream channel restoration and enhancement of: • 24,164 feet of perennial channel; • 9,204 feet of non-perennial channel; • 1,293 feet of transitional perennial channel; and, • 159 feet of transitional non-perennial channel. Transitional channel refers to the portions of Hennesy Creek and Midnight Creek where stream restoration will entail recontouring mine disturbance to match existing slopes and grades. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 7 through 42 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: Hangar Flats Pit Backfill</u> Stream channel restoration and enhancement of: • 8,798 feet of perennial channel; • 6,324 feet of non-perennial channel; and, • 5,418 feet of transitional non-perennial channel.	CMP, Appendix D, Sheets 43 through 61 and 112 through 132.

Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	
<u>On-Site Stream Channel Restoration and Enhancement: EFMC (Blowout Creek)</u> Stream channel restoration and enhancement of 5,452 feet of perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 62 through 71 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: Garnet Creek</u> Stream channel restoration and enhancement of: • 3,800 feet of perennial channel; • 193 feet of transitional perennial channel; and, • 1,185 feet of transitional non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 100 through 107 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: Fiddle Creek</u> Stream channel restoration and enhancement of 1,798 feet of perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 86 through 90 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: East Fork South Fork Salmon River</u> Stream channel restoration and enhancement of: • 15,204 feet of perennial channel; and, • 1,958 feet of non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 72 through 85 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: Hennessy Creek</u> Stream channel restoration and enhancement of: • 1,345 feet of perennial channel; and, • 692 feet of transitional perennial channel.	CMP, Appendix D, Sheets 97 through 99 and 112 through 132.

Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	
<u>On-Site Stream Channel Restoration and Enhancement: Midnight Creek</u> Stream channel restoration and enhancement of: • 1,331 feet of perennial channel; and, • 2,549 feet of transitional perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates that account for stream gradient, intrinsic potential, fish habitat, fish use, and sediment transport. Bank treatments and in-channel features (i.e., LWD, log jams, boulder clusters, and pools) will be incorporated into the channels to facilitate bank stabilization and habitat diversity. Revegetation will develop riparian, wetland, and upland zones for long-term bank stability, woody debris recruitment, overhead cover, shade, terrestrial/wetland habitat, and soil productivity.	CMP, Appendix D, Sheets 91 through 96 and 112 through 132.
<u>On-Site Stream Channel Restoration and Enhancement: West End Creek</u> Stream channel restoration and enhancement of 1,690 feet of non-perennial channel. Channel restoration and enhancement consists of establishing channel geometries with coarse substrates and an energy dissipation pool that accounts for sediment transport.	CMP, Appendix D, Sheets 108 through 111 and 124 through 130.
<u>On-Site Wetlands Restoration: Meadow Creek</u> Wetlands restoration of: • 3.07 acres of PAB Riparian Fringe and Floodplains Wetlands; • 26.33 acres of PEM Riparian Fringe and Floodplains Wetlands; • 21.68 acres of PSS Riparian Fringe and Floodplains Wetlands; • 83.03 acres of palustrine forested (PFO) Riparian Fringe and Floodplains Wetlands; • 1.56 acres of PEM Valley Margin Wetlands; • 1.10 acres of PSS Valley Margin Wetlands; and, • 1.36 acres of PFO Valley Margin Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands. Deposition/placement and revegetation of fan-like landforms at locations where rivulets from the native steeply sloping valley side walls meet the reclaimed margins of the TSF will develop Valley Margin Wetlands.	CMP, Appendix D, Sheets 133 and 134.
<u>On-Site Wetlands Restoration: Hangar Flats Pit Backfill</u> Wetlands restoration of • 20.04 acres of PEM Riparian Fringe and Floodplains Wetlands; • 2.55 acres of PSS Riparian Fringe and Floodplains Wetlands; and, • 14.46 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.

<u>On-Site Wetlands Restoration: EFMC (Blowout Creek)</u> Wetlands restoration of • 4.34 acres of PAB Riparian Fringe and Floodplains Wetlands; • 1.03 acres of PEM Riparian Fringe and Floodplains Wetlands; and, • 3.28 acres of PSS Riparian Fringe and Floodplains Wetlands. A grade control and groundwater cutoff structure will raise the water level in EFMC and allow shallow groundwater to recharge. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 135.
<u>On-Site Wetlands Restoration: Fiddle Creek</u> Wetlands restoration of • 1.35 acres of PSS Riparian Fringe and Floodplains Wetlands; and, • 1.27 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
<u>On-Site Wetlands Restoration: EFSFSR</u> Wetlands restoration of: • 19.44 acres of PEM Riparian Fringe and Floodplains Wetlands; • 2.80 acres of PSS Riparian Fringe and Floodplains Wetlands; and, • 7.43 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
<u>On-Site Wetlands Restoration: YPP backfill and Stibnite Lake feature</u> Wetlands restoration of • 0.07 acres of PAB Riparian Fringe and Floodplains Wetlands; • 2.26 acres of PEM Riparian Fringe and Floodplains Wetlands; • 0.80 acres of PSS Riparian Fringe and Floodplains Wetlands; and, • 16.70 acres of PFO Riparian Fringe and Floodplains Wetlands. Revegetation of floodplains along gently sloping segments of restored stream channels will develop Riparian Fringe and Floodplains Wetlands.	CMP, Appendix D, Sheet 133.
<u>On-site Restoration Work Stream Isolation and Re-watering</u> Project incorporation of site preparation, staging, and sequencing stream crossing work has been developed for instream restoration work as described in the Fish and Aquatic Resources Mitigation Plan (FMP), Section 5.4.7 (Brown and Caldwell, Rio ASE, and BioAnalysts 2021). A planning team with representation from project management, engineering, and fish biology will be assembled to coordinate with construction personnel and equipment operators to plan the staging and sequence for work area isolation, fish capture and removal, and dewatering, i.e.: • scheduling with in an appropriate instream work window; • establishing the length of channel to be isolated for each crossing; • conducting work area isolation and fish salvage in consideration of habitat requirements, flow and temperature conditions, and exposure to turbidity or other unfavorable conditions; and, • dewatering via a bypass flume or culvert with diversion by sandbags, sheet piling, or cofferdam. When stream segments require dewatering, they will be isolated using a method appropriate for the location, including block nets, sandbags, diversion, pumps, sheetpiling, flashboards, cofferdams, and other structures. The specific method will depend on the stream segment location,	Fish and Aquatic Resources Mitigation Plan, Section 5.4.7

diversion sequencing, operational requirements, segment length, segment slope, flow conditions, depth, and fish salvage (see below). All isolation barriers will be monitored during installation and operation. Partial dewatering will generally be conducted during low-flow periods to facilitate stream segment isolation and fish salvage. Whenever possible, dewatering will not begin until fish have been captured and removed for relocation. However, depending on the location and water depth, it may be necessary to partially draw down the water first to perform fish removal. Partial dewatering before fish salvage operations begin may also improve fish capture efficiency by reducing the total volume of stream habitat that needs to be salvaged. In those cases, dewatering pumps will be screened to meet NOAA Fisheries and IDFG standards to avoid entrainment of juvenile fish. Fish capture from work area isolation will consist of: • slowly reducing flow in the work area to allow some fish to leave volitionally; • installation of block nets upstream and downstream of the isolation area with the nets secured to stream channel bed and banks until fish capture is complete and exclusion of fish from the work area is necessary; • hourly monitoring of block nets during instream disturbance in the work area; • if block nets are in place for more than one day, they will be monitored daily to ensure they are secured to banks and are free of organic accumulation plus monitored every four hours for fish impingement if located in bull trout spawning and rearing habitat (unless a variance is granted by the USFS); • seining the isolated area to capture and relocate fish; • if areas are isolated overnight, minnow traps will be placed overnight in conjunction with seining; • collecting any remaining fish by hand or dip nets as dewatering continues; and, • if all other techniques have been exhausted, electrofishing may be used to capture remaining fish under electrofishing conservation measures. Captured fish will be relocated as quickly as possible to pre-planned release areas using aerated and shaded transport buckets holding limited numbers of fish of comparable size to minimize predation. Dead fish will not be stored in transport buckets but will be left on the streambank to avoid mortality counting errors. Sediment controls will include the implementation and use of the following as needed in appropriate locations: • Instream work will conform with the work, turbidity, and dewatering procedures as specified in design conservation measures (Rio ASE 2023) and adhere to Bonneville Power Administration Habitat Improvement Program conservation measures; • Placement of fine mesh silt fences and straw waddles; • Minimization of equipment wet crossings with vehicles and machinery crossing at right angles to the main channel whenever possible; • No construction equipment stream crossings will occur within 300 feet upstream or 100 feet downstream of an existing redd or spawning fish; • After construction, temporary stream crossings will be removed and banks restored while adhering to turbidity requirements; • Cofferdams and diversion structures will have one foot of freeboard; • Dewatering pump discharge will be released onto floodplain areas away from wetlands and construction activities where discharge will fully infiltrate prior to reaching wetlands and surface waters unless otherwise approved; • Any return flows from dewatering discharge will meet turbidity requirements; • Bag fill materials will be clean, washed, and rounded material meeting standard specifications for drain rock, streambed aggregate, streambed sediments, or streambed cobbles; and, • Work activities within the ordinary high-water channel will conform with the water quality standards established for the project. Upon completion of the instream work, flow diversions will be removed slowly to allow gradual rewatering of the isolated stream segment to minimize turbidity. Once the stream segment is rewatered, the upstream and downstream block nets will be removed. Erosion and sediment control for inwater work will be consistent with controls used for other aspects of the project. Turbidity monitoring and protocols will include:	

• Turbidity monitoring will be required and shall be completed in accordance with designated protocols (for the type of planned work); • Work will be performed in a manner that does not cause turbidity exceedances within the waterway; • Areas will be pre-washed before rewatering. Turbid wash water will be detained and pumped to the floodplain or sediment capture areas rather than discharging to fish-bearing channels; • Starting in early morning, one third of new channel flow will be introduced over a period of 1 to 2 hours; • The second third of flow will be introduced over the next 1 to 2 hours; • The final third of flow will be introduced once downstream turbidity verified to be within acceptable range; • If turbidity exceedances do occur, the work will stop to address the turbidity issues; and, • Construction discharge water will be collected to remove debris and sediment and will meet turbidity requirements for discharging back to receiving streams.	
<u>Off-Site Stream Channel Restoration and Enhancement: Upper Lemhi River</u> The existing single-threaded channel of a reach of the Upper Lemhi River will be bifurcated and obstructed using natural materials at multiple locations to induce flow into relic channels on the floodplain. This activity will be augmented by 5,721 feet of complete channel excavation and 6,663 feet of partial channel excavation on private land. A conservation easement for the private land is being pursued to ensure the durability of the activity.	CMP, Section 9.1.2.1
<u>Monitoring Plan for Restored Stream Channels</u> Following completion of restoration construction, annual monitoring will be implemented for a period of five years followed by bi-annual monitoring thereafter until stream restoration achieves designed ecological performance standards. The stream monitoring will include: • Restored stream channel as-builts (first year only); • Physical channel conditions (widths, slopes, bank conditions); • Riparian vegetation (number of species, percent cover, noxious weeds); and, • Functional assessment (after year five).	CMP, Section 12.1
<u>Monitoring Plan for Wetlands</u> Following completion of wetlands restoration, annual monitoring will be implemented for a period of five years followed by bi-annual monitoring thereafter until stream restoration achieves designed ecological performance standards. The stream monitoring will include: • Hydrology (water levels, water marks, drift lines, sediment deposits, drainage patterns); • Riparian vegetation (number of species, percent cover, noxious weeds); • Soils (organic wetland soil, organic matter on soil surfaces, soil color as an indicator of hydric soil, development of redoximorphic features); • Wetland delineation (after year five; and, • Functional assessment (after year five).	CMP, Section 12.2
<u>Maintenance Plan for Restored Channels and Wetlands</u> Per restored stream channel and wetland monitoring results, periodic maintenance will be conducted including: • Repair of damaged, eroded, or unstable slopes; • Removal of excess silt and/or debris; • Soil treatments;	CMP, Section 10

• Noxious weed control; • Vegetation protection; • Supplemental irrigation; • Supplemental planting and/or seeding; • Garbage removal; and, • Vandalism damage repair.	
<u>Long-Term Management for Restored Channels and Wetlands</u> Following attainment of performance objectives, the Mitigation Area (i.e., restored streams and wetlands) will be inspected every 10 years in perpetuity by Perpetua or its designated contractor until responsibility is relinquished to an appropriate and approved third party through a conservation easement or similar real estate agreement. The management will include evaluation of: • Does the floodplain contain streams, wetland, and riparian areas as originally designed? • Do the Mitigation Area floodplains remain free from excessive erosion? • Do the vegetation communities in wetlands appear health and remain intact? • Do the Mitigation Areas remain free of Idaho-listed noxious weeds? • Is signage and placarding in place and legible? • Are any trails or viewpoints in good repair and safe? • Do the Mitigation Areas remain free of any unintended roads, trails, or camping areas? Excluding any act of God, it will be the responsibility of the conservation easement holder to ensure the Mitigation Area is returned to as near the original design and associated success criteria as possible.	CMP, Sections 5 and 13

Table A-7. Summary of Environmental Design Features and Protection Measures: General – Water Resources.

Description	Reference
The Meadow Creek channel will be routed over the final Tailings Storage Facility (TSF) and TSF Embankment and Buttress, resulting in a long, relatively flat surface and a short, steep face. On top of the TSF surface, Meadow Creek will be contained within a broad floodplain corridor bound laterally by erosion-resistant terraces and vertically by a subsurface armor layer over a low-permeability stream liner.	2021 Modified Mine Plan
Perpetua will stabilize and restore East Fork Meadow Creek (EFMC) (Blowout Creek). EFMC wetland restoration will consist of restoring and enhancing palustrine aquatic bed (PAB), palustrine emergent (PEM), Palustrine scrub-scrub (PSS) wetlands that were impacted when a historical dam failed on EFMC. Headcutting and shallow aquifer dewatering have impaired and reduced functions of the wetland vegetation classes. A grade control and groundwater cutoff structure is proposed to raise the water level in EFMC as well as recharge the shallow groundwater system and reduce stream headcutting. A coarse rock drain will be constructed within the chute downstream of the failed dam to isolate the flow of EFMC from the actively eroding chute side slopes and to prevent further erosion of the gully bottom, facilitating subsequent restoration of a surface channel on top of the drain. Perpetua will stabilize the steep, confined, erosive middle reach to address the significant fine sediment load currently produced from this reach and restore the downstream, relatively low-gradient reach. The stabilization of EFMC is described in Section 1.7.10.2 and based on the design appearing in the Compensatory Stream and Wetland Mitigation Plan (CMP), Attachment D, Drawings 64 and 65.	2021 Modified Mine Plan
Perpetua will lead annual site visits for the U.S. Army Corps of Engineers (COE), U.S. Environmental Protection Agency (EPA), Idaho Department of Fish and Game (IDFG), and other interested agency personnel as needed to facilitate agency review of mitigation areas if desired. Final reporting and data archival requirements will be subject to permit conditions; however, it is anticipated that until the COE concurs that mitigation sites meet success criteria, monitoring reports will be prepared by Perpetua annually and submitted to DOE Walla Walla District, EPA, IDFG, Idaho Department of Lands (IDL), National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service (USFS), and other interested agencies, Stibnite Gold Project (SGP) partners, and stakeholders. After success criteria are met, permit conditions will set the frequency for long-term monitoring and reporting.	2021 Modified Mine Plan
Pre-construction water management activities will include the installation of surface water management features and implementation of best management practices to reduce erosion and sediment delivery to streams. These water management features and best management practices (BMPs) could include sedimentation ponds; run-on water diversion ditches, trenches, and/or berms; runoff water collection ditches; silt fence; water bars; culverts; energy dissipation structures; terraces; and other features specified in construction permits.	2021 Modified Mine Plan
Groundwater pumped from the dewatering wells will be considered to be contact water and will be managed through forced evaporation or active water treatment when the volume of pumped water exceeds the ore processing facility demand.	2021 Modified Mine Plan
Channel segments constructed over fill or excavated in permeable materials will be constructed over a geosynthetic liner to reduce seepage. A transition layer of sand/gravel followed by riprap or similar will be placed over the liner for erosion protection.	2021 Modified Mine Plan
Secondary containment for pipelines will consist of an open geosynthetic-lined trench, pipe-in-pipe, or backfilled geomembrane-wrapped trench, depending on location, and the pipeline corridor will drain to one of two pipeline maintenance ponds – one at the truck shop and one at the ore processing facility.	2021 Modified Mine Plan
A lined tailings pipeline maintenance pond will be located at the ore processing facility, to which tailings and process water in the tailings distribution or water reclaim pipelines will drain by gravity during maintenance shutdowns or if there is a leak in either pipeline. The pond will typically be empty except during maintenance or unforeseen problems with the tailings pipeline, pumping system, or TSF. The pond is	2021 Modified Mine Plan

Description	Reference
designed to contain the contents of the pipelines and the runoff from the pond and lined pipeline corridor from a 100-year, 24-hour storm event plus snowmelt.	
Underdrain collection sumps and downgradient monitoring wells will be used for TSF leak detection.	2021 Modified Mine Plan
Water treatment will continue until metal concentrations from each source have stabilized at levels that meet water quality standards for discharge.	2021 Modified Mine Plan
A truck wash facility will include an oil/water separation system and water treatment facilities to enable reuse of the wash water.	2021 Modified Mine Plan
The underdrain system will convey spring and seep flows beneath both facilities to a collection sump at the buttress toe where the flows will be monitored for water quality prior to release into the stream system or capture for use in the processing circuit or treatment prior to discharge, depending on water quality.	2021 Modified Mine Plan
During operations, runoff generated from direct precipitation on the TSF will be retained in the TSF water pool for reclaim to the ore processing circuit.	2021 Modified Mine Plan
Surface water diversions will be constructed surrounding all major facilities such as the TSF, development rock storage facility (DRSFs), process plant, open pits, and the Stibnite Worker Housing Facility.	2021 Modified Mine Plan
Surface water diversions will be designed to convey water without eroding during high flow/flood events (100-year, etc.) appropriate to the risk level of the facility.	2021 Modified Mine Plan
Contact water from mine facilities (DRSFs, ore stockpiles, open pits, etc.) will be collected with ditches, sumps, and ponds, and generally reused for process makeup. Excess contact water will be evaporated or treated to meet discharge standards and discharged via permitted national pollutant discharge elimination system (NPDES) outfalls.	2021 Modified Mine Plan
Runoff generated from precipitation on general infrastructure areas, including haul roads, laydown yards, and reclamation areas will be routed in channels or through culverts towards stormwater basins where sediment can collect, and water can evaporate, percolate into the ground, or be discharged as appropriate.	2021 Modified Mine Plan
Runoff from roads, building sites, and parking lots will be intercepted and processed using sediment traps/ponds, berms, and filtration materials. Design and implementation of these features will be based on local hydrologic conditions and EPA, USFS, Idaho Department of Environmental Quality (IDEQ), and IDL requirements/recommendations.	2021 Modified Mine Plan
Runoff generated from direct precipitation on the DRSFs, mine pits, ore stockpiles, ore processing facility area, and truck shop area will be collected in stormwater basins where water can collect and be evaluated for treatment and discharge or used as process makeup water for mine operations.	2021 Modified Mine Plan
Diversions, underdrains, underdrain outlets, and contact water ponds will utilize low-permeability liners or solid-wall pipes as required to maintain segregation of clean and potentially mine-impacted water, promote geotechnical stability, and/or prevent water loss.	2021 Modified Mine Plan
If ore grade, mineralized, or legacy materials are encountered during construction of the mine features, stormwater runoff from these areas will be contained and managed as contact water.	2021 Modified Mine Plan
Non-contact stormwater will be diverted around mining facilities in controlled conveyances with erosion and sediment control BMPs as needed.	2021 Modified Mine Plan

Description	Reference
Perpetua will strive to minimize the volume of TSF water treated and released to surface waters during reclamation and post-closure such that it will not exceed the difference between precipitation on the TSF and any areas contributing to it and evaporation from the same areas on an annual basis.	2021 Modified Mine Plan
Treat all contact water that is to be discharged directly to surface waters to the extent required to meet Idaho Pollutant Discharge Elimination System (IPDES) requirements, except stormwater runoff from areas of the mine eligible for coverage under the multi-sector general permit (MSGP).	2021 Modified Mine Plan
Design the water treatment system (WTP [water treatment plant] and storage ponds) with sufficient capacity to manage seasonal flow variability, with the consideration that flows during the spring snowmelt period that occur in an extremely wet year (e.g., the 95th percentile wet weather year) may be temporarily stored in the mine pits to reduce the maximum instantaneous flow rate to the treatment system.	2021 Modified Mine Plan
Implementation of water management and collection will be subject to adaptive management per monitoring of water quantity and water quality effects of the Project, particularly important for subsurface flow management—dewatering and groundwater drainage.	2021 Modified Mine Plan
Maximum treatment system flow capacity of 4,000 gallons per minute (gpm) was selected as the design capacity of the WTP to manage up to the 95th percentile year condition in conjunction with the water management measures.	2021 Modified Mine Plan
WEP lake water will be treated, if necessary, with temporary equipment used when needed, or actions taken to prevent discharge entirely. The water level in the pit will be monitored and, if it rises above a preset threshold elevation, a temporary treatment system will be mobilized and operated until the level has subsided to below that threshold and is projected to continue declining.	2021 Modified Mine Plan
During operations, contact water from SGP facilities (e.g., the TSF, including its embankment and buttress, development rock, stockpiles, open pits) and occasionally pit dewatering water, will be directed to one of five site contact water collection ponds and subsequently directed to the WTP. Open pit dewatering water that is not directed to site contact water collection ponds will be pumped directly to the WTP. See also Figures 14 and 15. A treatment process consisting of sodium hypochlorite oxidation, two-stage iron coprecipitation, and solids separation with contingent mercury precipitation via organic sulfide precipitant addition between iron precipitation stages was selected. Influent waters will be stored in lined storage ponds for flow equalization and pumped into the WTP. This operational water treatment generally targets dissolved nitrate, metals, and oxyanions in influent solution, primarily arsenic and antimony. Addition of the mercury-sequestering precipitant is included as a contingency for the design to account for uncertainties regarding the effectiveness of iron coprecipitation in reducing dissolved mercury and methylmercury concentrations to levels below applicable receiving stream standards. Residual solids from the treatment plant will be placed in the TSF. Under an IPDES permit, the WTP effluent will be directed to Meadow Creek at a location upstream of the HFP when flow augmentation is required and otherwise to the East Fork South Fork Salmon River (EFSFSR) for the remainder of operations (i.e., when Hangar Flats groundwater pumping results in decreased Meadow Creek baseflow). Treated water will be tested for compliance with IDEQ water quality standards. The water chemistry and characteristics (i.e., temperature, turbidity) of receiving water will also be monitored.	Water Management Plan, Section 6.2
Thirty-three surface water monitoring locations proposed in the Water Resources Monitoring Plan (WRMP) are located upstream and downstream of Project activities and facilities such as the worker housing area, the TSF, open pit mining operations, the ore processing area, and the downstream boundary of the mine operations area on the EFSFSR. In addition to streamflow, other parameter information will be obtained at these locations (e.g., water temperature and chemistry). The monitoring information collected will be used to inform water management and water protection activities. See also Section 1.10.	Water Resources Monitoring Plan, Section 4.2.1, Table 4-1, Figures 4-3, 4-5, 4-7, and 4-9.

Description	Reference
The temporary and mine operating period stream diversions will be constructed and operated to meet or exceed minimum design criteria for surface flow events (100-year, 24-hour event except for the EFSFSR Tunnel which uses a 500-year, 24-hour event), freeboard (one-foot), and bankfull width (1.5-year event). The stream diversions will consist of either: (1) rock-cut channels along steep slopes and in areas with shallow or at-surface bedrock; (2) excavated earthen channels and berms constructed of alluvium or colluvium; or (3) pipes. Some diversions will have sections that are fully conveyed in culverts of pipes in areas where constructing an open channel such as steep hillslopes or underneath roads or mine features, or where needed to limit warming of the diverted stream. Diversion channel segments constructed in erodible materials will be lined with riprap or other erosion-resistant lining, where needed, to prevent erosion; the rock-cut channels will be non-erodible and not require riprap lining.	Water Management Plan, Table 2-1. Water Management Plan, Section 6.1.4
Stream diversion channel segments constructed over fill or excavated in permeable materials will be lined with a geosynthetic liner (e.g., high-density polyethylene [HDPE], linear low-density polyethylene, or geosynthetic clay liner [GCL]) to prevent seepage where it will create undesired loss of water or geotechnical instability (such as within the groundwater drawdown influence of pits during operations). If a geosynthetic liner is used, a bedding layer or geotextile may be placed under the liner as needed, and a transition layer of sand/gravel or geotextile followed by riprap placed over the liner for erosion protection. Some channel segments (particularly outfall chutes) will be lined with geocomposite products such as HydroTurf (a composite of HDPE, engineered turf, and concrete binder), which combines erosion protection and seepage prevention in a single product. The stream diversion segments anticipated to be constructed with a geosynthetic liner include the non-rock-cut segments of Meadow Creek at the TSF, the Meadow Creek stream restoration corridor at HFP, and open channel (i.e., non-piped) segments of West End Creek above WEP.	Water Management Plan, Section 6.1.4
Pre-construction water management activities will include the installation of surface water management features and implementation of BMPs to reduce erosion and sediment delivery to streams. These water management features and BMPs could include sedimentation ponds; run-on water diversion ditches, trenches, and/or berms; runoff water collection ditches; silt fence; water bars; culverts; energy dissipation structures; terraces; and other features specified in construction permits. Prior to initiating construction, a Notice of Intent for a Construction General Permit (CGP) will be submitted along with the Stormwater Pollution Prevention Plan (SWPPP), and erosion prevention and sediment control BMPs will be used to manage runoff. BMPs recommended by the IDL and IDEQ include silt fencing, straw wattles, sedimentation ponds, water bars, flow spreaders, energy dissipators and other features (IDL 1992; IDEQ 2005). During construction, the BMPs will be inspected and maintained as required by the CGP (i.e., weekly inspections of the condition of BMPs plus turbidity monitoring which become a daily inspection for the day following precipitation events greater than 0.25 inches; weekly/daily reports are maintained on site). If necessary, corrective actions will be taken and the SWPPP will be updated to reflect changes to the BMPs and stormwater management practices. Once construction activities have been completed and the disturbed areas have been stabilized, a Notice of Termination for the CGP will be submitted. After that time, stormwater will be managed using BMPs recommended by the IDL and IDEQ. General stormwater that is not mine contact water will be managed under an Idaho Multisector General Permit while stormwater that is mine contact water will be collected for consumptive use or water treatment as described in Section 1.7.10.1. Although Valley County does not have specific stormwater requirements regarding post-construction stormwater management, the 2010 Valley County Comprehensive Plan states: "Valley County has adopted IDEQ's Catalog of Stormwater BMPs for Idaho Cities and Counties along with a Valley County specific addendum table to assist local agencies and developers with the selection, design, installation and maintenance of BMPs to reduce stormwater pollution."	Refined Proposed Action 2021 MMP, Section 3.6.1 Water Management Plan, Section 6.1.1 Refined Proposed Action 2021 MMP, Section 3.3.2
Dust emission controls (i.e., water sprays) will be employed to reduce dust from the ore processing in the crushing and conveying operations. Ore grinding will occur within an enclosed building.	2021 MMP, Section 3.8 2021 MMP, Table 4-2

Description	Reference
Dust control will be employed along transportation corridors and active mining areas using aquatic safe dust suppression chemicals and application methods to reduce the transmission of particulates to wildlife corridors and natural areas (i.e., application along roadway centerline).	
Preconstruction weed treatments such as mechanical control and herbicide application will be limited to areas expected to have unavoidable ground-disturbing activities. Any herbicide use will be in accordance with the South Fork Salmon River Sub-Basin Noxious and Invasive Program (Forest Service 2010b). Specific measures for mixing, loading, and disposal of herbicides as well as response to any spills are described in the Stibnite Gold Project Weed Management Plan. The existing Weed Management Plan (ESOP-023) for the Golden Meadows Exploration Project will be expanded to cover the SGP. The Plan references Title 22 Chapter 24 (22-2407) of the Idaho Code and the Forest Service' South Fork Salmon River Sub Basin Noxious and Invasive Weed Management Program. The existing program has been implemented in collaboration with the Valley County Weed Management Program. The Weed Management Plan is part of the Plan of Restoration and Operations submittal. Aquatic safe herbicides will be used during vegetation management activities and noxious weed control along with adherence to chemical label restrictions, federal/state rules on usage plus proper equipment usage for chemical application by trained personnel. Noxious weed management in areas with whitebark pine will be controlled manually or by herbicide approved for use on Forest lands where the label doesn't restrict use in conifer stands. Herbicides such as Pictoram (Tordon TM) that are known to have a high degree of mortality in woody species, will not be used in vicinity of whitebark pine. No aerial applications of herbicide will be made in whitebark pie stands. Herbicide use will be limited to spot treatment in the vicinity of whitebark pine and will maintain a minimum distance of 3.3 feet (1 meter) from a whitebark pine tree. Ground-based broadcast applications will maintain a minimum distance of 10 feet (3 meters) from the trunk of a whitebark pine tree. Inspection all access routes, drill platforms, pad locations and sump construction sites will be conducted prior to Project-related activities and if they are found to be weed-infested, then treatment the weed infestation with herbicides or by manually removing infestations will be conducted prior to ground disturbing activity.	2021 MMP, Table 4-2
The SGP includes several design features incorporated into the mine plan that are meant to minimize or avoid transportation related risks. These include road construction design standards to reduce sedimentation and dust impacts, road design features and maintenance protocols to address geologic hazards, road construction material choices to avoid surface water impacts, bridge restrictions and load hauling rules to increase safety, and a dedicated facility for road maintenance. Guidelines and standards for designing National Forest System (NFS) Roads as published in the Forest Service handbook (FSH) 7709.56 (published in 2010 with partial amendments in 2011 and 2014) were used as the primary basis for the design criteria. The FSH incorporates design standards for two lane service roads from American Association of State Highway and Transportation Officials (AASHTO's) Guidelines for Geometric Design of Very Low-Volume Roads (average daily traffic [ADT] less than 400). Valley County has adopted the 'Greenbook' AASHTO standards. AASHTO's Guidelines of Very Low-Volume Local Roads (ADT less than 400) provides a functional classification for Rural Resource Recovery Roads specifically for logging and mining operations. Road construction material for either of the mine access routes will come from borrow sources that are located along the access route. Borrow site material quality assessment and construction material specifications are included in documentation supporting the Feasibility Study Access Road Design memorandum (Parametrix 2018), which recommends targeting USFS standard specifications for aggregate quality. Road construction materials for haul roads on the SGP will be sourced from quartzite development rock from the West End mine pit that demonstrates relatively low arsenic concentrations compared to other available development rock. An evaluation of estimated haul road	Transportation Management Plan, Section 3.1.1 Transportation Management Plan, Section 3.3.11

Description	Reference
runoff water quality based on the use of this material was prepared by SRK Consulting, Inc. (SRK) (2020). It concluded that runoff from haul road surfaces will not exceed any of the strictest applicable water quality criteria. Modeling of haul road fugitive dust is addressed in Appendix A of the 2021 MMP Air Quality Analysis Addendum (Air Sciences 2021) which concludes that dust control measures will limit dust emissions to acceptable levels. Road surfaces will be stabilized and managed to minimize transport of sediment, dust, and other materials, especially near watercourses with inspections at the beginning of spring and fall seasons at a minimum. Crushed rock will be placed on access roads as needed to provide a durable surface and limit sediment transport into nearby streams. Erodible (i.e., non-rock cut) slopes along roads will be mulched, hydro-seeded, or covered with rock or coarse gravel to minimize the potential for sediment mobilization. During winter road maintenance, snow will be removed by plowing to the roadway surface when practical. Care will also be taken to avoid disposing of collected snow, which may contain sand or gravel, into nearby streams and rivers. Coarse sand (with less than 20 percent fines) will be used for winter sanding of the main access road and haul roads in combination with a fine to medium gravel as needed, (approximately 1/4 - 5/8-inch sizing).	
Personnel who transport, handle, or use mine processing reagents, fuel, or other materials that have the potential to be released and impact surface water and groundwater quality will receive appropriate training in BMPs, spill response procedures, and reporting requirements. Schedules will be developed for planned dates and times for transport of fuel. The schedules will be communicated with staff and drivers so that timing of fuel transport is known, and arrangements can be made to minimize possible hazards. Fuel hauling will be done with single chassis units (i.e., no pup trailers are allowed). Transportation of fuel will be done during daylight hours. Spill response equipment is located along portions of the access route and in the Perpetua Spill Response trailer. Prior to material hauls, areas of "flat water" along the route will be communicated to appropriate hazardous materials response personnel to identify areas of potential booming in waterways adjacent to the route. Documented annual inspections of commercial transport vehicles are required by 49 CFR 396.17-23. Inspections will be conducted by a qualified U.S. Department of Transportation (USDOT) inspector. Commercial transport vehicles will also be inspected by the drivers prior to transport. Transport companies are required to document DOT annual inspections and vehicle inspections. In addition, daily inspection of transport vehicles will occur as required by Mine Safety and Health Administration (MSHA) requirements. Material transporters to the site will be required to check in at the Stibnite Gold Logistics Facility (SGLF). Safety inspections of all transport vehicles will be conducted by Perpetua personnel prior to transportation of fuel and materials. Safety measures during hazardous road conditions will be applied including signage visible during nighttime and inclement weather, road edge delineators visible above snow accumulations, and detention of traffic at the SGLF, mine site, or point of origin during storm events, wildfires, or other hazardous conditions. Material transporters to the site will be required to provide documentation of successfully completed training in responding in the event of spills or other releases of transported materials and will have spill cleanup kits on the vehicle at all times. Material transporters to the site will be familiarized with the transportation route prior to transportation of fuel. Pilot vehicles will be used to escort shipments of fuel, chemicals, reagents, or antimony concentrate from the site. The pilot vehicles will have radio contact with the site and the transport vehicle. Pilot and emergency response vehicles will carry appropriate spill containment and first aid equipment. The pilot vehicle will advise oncoming traffic to park until the convoy passes and will regulate the speed of the transporting vehicle so that it does not exceed posted speed limits and safety conditions inherent to the road.	Transportation Management Plan, Section 3.2 Transportation Management Plan, Section 3.2.5

Description	Reference
Road signs will be placed at both the start and end of the route while a convoy is operating, indicating to the public that a fuel convoy is in progress and to use caution.	
As determined in the *Decision Notification and Finding of No Significant Impact, Golden Meadows Exploration Project, Krassel Ranger District, Payette National Forest, January 2016: Details of Decision Attachment A, pg. A-38 (pg. in PDF file).* "Helicopter flight times will be minimized over area waterways, especially flights over Meadow Creek, EFSFSR, and the Glory Hole, in accordance with Federal Aviation Administration (FAA) regulations, to the greatest extent possible. Stream corridors will not be used as routine helicopter flyways."	DR-FONSI for Golden Meadows Exploration Project
Under the Proposed Action, the volume and types of hazardous materials transported, stored, and used at the mine site and off-site facilities will increase from the current conditions of the permitted exploration operations. Substantial quantities of fuels, lubricants, and chemicals will be transported annually via large trucks, and will be stored in aboveground storage tanks, bins, totes, and drums, within the required secondary containment designed to prevent spill releases to the environment. There will be no long-term storage of wastes on-site and waste disposal will occur at licensed off-site facilities. Liquid Petroleum Products and Wastes Aboveground storage tanks will be used for fuels and other petroleum fluids, including gasoline, diesel fuel, lubricants, coolants, hydraulic fluids, and propane at the mine site, as outlined in a SPCC Plan required for the mine site under Section 311(j)(1)(C) of the clean water act (CWA). The storage tank facility for gasoline, diesel fuel, and propane will be located near the maintenance workshop with additional propane storage at the ore processing facility area, the underground portal area, and the worker housing facility. Motor oils, lubricants, antifreeze, and solvents will be shipped to the mine site on trucks. These will be stored in approved containers located within, or directly adjacent to, the maintenance shop and contained within secondary containments to prevent spills into the environment. All used petroleum products, waste antifreeze, and used solvents will be collected in approved containers, transported off site, and disposed or recycled. All liquid petroleum products will be managed in closed tanks or containers that are located within secondary containment areas such that a complete release of petroleum from the largest tank or container with the secondary containment area will be retained in the area without release to the environment. The procedures in the SPCC Plan will cover all activities related to receipt, storage, and dispensing petroleum products in a manner that will minimize spills and prevent releases outside of the secondary containment areas. Inspections, security, and maintenance activities of all petroleum storage facilities will minimize the potential for spills from tanks and containers, and prompt cleanup of any such spills. The Proposed Action includes the operation of four new substations and upgrades to five existing substations, which will require quantities of dielectric oils (i.e., mineral oils). These oils will be contained within the substation equipment and as per the site-specific SPCC plans, design of the substation yards will prevent discharges out of the yards in the event of a leak from the electrical equipment. Written spill response procedures and pre-positioned spill response supplies and tools will assist in containing and cleanup of any spills within and outside of secondary containments. SGP personnel will be trained in the execution of the SPCC Plan which will be reviewed and updated as needed through all phases of the SGP from construction through closure. Spills of fuel or oils outside of secondary containments will be responded to in a manner to control the size of the spill. The spilled petroleum and contaminated soil will be cleaned up and placed in steel bins or drums to be shipped off site for treatment or disposal.	2021 MMP, Section 5.1.3

Description	Reference
Solid Waste Management All municipal waste and construction and demolition waste generated by the SGP will be collected in wildlife-resistant containers and hauled offsite for disposal in a municipal waste landfill. Small scale composting associated with organic materials generated at the worker housing facility may be conducted at the Fiddle growth media stockpile (GMS). Hazardous Waste Management Material the meets the classification of hazardous waste will be collected and stored according to Idaho regulations implementing federal Resource Conservation and Recovery Act (RCRA) regulations on hazardous waste management. Such wastes will be accumulated in approved containers at designated collection locations in the facilities. These containers will be transferred to a 90-day storage site at the facilities prior to shipping to an offsite, permitted hazardous waste disposal facility. The handling of hazardous waste, from generation through off-site disposal, will be done in concert with written procedures to comply with all applicable parts of the Idaho hazardous waste regulations. This will include written contingency plans identifying response and notifications actions in the event of a spill of hazardous waste at the SGP. The largest quantity of hazardous waste routinely produced by gold mines is laboratory assay wastes containing lead. These materials are solids like slag, cupels, crucibles, and the like. These wastes are contained in steel bins that are sealed at the mine site before being shipped off site to permitted hazardous waste disposal facilities. In the unlikely event of a spill of these materials the spilled material could be readily recovered with mechanical means appropriate to the spill event, placing the material and any contaminated soil in a suitable container by a person equipped with appropriate personal protection equipment. The recovered material will be replaced into the accumulation bins. Autoclave refractory liner bricks are typically non-hazardous when new. They can become contaminated with metals during use at mine sites such that they must be handled as hazardous wastes when removed during maintenance relining of an autoclave. This will be determined at the SGP through operational experience during maintenance activities when the autoclave liner was rebuilt. Spent refractory material will be properly managed and disposed-based on its characteristics when the waste was generated. Smaller quantities of hazardous waste typically consist of waste maintenance materials such as solvents, paints, batteries, lamps, and electrical equipment. These materials will be accumulated in steel drums positioned near the points of generation of these materials. Any drums of liquid hazardous waste will be placed in secondary containment. Any spills will immediately be contained and remediated according to the site contingency plans. Mercury and Mercury Containing Materials In the gold and silver leaching process, small amounts of mercury will also be dissolved from the ore and follow the gold and silver through the rest of the process. During the carbon stripping process, a small amount of mercury may not desorb from the activated carbon. This residual mercury will volatilize in the carbon reactivation kiln and be controlled with a venturi scrubber and sulfur-impregnated carbon columns in the kiln off-gas stream. Solid waste from this process (i.e., the carbon canisters and filter packs) will be disposed offsite in a permitted solid waste or hazardous waste disposal facility depending on the mercury characteristics of the wastes.	
Section 6 of IDL's Best Management Practices for Mining in Idaho (IDL 1992) will be observed, including if water is encountered in exploration holes, water zones will be sealed off during abandonment to prevent crossflow.	Section 6 of IDL's Best Management Practices for Mining in Idaho (IDL 1992)
Perpetua will implement surface water quality baseline turbidity monitoring, as defined in the IDEQ permit clauses.	
Drilling mud and hole plug products, if utilized, will conform to American Petroleum Institute guidelines for ensuring groundwater integrity.	American Petroleum Institute guidelines

Description	Reference
Perpetua will monitor stormwater runoff and stormwater BMPs as per the Stormwater Pollution Prevention Plan (SWPPP). Stormwater monitoring, inspections, and reporting will be conducted in accordance with the IPDES MSGP and the SWPPP.	IPDES MSGP and the SWPPP
All activities will be conducted in accordance with Idaho environmental anti-degradation policies, including IDEQ water quality regulations at IDAPA 58.01.02 and applicable federal regulations.	IDAPA 58.01.02
Dust abatement chemicals will be used in accordance with the applicable road maintenance Biological Assessment. Apply dust- abatement additives and stabilization chemicals (typically $MgCl_2$, $CaCl_2$, or lignin sulphonates) to avoid run-off of applied dust abatement solutions to streams. Spill containment equipment will be available during chemical dust abatement application. Where the road surface is within 25 feet (slope distance) of surface water, dust abatement will only be applied to a 10-foot swath down the centerline of the road. The rate and quantity of application will be regulated to insure all of the chemical is absorbed before leaving the road surface.	2021 Modified Mine Plan

Table A-8. Summary of Environmental Design Features and Protection Measures: General – Wastes and Hazardous Materials.

Description	Reference
Oils, solvents, and lubricants will be stored in approved containers located within, or directly adjacent to, the maintenance shop and contained within secondary containments to prevent spills into the environment. All used petroleum products, waste antifreeze, and used solvents will be collected in approved containers, transported off site, and disposed or recycled.	2021 Modified Mine Plan
Nitric and sulfuric acid will be transported in tanks designed to prevent spills even in the event of rollovers.	2021 Modified Mine Plan
Nitric and sulfuric acids will be stored in specialized non-corrosive, polyethylene-lined tanks located within the ore processing facility and will have secondary containment.	2021 Modified Mine Plan
Liquids will be shipped to the Stibnite Gold Project (SGP) in tank trucks designed for spill prevention and escorted to the SGP by pilot cars manned and equipped to handle spills.	2021 Modified Mine Plan
Other legacy materials may be encountered during construction and operations. If encountered, these materials will be characterized to determine potential for reprocessing, reuse, or disposal.	2021 Modified Mine Plan
Small scale composting associated with organic materials generated at the worker housing facility may be incorporated within the centralized growth media stockpile (GMS) in the Fiddle valley.	2021 Modified Mine Plan
Personnel transporting, handling, or using any hazardous chemicals (including sodium cyanide) will be trained to ensure the safe use of such materials. Perpetua will design, construct, and manage facilities to conform to the International Cyanide Management Institute Code (ICMC).	2021 Modified Mine Plan
Fuel and other petroleum products at the site will be stored in above ground containment structures, with appropriate secondary containment measures.	2021 Modified Mine Plan
Perpetua will maintain a recycling program at the SGP.	2021 Modified Mine Plan
The operator will immediately report any fuel, oil, or chemical discharges or spills greater than 25 gallons on land, or any spill directly in a stream to the Idaho Department of Environmental Quality (IDEQ), Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), and NOAA Fisheries as required by applicable federal and state regulations by phone and/or fax (or as soon as possible after on-site containment efforts are implemented as per the Spill Prevention, Control and Countermeasure [SPCC] plan), and initiate emergency consultation.	2021 Modified Mine Plan
Helicopter flight times will be minimized over area waterways, especially flights over Meadow Creek, East Fork South Fork Salmon River (EFSFSR), and the Yellow Pine Pit (YPP) lake, in accordance with Federal Aviation Administration (FAA) regulations, to the greatest extent possible. Stream corridors will not be used as routine helicopter flyways.	2021 Modified Mine Plan
All fuel transport drivers will be required to have spill response, safety, and resource awareness training. In this program, drivers will be informed of the Idaho State Emergency Medical Service, first hazardous materials responder actions, and the importance of anadromous fisheries that must be protected. In addition, each driver will participate in a safe-driver training course that is specific for the Perpetua fuel convoy. The course will cover the standard operating procedures (SOP) as well as discuss causes of accidents and how to minimize risk.	2021 Modified Mine Plan
Remove, reprocess, reuse, or isolate various existing sources of pollutant loading from historical mining operations.	2021 Modified Mine Plan

Description	Reference
Comply with regulations under Idaho's Solid Waste Management Rule and required permits, depending on the type and size of composting program implemented.	2021 Modified Mine Plan
Consult with IDEQ and the local Health District on design and oversight of the composting program.	2021 Modified Mine Plan
Provide safe storage of chemicals and petroleum products, a SPCC plan includes measures to avoid inadvertent release of hazardous materials into the environment and describes response and remediation measures to minimize effects of an inadvertent release.	2021 Modified Mine Plan
Remove all hazardous materials and debris during restoration effort for proper facility closure during operations and post-mining restoration efforts.	2021 Modified Mine Plan
Prohibit solid and sanitary waste facilities in riparian conservation areas (RCAs). If no alternative to locating mine waste (waste rock, spent ore, tailings) facilities in RCAs exists, then: • Analyze waste material using the best conventional methods and analytic techniques to determine its chemical and physical stability characteristics. • Locate and design waste facilities using the best conventional geochemical and geotechnical predictive tools to ensure mass stability and prevent the release of acid or toxic materials. If the best conventional technology is not sufficient to prevent such releases and ensure stability over the long term, and such releases or instability will result in exceedance of established water quality standards or will degrade surface resources, prohibit such facilities in RCAs. • Monitor waste and waste facilities to confirm predictions of chemical and physical stability and make adjustments to operations as needed to avoid degrading effects to beneficial uses and native and desired non-native fish and their habitats. • Reclaim and monitor waste facilities to ensure chemical and physical stability and revegetation to avoid degrading effects to beneficial uses and native and desired non-native fish and their habitats. • Require reclamation bonds adequate to ensure long-term chemical and physical stability and successful revegetation of mine waste facilities.	BNF and PNF: MIST09
Transport hazardous materials on the Forest in accordance with 49 CFR 171 in order to reduce the risk of spills of toxic materials and fuels during transport through RCAs.	BNF and PNF: SWGU11
A SPCC shall be prepared in accordance with 49 CFR parts 171 through 180, including packaging, transportation, incident reporting, and incident response. Include the following items within the SPCC Plan: • During off-loading of fuel from fuel vehicles or during refueling operations have a standard marine-type fuel containment boom (which will be of sufficient length for a worst-case discharge), spill prevention kit, and fire kit readily available on site. • Store two or more spill containment/response caches along each of the fuel delivery routes. • Spill response team will carry sufficient containment equipment for one full fuel tanker. • Include the USFS as a party to be notified in the event of a hazardous materials spill. • Intake pumps, engines, fuel storage, fuel containment site, and other equipment with fuel or lubricants will be inspected at each refueling and periodically between refueling for leakage or spillage. • Pilot and emergency spill response vehicles will carry appropriate containment and first aid equipment. • All fuel containers will be marked with contents, owner's name and contact information. • Material Safety and Data Sheets for all products will be posted and available on site with the SPCC plan.	49 CFR 171

Description	Reference
• Intake pumps will not be situated within the active stream/ditch channel and will be placed within containment vessels capable of holding 120 percent of the pump engine's fuel, engine oil and hydraulic fluid. The smallest practical pump and intake hose will be used. • Following large storm events, the intake pumps will be inspected to determine if stream flow has encroached into the pump area and if the pump needs to be moved so it remains above flowing water. • A spill prevention and clean-up kit will be placed at the intake pump site and will consist of absorbent pads and/or boom (which will be sufficient length for a worst-case discharge), drip pan, a shovel, and a fire extinguisher. • Spare fuel for the water intake pump will be stored in approved [29 CFR 1926.152(a)(1)] fuel storage containers placed into a secondary containment vessel capable of holding at least 120 percent of the volume of the fuel in the fuel container. • A copy of the SPCC plan will be kept at an appropriate on-site facility.	
Unless otherwise authorized, all garbage or refuse should be removed from NFS lands. This includes, but is not limited to, empty fuel and lubricant containers. Food and garbage will be stored either indoors, in vehicles, or if outside, in wildlife-proof containers. No garbage will be burned.	BNF and PNF: MIGU04
New facilities for storage of fuels and other toxicants will be located outside of occupied Regional Forest Sensitive, Forest Watch, and TEPC plant habitat.	BNF and PNF: TEST11
Do not authorize storage of fuels and other toxicants or refueling within RCAs. Storage of fuels and other toxicants or refueling sites within RCAs shall be approved by the responsible official and have an approved spill containment plan commensurate with the amount of fuel.	BNF and PNF: SWST11

Table A- 9. Summary of Environmental Design Features and Protection Measures: General – Other.

Description	Reference
Busing and/or vanpooling will be provided for Perpetua and contractor employees from the Stibnite Gold Logistics Facility (SGLF) to the Stibnite Gold Project (SGP). The associated parking area will accommodate approximately 300 vehicles. To the degree practicable, Perpetua will mandate the use of busing and vans for employee and contractor transportation to the SGP and the worker housing facility.	2021 Modified Mine Plan
Perpetua will utilize "smart grid" technology to reduce energy consumption, such as auto dimming lights in offices.	2021 Modified Mine Plan
Perpetua employees and contractors will be informed about relevant governmental regulations intended to protect cultural and historic resources.	2021 Modified Mine Plan
Perpetua will repair and rehabilitate habitats adversely affected by historical mining impacts in the SGP area within the disturbance footprint of the modified mine plan.	2021 Modified Mine Plan
Perpetua will increase the ground limestone dosage to the pre-oxidized concentrate as it is fed into the autoclave to address the potential for creation of soluble arsenic. By decreasing the free acid levels (increasing the pH) in the autoclave by increasing the ground limestone dosage in the autoclave feed increases the quantity of crystalline (stable) arsenic compounds in the resultant slurry with a proportional decrease in the quantity of amorphous (unstable) arsenic compounds.	2021 Modified Mine Plan
Perpetua will monitor levels of soluble arsenic in the tailings. If soluble arsenic levels are higher than anticipated, Perpetua will treat the oxidized concentrate with hot arsenic cure (HAC) prior to neutralization.	2021 Modified Mine Plan
The ore processing area will be designed to provide for containment of ore processing materials, chemicals, wastes, and surface runoff. Potentially hazardous chemicals and wastes will be stored within buildings or areas with both primary and secondary containment. Surface runoff within the ore processing area will be directed to a contact water pond (constructed with geosynthetic liners) for collection. Leaks or spills escaping primary and secondary containment will flow to the contact water pond for collection and will not discharge off site.	2021 Modified Mine Plan
The processing circuit will be housed in a steel frame building set on concrete foundations with interior curbing to provide secondary containment; the interior curbing will be high enough to contain 110 percent of the volume of the largest tank.	2021 Modified Mine Plan
The gold and silver leaching circuit will be designed and operated consistent with the International Cyanide Management Institute Code (ICMC) (https://www.cyanidecode.org) and the Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining (https://responsiblemining.net/resources/). Accordingly, impermeable secondary containment for cyanide unloading, storage, mixing and process tanks shall be sized to hold a volume at least 110 percent of the largest tank within the containment and any piping draining back to the tank, with additional capacity for the design storm event, if applicable. Pipelines containing process water or process solution shall also use secondary containment in combination with audible alarms, interlock systems, and/or sumps as spill control measures.	2021 Modified Mine Plan
Cyanide-bearing solutions used in ore processing will be neutralized to approximately 10 milligrams per liter weak acid dissociable (WAD) cyanide before the material is pumped to the tailings storage facility (TSF). Residual cyanide will be treated using a sodium metabisulfite and air system to detoxify the cyanide by oxidation to form cyanate.	2021 Modified Mine Plan
An Explosives and Blasting Management Plan will be prepared for the SGP (based on the measures described in the Fish and Aquatic Resources Mitigation Plan (FMP) Section 5.6 and incorporated into the Project decision). Explosives storage, transport, handling, and use will comply with applicable Department of Homeland Security, Bureau of Alcohol, Tobacco, Firearms and Explosives, and Mine Safety and Health Administration (MSHA) regulations.	2021 Modified Mine Plan
For safety and security reasons, no alcohol, firearms, or illegal drugs will be permitted on site.	2021 Modified Mine Plan

Description	Reference
Air emissions, groundwater, surface water, and aquatic parameters will be monitored during mine construction, operation, closure, and post-closure as specified in the final authorizations from the regulating agencies. See Section 1.10. for an expanded description of the monitoring program.	2021 Modified Mine Plan
Monitoring will be conducted following the completion of closure and reclamation of all facilities and disturbance areas to demonstrate compliance with permit requirements and to measure the success of reclamation and mitigation.	2021 Modified Mine Plan
The draft Environmental Monitoring and Management Plan (EMMP) includes the following plans for monitoring aquatic resources: Stream and Wetlands Monitoring and Management Plan and Fisheries and Aquatic Habitat Monitoring and Management Plan.	2021 Modified Mine Plan
An 8-mile temporary 16-foot-wide groomed over snow vehicle (OSV) trail will be created adjacent to Johnson Creek Road between Landmark and Trout Creek Campground during construction of the Burntlog Route.	2021 Modified Mine Plan
A 16-foot-wide groomed OSV trail will be created south of Warm Lake Road to connect the southern end of Johnson Creek Road to the Landmark-Stanley Road. This 0.3-mile route will be used throughout construction and operations.	2021 Modified Mine Plan
During construction, approximately 11 miles of groomed OSV trail will be maintained along Cabin Creek Road (FR 467).	2021 Modified Mine Plan
Equipment, materials, and vehicles will be stored at specified work areas or construction yards.	2021 Modified Mine Plan
The operator shall comply with all applicable Federal and State fire laws and regulations and shall take all reasonable measures to prevent and suppress fires on the area of operations and shall require their employees, contractors and subcontractors to do likewise.	36 CFR 228.11
The operator shall comply with State of Idaho fire protection procedures (as outlined in IDAPA 20.04.01) and any local Valley County Fire District regulations and shall require their employees, contractors and subcontractors to do likewise.	IDAPA 20.04.01
Several fire-response kits will be spaced strategically around the Project area and be inspected annually.	2021 Modified Mine Plan
On-site staff will maintain contact with Krassel District Ranger to ensure appropriate procedures are followed in the event of implementation of fire restrictions or woodland use restrictions (e.g., "Red Flag Warnings").	BNF and PNF: FRGU13, SCGU13, SCGU14, SCGU15 BNF: REGU12, REGU15 PNF: REGU13, REGU16
Public firewood cutting and gathering along the Burntlog route will not be allowed.	2021 Modified Mine Plan
Road reconstruction and/or upgrades to NFR 51290 (Meadow Creek Lookout Road) on the ridgeline dividing Meadow Creek from the Indian Creek drainage will be restricted to 30 feet either side of the centerline of the existing alignment to prevent potential for direct impacts to the Frank Church River of No Return Wilderness.	Design Feature developed for compliance with BNF and PNF: LSST03, LSST05

APPENDIX B

GOLDEN MEADOWS SUMMARY OF ENVIRONMENTAL DESIGN FEATURES AND PROTECTION MEASURES

A variety of standard operating procedures (SOPs) and project design features (PDFs) were incorporated into the Golden Meadows proposed action to minimize and avoid the risk of adverse impacts to ESA-listed fish and designated critical habitat. These SOPs and PDFs are fully described in the Golden Meadows BA Amendment and its supporting documentation. The most notable SOPs and PDFs for protection of ESA-listed species and designated critical habitat are listed below.

- All petroleum products will be transported in accordance with state and Federal Department of Transportation regulations, and handled and stored as per applicable state and Federal petroleum product storage and handling laws and regulations.

- Fuel hauling will only occur during daylight hours and when weather conditions are acceptable. Acceptable weather conditions will be determined jointly by the MGI [Midas Gold Inc.], the PNF [Payette National Forest], and the Valley County Road Department on a case-by-case basis.

- Setup and confirmation of at least two caches for spill response equipment will occur on the fuel delivery route.

- The pilot and emergency response vehicles will carry appropriate containment and spill response equipment. All drivers will be required to have spill response, safety, and resource awareness training.

- A spill prevention control and countermeasure (SPCC) plan will be implemented.

- Staff handling fuel or petroleum products will be trained to successfully implement the SPCC plan. Inspections of fuel storage and handling areas will be conducted as specified in the SPCC plan.

- A spill prevention and cleanup kit consisting of absorbent pads, absorbent booms, shovels, and a fire extinguisher will be placed at the fuel storage site (private property), at the core shack (private property), and at drill sites or any other areas where fuel and/or petroleum products are present.

- Water intake pumps will be placed in containment capable of holding 120% of the pump engine's fuel, engine oil, and hydraulic fluid. The smallest practical pump and intake hose will be used.

- Any fuel, oil, or chemical discharges; or spills greater than 25 gallons on land, or any spill directly in a stream will be reported to NMFS immediately (or as soon as possible after onsite containment efforts are implemented as per the SPCC plan) and emergency consultation will be initiated. Spill response will be in accordance with the SPCC plan, which includes a trained onsite emergency response team.

- For drill areas with a higher risk of drilling fluids emerging at the ground surface, the following SOPs will be implemented:

  - Drillers will exercise a high degree of vigilance for signs of lost circulation at shallow depths.

  - The casing will be advanced simultaneously with the drill string through the alluvial section of all drill holes.

  - Regular monitoring of the adjacent slopes below the drill rig for daylighting of drilling fluids will be performed by environmental technicians. Stream channels in these areas will also be regularly monitored. At least one person will be stationed on the slope below the drill rig at all times until surface casing is set.

  - For drill holes proposed to be sited within an RCA [riparian conservation area] in areas identified as having risk for daylighting of drilling fluid, an interdisciplinary team including the PNF resource specialists and MGI geologists, drillers, and environmental technicians will conduct an onsite review of all geologic target considerations and environmental risk and mitigation factors in order to identify the optimal hole locations that would present the least environmental risk.

  - Silt fence, straw wattles, portable sumps, pumps, and hoses will be pre-staged for emergency use to contain drilling fluid should it daylight. A PNF representative will verify that such measures are in place on the ground at locations warranting such precautionary measures.

- Sediment and erosion control BMPs [best management practices] will be implemented to minimize the potential for sediment to reach steams. For example, to minimize sediment runoff from temporary roads and roadbeds, water bars, silt fencing, certified weed-free waddles, and/or weed-free straw bales will be installed in strategic downslope areas and in RCAs. Proper BMPs will be used to prevent sediment from escaping drill pad and sump locations.

- Road rutting from traffic will be minimized by requiring construction and maintenance of surface drainage structures (e.g., water bars), application of surfacing material, and by restricting road use when conditions are unacceptable due to moisture that is leading to the onset of rutting and concentrations of turbid flow.

- Road maintenance will be conducted along the Stibnite Road under a cooperative agreement with Valley County (this segment of road is operated under a Forest Roads and Trail Act easement between Valley County and the PNF). Road maintenance and improvement actions that will be performed include, but are not limited to, cleaning roadside ditches and improving drainage, reducing potential rock fall, improving and regrading roadway surfaces, replacing soft roadway materials, and adding surface coat aggregate with appropriate gradation and durability characteristics followed by application of dust abatement and binding products in select areas. Maintenance activities will be performed in accordance with the PNF Road Maintenance Programmatic (NMFS Tracking #2008/04131), unless otherwise noted in this letter (i.e., application of dust abatement chemicals).

- Additional road maintenance on the Stibnite Road will focus on those areas where modeled sediment delivery is greater than 0.1 tons of sediment per year (using GRAIP). These areas will be inspected and prioritized for surface aggregate. Placement of surface aggregate will occur during the first summer of project implementation.

- A gate will be installed within 300 feet of the bridge just east of the Profile Gap Road (Forest Service [FS] Road 340) and Stibnite Road (FS Road 412) intersection. The gate will be closed during the snow plowing and spring-break up seasons in order to regulate full-sized vehicle access to the project area. This will help avoid damage caused by motorized vehicles that could lead to excessive erosion and deterioration of the overall road condition. Administrative access beyond the gate by landowners, law enforcement, or government personnel may be permitted by Valley County.

- No chemical deicers or sand/gravel less than 3/8-inch will be used on roads.

- Dust abatement chemicals will be applied in a manner that avoids runoff into the streams. Where the road surface is within 25 feet (slope distance) of surface water, dust abatement chemicals will only be applied to a 10-foot swath down the centerline of the road. The rate and quantity of application will be regulated to ensure all of the chemical is absorbed and does not leave the road surface.

- Unless a request is made to reauthorize road use, all temporary roads will be decommissioned immediately after use to a condition equivalent to, or better than, their condition prior to use.

- Drill sites and other reclaimed drill areas will be monitored during spring runoff to ensure that sediment and erosion control BMPs are in place and working so that soil erosion is minimized.

- Travel and drilling off designated routes on NFS lands will only occur when there is adequate snow depth or frozen soil to prevent rutting and puddling. Snow used to build snow bridges across non-fish bearing streams will not contain soil or other debris.

- When a drill pad is needed in an RCA, MGI will submit a written request to the PNF for approval of the location. The request must include an explanation as to why there is no reasonable alternative to siting the pad in an RCA. MGI must receive approval from the PNF prior to pad construction. Drill pads in RCAs will be sited to avoid removing any large trees to the extent possible. Any trees that are felled within the RCA will be left in the RCA.

- Drill pads will not be located within 100 feet of streams.
- Employees and staff will receive training and direction to avoid harassment of spawning adult Chinook salmon and steelhead.
- Visual turbidity monitoring will occur immediately upstream and downstream of active drilling operations for drills working within 300 feet of surface water. If monitoring of the proposed action identifies unanticipated effects to fish or fish habitat, activities will cease until corrections can be made. The Level 1 Team will be informed or consultation will be reinitiated.

APPENDIX C

WEED TREATMENT DESIGN FEATURES AND PROTECTION MEASURES
(PNF 2020; NMFS 2020)

Table C-1. Herbicides proposed for use, application rates, and buffers from water.

Herbicide[1] (Active Ingredient)	Commonly Used Brand Names[2]	Maximum Application Rate (pounds active ingredient or acid equivalent per acre)	Typical Application Rate (pounds active ingredient or acid equivalent per acre)	Ground Application Buffer from ordinary high water mark (feet)		
				Broadcast Spray	Spot Spray	Hand Wicking
2,4-D amine	Amine 4, Weedar® 64	2.0 lb ae/acre/app 4.0 lb/ae/acre/year	1.0–2.0 lb ae/ac	100	OHWM	OHWM
Aminopyralid	Milestone®	0.11 lb ae/acre/year	0.078–0.11 lb ae/ac	100	OHWM	OHWM
Chlorsulfuron	Telar®	0.02 product/acre/year (0.12. lb ai/acre/year)	0.01–0.02 lb ai/ac	100	50	15
Clopyralid	Transline®	0.5 lb ae/acre/year	0.1–0.5 lb ae/ac	100	50	15
Dicamba	Banvel®	1.0 lb ai/acre/app 2.0 lb ai/acre/year	0.5–2.0 lb ai/ac	100	50	15
Fluroxypyr	Vista® XRT®, Starane®, Spotlight®	0.5 lb ae/acre/year	0.25 lb ae/ac	100	50	15
Glyphosate	Rodeo®, Roundup®, Accord®	1.7 lb ae/acre/app 4.0 lb ae/acre/year	0.5–3.0 lb ae/ac	100	100 (OHWM for aquatic-approved products)	100 (OHWM for aquatic-approved products)
Imazamox	Beyond®, Raptor®	0.5 lb ae/acre/year	0.5 lb ae/ac	100	OHWM	OHWM
Imazapic	Plateau®	0.1875 lb ai/acre/year	0.09–0.16 lb ai/ac	100	15	OHWM
Imazapyr	TVC Total Vegetation Control®, Assault®, Chopper®, Arsenal®	1.5 lb ae/acre/year	1.0 lb ae/ac	100	OHWM	OHWM
Metsulfuron-methyl	Escort®	0.15 lb ai/acre/year	0.01–0.02 lb ai/ac	100	50	OHWM
Picloram	Tordon™	1.0 lb ai/acre/year	0.25–1.0 lb ai/ac	100	50	50
Sulfometuron methyl	Oust Weed Killer® DPX 5648	0.03–0.281 lb ai/acre/app 0.03–0.38 lb ai/acre/year	(0.09–0.38 lb ai/ac)	100	50	15
Triclopyr TEA: triethylamine salt	Element 3A®, Garlon 3A®	2.0 lb ae/acre/year	1–2.0 lb ae/ac	100	OHWM	OHWM
2,4-D amine	Amine 4, Weedar® 64	2.0 lb ae/acre/app 4.0 lb/ae/acre/year	1.0–2.0 lb ae/ac	100	OHWM	OHWM
Aminopyralid	Milestone®	0.11 lb ae/acre/year	0.078–0.11 lb ae/ac	100	OHWM	OHWM

OHWM = ordinary high-water mark.
[1] Aquatic formulations of 2,4-D amine, glyphosate, imazamox, imazapyr, and triclopyr TEA shall be used.
[2] Other product brands of identical or "substantially similar" formulation may be added or substituted in the future (as described in the Payette National Forest Programmatic Activities consultation (NMFS 2020; PNF 2020).

Table C-2. Recommended adjuvant type by herbicide proposed for use on the Payette National Forest.

Herbicide	Recommended Adjuvant Types
2,4-D	NIS, Nitrogen sources, MSO
Aminopyralid	NIS
Chlorsulfuron	NIS, MSO, organosilicone
Clopyralid	NIS, MSO
Dicamba	Any as allowed by label
Fluroxypyr	No specific adjuvants are recommended
Glyphosate	NIS
Imazamox	NIS, MSO, organosilicone
Imazapic	NIS, MSO, organosilicone
Imazapyr	NIS, MSO
Imazamox	NIS, Nitrogen sources, MSO, petroleum/crop oil concentrate
Metsulfuron methyl	NIS, MSO, organosilicone
Picloram	None needed; can add as per surfactant manufacturer's label
Sulfometuron methyl	Any allowed by label
Triclopyr triethylamine salt (TEA)	NIS

NIS = non-ionic surfactant; MSO = methylated or ethylated seed oils

Table C-3. Required mitigations and best management practices for invasive weed management activities that will be implemented to avoid or minimize potential effects on the Payette National Forest.

Treatment Method	Category	Mitigations and Best Management Practices
Chemical	General	• Contracts and agreements will include all of these design criteria as a minimum. • Annual reports and plans will be presented to the Level 1 Team. • New end use products that meet the Adaptive Management Strategy criteria will be presented to the Level 1 Team for herbicide use approval.
	Application	• Herbicide application shall comply with applicable laws, policy, guidelines, and product label directions. • A state certified applicator will oversee all herbicide applications. • Applicators will read and follow label directions, including instructions for herbicide use, application rates, equipment and techniques, personal protective equipment for applicators and mixers, and container disposal. • Program managers will ensure proper permitting is in place prior to implementation. • Material safety data sheets, safety plans, spill prevention plans, and clean-up kits will be available to applicators and mixers. Wind speed and direction and equipment and spray parameters will be monitored throughout herbicide application.
		• Herbicides will not be applied when sustained wind conditions exceeding 5 miles per hour in riparian areas or 8 miles per hour in upland areas. • Herbicides will not be applied if the weather forecast predicts precipitation within the next 24 hours. • Accurate and detailed application records will be kept. • Practical measures to restrict access to herbicides, adjuvants, and spray equipment by unauthorized personnel will be implemented. • The 5-Year Herbicide Safety Plan will be updated with completion of this consultation and implemented during herbicide use. • Indicator dye will be used in the herbicide mix to visually ensure uniform coverage and minimize overlapped or skipped areas and treatment of non-target areas. • Low pressure and larger droplet sizes will be used to the extent possible, to minimize herbicide drift during broadcast operations. • Appropriate nozzles designed for herbicide application will be used.

Treatment Method	Category	Mitigations and Best Management Practices
		• Herbicides will be applied to infestations containing biological control agents at times when the effects of herbicides to the host plants will not interfere with the agent's life cycle, to the extent practicable. • Spray pattern that avoids applying herbicide to non-target species will be used.
Chemical (Cont.)	Equipment	• Conduct equipment and personnel inspections and equipment maintenance and calibration, as needed, to ensure proper herbicide application and to meet regulatory requirements. Make repairs and replace parts promptly. • All equipment used for treatments will be cleaned of external oil, grease, dirt and mud, and leaks repaired, before entering areas that drain directly to streams or wetlands. Spill packs will also be on hand for minor leaks/spills. • Fuel storage and/or refueling will not occur within riparian conservation areas (RCAs). Engine and hydraulic fluids will be monitored for leaks.
	Application Near Water	• Applicators are required to use more risk-averse application methods in sites that are close to stream channels. Key provisions include using the least toxic chemicals to aquatic resources near water, and more precise herbicide application methods in stream side areas, such as wicking, wiping, or hand spraying with a single nozzle. • Within or near aquatic systems, only products labeled for aquatic application will be used. • No broadcast spray applications will occur within 100 feet of live water. • No chemical herbicides will be used within a 100-foot radius of any potable water spring development. • Dyes will be used in riparian areas to provide visual evidence of treated vegetation. Water-soluble colorants, such as Hi-Light blue dye, will be used within 100 feet of water and other situations, as needed, to enable applicators and inspectors to properly apply herbicides.
	Transport	• Transport only the quantity of herbicide and adjuvants needed for a project. Transport secured containers in such a way as to prevent the likelihood of spills and make periodic checks en route to help avoid spillage. When supplies need to be transported over water by boat, raft, or other watercraft, carry herbicides and adjuvants in watertight, floatable containers. • Use off-highway vehicles (OHVs), which are administratively allowed to travel off designated motorized routes, to transport or spray herbicides. Do not take OHVs off designated routes if damage to soils could occur due to wet conditions. Take care to ensure disturbance to desirable vegetation is minimized and no visible "trail" creation occurs.
	Mixing	• Water used for mixing will be obtained prior to going into the field. • Water may be transported via back-pack sprayers, saddle tanks, or portable containers to mixing site in the backcountry locations. • Where herbicides are mixed, mixing/filling, storing of sprayers will not occur within 100 feet of live water. • Mixing/filling will be limited to locations where drainage will not allow runoff or spills to move into live water, and in locations where potential contamination of ground water will not occur.
	Chemical Specific	• No ester formulation of 2,4-D or triclopyr-Butoxyethyl Ester will be used. • The polyoxymethylene tallow amine adjuvant (e.g., Roundup Pro) will only be used in uplands where there is no potential for movement into aquatic systems. • No more than one application of picloram (trade names: Tordon 22K, Grazon, Pathway, Tordon 101) will occur on a given site in any given year unless the cumulative amount applied is less than or equal to the maximum label rate for a single application to reduce the potential for picloram accumulation in the soil. Before multiple applications are administered, a soil scientist and/or hydrologist should survey the treatment area to determine a very low possibility of delivery to surface or groundwater. • Picloram will not be used within 50 feet of any stream for any reason and will generally not be used within a 100-foot buffer unless other herbicides are not considered effective in controlling certain weed species, such as leafy spurge or rush skeletonweed.

Treatment Method	Category	Mitigations and Best Management Practices
		• Picloram will not be used where soils are highly permeable (i.e., silt loam and sand soils), and in floodplains or where there are shallow water tables. • Allow only one application of chlorsulfuron per growing season, except for industrial use sites, where total pounds applied per year may not exceed 0.125 lb ai/ac.
		• Telar (Chlorsulfuron) will not be used within an annual floodplain or where the water table is within 6 feet of the surface. • Clopyralid and Imazapic should not be applied where soils have a rapid to very rapid permeability throughout the profile (such as loamy sand to sand) and the water table is shallow. • Imazapic should only be applied where there is level terrain and a well-developed vegetative buffer strip between areas to which this product is applied and surface water.
Manual	General	• Treatments in RCAs will only be accomplished using hand tools (e.g., hand clippers, hoes, rakes, shovels, etc.) or mechanical tools that do not disturb the soil (e.g., chainsaws, power brush saws, line trimmers, etc.). • Mechanical treatments will occur on slopes less than 45%, a maximum of 25 acres per project and landtype erosion hazard ratings to low or moderate. • A 25-foot vegetative buffer will be maintained next to live water for all treatments that cause ground disturbance. • Minimize soil disturbance as much as possible to minimize germination of invasive plant seeds and bare soil. • Avoid non-target species damage to the extent practicable. • Select mechanical methods to effectively control the target species (e.g., grubbing/hoeing is inappropriate for rhizomatous species and may increase the density of the invasive plant population as root fragments sprout and become new plants). • Apply mechanical treatments at the proper stage of plant growth when treatment will be most effective at controlling the target invasive plant. • Thoroughly inspect and clean all equipment and clothing to remove invasive plant seeds or vegetative propagules to prevent the movement of the invasive plant to another site. • To the extent practicable, conduct clipping and removal of seed stalks prior to seed maturity to reduce inputs to the seed bank or when seeds are easily picked up and transported by vectors such as wind, humans, or animals. • Specific to aquatic invasive plants, hand-pulling and/or smothering may be used when an infestation is very limited in extent and occurs close to the shoreline of a waterbody but has not yet infested deeper waters. • Mechanical treatments should not occur on any slopes where excessive erosion to waterbodies (e.g., slope fall lines to lakes, streams, etc.) and resource damage will occur. Proper erosion control techniques will be utilized on steep slopes to prevent excessive erosion and resource damage from occurring.
Biological	General	• Use only biological control agents approved by the U.S. Department of Agriculture Animal, Plant Health Inspection Service, and the state of Idaho. • Use Forest Service protocols for documentation of releases and monitoring and share release information with the Idaho State Department of Agriculture. • To the extent practicable, collect biological control agents locally or from areas with similar climatic and weather conditions, land and soil types, and cover types to maximize successful establishment. • Distribute biological control agents at the optimal season and life cycle stage to optimize the likelihood of successful establishment. Distribute quantities sufficient to optimize successful short-term establishment. • For those agents that self-disperse poorly, actively assist the distribution throughout target infestations by redistribution (collecting and moving the agent to new locations).
Rehabilitation	General	• Seed mixes or plant species will be approved a U.S. Forest Service botanist. • Wheeled or tracked equipment used for rehabilitation will be kept outside the RCAs.

REFERENCES

NMFS (National Marine Fisheries Service). 2020. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Payette National Forest Programmatic Activities (Seven Forest-wide Activities). December 15, 2020. 269 pp.

PNF (Payette National Forest). 2020. Programmatic Biological assessment for the potential effects from road maintenance; trails, recreation, and administrative site operation and maintenance; fire management; invasive weed management, timber harvest and pre-commercial thinning; miscellaneous forest products; and fish habitat and riparian sampling to Snake River fall and spring/summer Chinook salmon, Snake River sockeye salmon, Snake River steelhead, Columbia River bull trout, Northern Idaho ground squirrel, Canada lynx, and wolverine on the Payette National Forest. May 11, 2020.

Appendix D

Lemhi Little Springs Habitat Restoration Construction Details and Preliminary Design Drawings (Rio ASE 2023)

1. Description of Work Elements

    a. Channel excavation to create new perennial and non-perennial, multi-threaded, channel networks to include pool and riffle features.
    b. Offsite haul of material generated from project excavations to an approved contractor provided spoil location.
    c. Installation of numerous types of wood habitat structures (i.e., beaver dam analogue, apex jam, bleeder jam, individual tress and logs, and bank jams) and bank and floodplain roughening treatments (using natural materials such as woody debris, coir fabric, rock and soil, and vegetation).
    d. Installation of constructed riffles and strategic filling of existing channels for conversion to floodplain habitats.
    e. Installation of temporary construction access routes, staging areas, and stream crossings and/or bridges.
    f. Revegetation through planting and seeding of native species within riparian, wetland, and upland zones.

2. General Construction Sequence

    a. Mobilize to the site, install erosion and sediment control measures in accordance with the stormwater pollution prevention plan (SWPPP), install temporary construction entrances/exits, perform clearing for temporary access routes, perform staking and/or localization of survey and/or machine control.
    b. Work area isolation (i.e., cofferdams, pumping, and water management) and fish salvage.
    c. New channel construction (excavation, hauling, wood habitat structures, constructed riffles, and bank treatments). Channel construction outside of the ordinary high water mark (OHWM) may be performed outside of the in-water work window.
    d. Filling or blocking existing channel segments.
    e. Prewash and activate new channels while isolated from the existing Lemhi River or active water. Perform fish salvage within existing channels to be filled.
    f. Finish grading of all floodplain areas.
    g. Reclamation of temporary construction access routes and staging areas to pre-existing conditions.
    h. Planting, seeding, final inspection, site cleanup, and demobilization.

3. Work Schedule

    a. The approved in-water work window for this project is July 1 to August 23. All work requiring equipment to operate partly or wholly below the OHWM shall be completed during the in-water work window. Work that is outside of OHWM may be completed prior to and/or after the in-water work window if approved by the contracting officer.

b. The contractor may not leave the work site or suspend activity for more than five (5) consecutive days after mobilizing to the site and prior to reaching substantial completion unless otherwise approved by the contracting officer.

4. Contractors Use of Premises

   a. Prior to performing work, contractor shall become thoroughly familiar with the project site, site conditions, and all portions of work.
   b. The contractor shall only use designated temporary access routes and stream crossings.
   c. The contractor shall take all measures necessary to minimize damage to existing vegetation during construction activities.
   d. The contractor shall only remove trees and shrubs that are absolutely necessary for the execution of the work and shall make all efforts to minimize tree and shrub removal. Contractor shall obtain prior approval from contracting officer to remove any tree or shrub from outside disturbance limits. Any tree or shrub unnecessarily removed from the work site shall be replaced by a new tree or shrub of equal or greater value at the sole expense of the contractor as approved by the contracting officer.

5. Equipment and Refueling

   a. Contractor is required to pressure wash and remove all dirt, grease, oil, fuel, vegetation, and weed seeds before bringing equipment onto the site.
   b. Complete vehicle and equipment staging, cleaning, maintenance, refueling, and fuel storage 150 feet away from any natural waterbody.
   c. Inspect all vehicles and equipment operated within 150 feet of any natural waterbody daily for fluid leaks before leaving staging areas. Repair any leaks detected in designated temporary construction staging areas before resuming operation. Document inspections in a record to be made available for review on request by the contracting officer and regulatory agencies.
   d. Use of equipment in flowing water is limited by applicable permits. Equipment must be thoroughly cleaned before entering the water.
   e. Hydraulics fluids – all equipment performing work in active stream channels, or permanent water bodies during project construction must use hydraulic oil that meets or exceeds environmentally acceptable lubricants by the U.S. EPA (2011) (e.g., mineral oil, polyglycol, vegetable oil, synthetic ester; Mobil® biodegradable hydraulic oils, Total® hydraulic fluid, Terresolve Technologies Ltd.® biobased biodegradable lubricants, Cougar Lubrication® 2xt bio engine oil, series 4300 synthetic bio-degradable hydraulic oil, 8060-2 synthetic bio-degradable grease no. 2, etc. Or meet stringent acute aquatic toxicity, which is inherently biodegradable[17]. All products shall be American Petroleum Institute (API) certified and the vendor shall

[17] This does not include trucks, dozers, front end loaders, etc., that are operated on the floodplain or involved in the construction of new channels prior to adding water flow or filling abandoned channels after de-watering.

furnish documentation of the certification upon request. Products must meet manufacturer's performance and warranty requirements.

6. Special Procedures

   a. Instream Work

      i. Proposed earthwork activities will occur inside and outside of the OHWM. The contractor is required to perform the work in a manner that does not cause turbidity exceedances to include proper turbidity controls such as installation of cofferdams, pumping, or other facilities approved by the contracting officer.
      ii. Streambank vegetation shall be preserved and protected to the extent practical. No tree or shrub shall be removed unless approved by the contracting officer. The contractor shall not disturb the roots of woody vegetation in this area during project excavations to the extent practical.

   b. Turbidity Monitoring and Protocols

      i. Turbidity monitoring is required and shall be completed by the sponsor in accordance with the established protocols.
      ii. The contractor is required to perform the work in a manner that does not cause turbidity exceedances. If turbidity exceedances occur, the contractor shall stop work at the direction of the contracting officer until further notice. Any delays due to turbidity exceedances caused by the contractor will be at the contractor's sole expense.

   c. Temporary Utilities

      i. All generators shall be placed outside of the OHWM with appropriate spill prevention and containment measures.

7. Temporary Environmental Controls

   a. The contractor shall:

      i. Prepare, file, implement, and maintain a SWPPP for the project.
      ii. Prepare a spill prevention, control, and countermeasure (SPCC) plan for this project to include requirements to prevent spills throughout construction.
      iii. Provide all labor, equipment, and materials to control dust on all access roads and disturbed areas several times per day to prevent dust nuisance or damage to persons, property, or activities, included but not limited to crops, cultivated fields, wildlife habitats, residences, agricultural activities, recreational activities, traffic, and similar conditions.
      iv. Provide specialty mufflers for continuously running generators, pumps, and other stationary equipment.

v. Perform construction activities by methods that will prevent entrance, or accidental spillage, of solid matter, contaminants, debris, or other pollutants or wastes into streams, flowing or dry watercourses, lakes, wetlands, reservoirs, or underground water sources. Such pollutants and wastes include, but are not restricted to refuse, garbage, cement, sanitary waste, industrial waste, hazardous materials, radioactive substances, oil and other petroleum products, aggregate processing tailings, mineral salts, and thermal pollution.
vi. Ensure absorbent pads to soak up leaks and a fuel spill response kit (including rag pads and booms) of appropriate size for the equipment are available on site at all times and readily available throughout the construction period.

8. General Conservation Measures Applicable to All Actions

a. Timing of In-water Work

b. Idaho Department of Fish and Game (IDFG) guidelines for timing of in-water work windows will be followed.

i. Changes to established work windows will be approved by regional state biologists.
ii. The in-water work window will be provided in the construction plans.

c. Site Layout and Flagging

i. Construction areas will be clearly flagged prior to construction.
ii. Areas to be flagged will include:
iii. Sensitive resource areas, such as areas below OHWM, spawning areas, springs, and wetlands;
iv. Equipment entry and exit points;
v. Road and stream crossing alignments;
vi. Staging, storage, and stockpile areas; and,
vii. No-spray areas and buffers.

d. Temporary Access Roads and Paths

i. Existing access roads and paths will be preferentially used whenever reasonable, and the number and length of temporary access roads and paths through riparian areas and floodplains will be minimized.
ii. Temporary access roads and paths will not be built on slopes where grade, soil, or other features suggest a likelihood of excessive erosion or failure. If slopes are steeper than 30%, then the road will be designed by a civil engineer with experience in steep road design.
iii. The removal of riparian vegetation during construction of temporary access roads will be minimized. When temporary vegetation removal is required, vegetation will be cut at ground level (not grubbed).

iv. At project completion, all temporary access roads and paths will be obliterated, and the soil will be stabilized and revegetated. Road and path obliteration refer to the most comprehensive degree of decommissioning and involves decompacting the surface and ditch, pulling the fill material onto the running surface, and reshaping to match the original contour.

e. Temporary Stream Crossings

i. Existing stream crossings will be preferentially used whenever reasonable, and the number of temporary stream crossings will be minimized.
ii. Temporary bridges and culverts will be installed to allow for equipment and vehicle crossing over perennial streams during construction. Treated wood shall not be used on temporary bridge crossings or in locations in contact with or directly over water.
iii. For projects that require equipment and vehicles to cross in the wet:
    1. The location and number of all wet crossings shall be documented in the construction plans;
    2. Vehicles and machinery shall cross streams at right angles to the main channel whenever possible;
    3. No stream crossings will occur 300 feet upstream or 100 feet downstream of an existing redd or spawning fish; and,
    4. After project completion, temporary stream crossings will be obliterated and banks restored.

f. Staging, Storage, and Stockpile Areas

i. Staging areas (used for construction equipment storage, vehicle storage, fueling, servicing, and hazardous material storage) will be 150 feet or more from any natural waterbody or wetland. Staging areas closer than 150 feet will be pre-approved.
ii. Natural materials used for implementation of aquatic restoration, such as large wood, gravel, and boulders, may be staged within 150 feet if clearly indicated in the plans that area is for natural materials only.
iii. Any large wood, topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration at a specifically identified and flagged area.
iv. Any material not used in restoration, and not native to the floodplain, will be disposed of outside the 100-year floodplain.

g. Equipment

i. Mechanized equipment and vehicles will be selected, operated, and maintained in a manner that minimizes adverse effects on the environment (e.g., minimally-sized, low pressure tires; minimal hard-turn paths for tracked vehicles; temporary mats or plates within wet areas or on sensitive soils).

ii. Equipment will be stored, fueled, and maintained in a clearly identified staging area that meets staging area conservation measures;
iii. Equipment will be refueled in a vehicle staging area or in an isolated hard zone, such as a paved parking lot or adjacent, established road (this measure applies only to gas-powered equipment with tanks larger than 5 gallons);
iv. Biodegradable lubricants and fluids will be used on equipment operating in and adjacent to the stream channel and live water.
v. Equipment will be inspected daily for fluid leaks before leaving the vehicle staging area for operation within 150 feet of any natural water body or wetland; and,
vi. Equipment will be thoroughly cleaned before operation below OHWM, and as often as necessary during operation, to remain grease free.

h. Temporary Erosion Control

i. Temporary erosion controls will be in place before any significant alteration of the action site and appropriately installed downslope of project activity within the riparian buffer area until site rehabilitation is complete;
ii. If there is a potential for eroded sediment to enter the stream, sediment barriers will be installed and maintained for the duration of project implementation;
iii. Temporary erosion control measures may include sedge mats, fiber wattles, silt fences, jute matting, wood fiber mulch and soil binder, or geotextiles and geosynthetic fabric;
iv. Soil stabilization utilizing wood fiber mulch and tackifier (hydro-applied) may be used to reduce erosion of bare soil if the materials are noxious weed free and nontoxic to aquatic and terrestrial animals, soil microorganisms, and vegetation;
v. Sediment will be removed from erosion controls once it has reached one-third of the exposed height of the control; and,
vi. Once the site is stabilized after construction, temporary erosion control measures will be removed.

i. Emergency Erosion Controls

i. The following materials for emergency erosion control will be available at the work site:
   1. A supply of sediment control materials; and,
   2. An oil-absorbing floating boom whenever surface water is present.

j. Dust Abatement

i. The project sponsor will determine the appropriate dust control measures by considering soil type, equipment usage, prevailing wind direction, and the effects caused by other erosion and sediment control measures.

ii. Work will be sequenced and scheduled to reduce exposed bare soil subject to wind erosion.
iii. Dust-abatement additives and stabilization chemicals (typically magnesium chloride, calcium chloride salts, or lignin sulfonate will not be applied within 25 feet of water or a stream channel and will be applied so as to minimize the likelihood that they will enter streams. Applications of lignin sulfonate will be limited to a maximum rate of 0.5 gallons per square yard of road surface, assuming mixed 50:50 with water.
iv. Application of dust abatement chemicals will be avoided during or just before wet weather, and at stream crossings or other areas that could result in unfiltered delivery of the dust abatement materials to a waterbody (typically these would be areas within 25 feet of a waterbody or stream channel; distances may be greater where vegetation is sparse or slopes are steep).
v. Spill containment equipment will be available during application of dust abatement chemicals.
vi. Petroleum-based products will not be used for dust abatement.

k. Spill Prevention, Control, and Counter Measures

i. A description of hazardous materials that will be used, including inventory, storage, and handling procedures will be available on-site.
ii. Written procedures for notifying environmental response agencies will be posted at the work site.
iii. Spill containment kits (including instructions for cleanup and disposal) adequate for the types and quantity of hazardous materials used at the site will be available at the work site.
iv. Workers will be trained in spill containment procedures and will be informed of the location of spill containment kits.
v. Any waste liquids generated at the staging areas will be temporarily stored under an impervious cover, such as a tarpaulin, until they can be properly transported to and disposed of at a facility that is approved for receipt of hazardous materials.
vi. Pumps used adjacent to water shall use spill containment systems.

l. Invasive Species Control

i. Prior to entering the site, all vehicles and equipment will be power washed, allowed to fully dry, and inspected to make sure no plants, soil, or other organic material adheres to the surface.
ii. Watercraft, waders, boots, and any other gear to be used in or near water will be inspected for aquatic invasive species.
iii. Wading boots with felt soles are not to be used due to their propensity for aiding in the transfer of invasive species unless decontamination procedures have been pre-approved.

LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
PRELIMINARY DESIGN DRAWINGS

PREPARED FOR:
PERPETUA RESOURCES
405 S 8TH STREET, STE 201
BOISE, ID 83702

PREPARED BY:
RIO APPLIED SCIENCE & ENGINEERING, LLC
3380 AMERICANA TERRACE, STE 390
BOISE, ID 83706

PROJECT GOALS AND OBJECTIVES:

PROJECT GOALS:

1. INCREASE AND IMPROVE AQUATIC HABITAT FOR LIMITING LIFE STAGES OF ENDANGERED SPECIES ACT (ESA) LISTED FISH:
   - 1.1. PRE-SMOLT (OVER-WINTERING REARING)
   - 1.2. PARR (HIGH FLOW REFUGIA AND SUMMER REARING)
   - 1.3. ADULT (SPAWNING AND HOLDING)
2. RESTORE NATURAL CHANNEL PROCESSES TO MAINTAIN DIVERSE HABITAT.

PRIMARY OBJECTIVES TO ADDRESS LIMITING FACTORS:

1. DO NO HARM TO EXISTING HABITAT AND KNOWN SPAWNING AND REARING AREAS.
2. INCREASE IN-STREAM HYDRAULIC DIVERSITY AND VELOCITY GRADIENTS
3. INCREASE POOL SIZE, FREQUENCY, AND COMPLEXITY.
4. INCREASE IN-STREAM COVER AND INTERSTITIAL SPACE ALONG CHANNEL MARGINS LEADING UP TO AND DURING SPAWNING.
5. REDUCE WIDTH-TO-DEPTH RATIO WHERE CHANNEL IS OVER-WIDENED TO INCREASE VELOCITY GRADIENTS, FLOODPLAIN CONNECTION, POOL SCOUR POTENTIAL, SHADE, COVER, AND NATURAL CHANNEL FORMING PROCESSES.
6. INCREASE FREQUENCY, DURATION, AND AREA OF FLOODPLAIN CONNECTION TO PROVIDE HIGH FLOW REFUGIA, IMPROVE FINE SEDIMENT DISTRIBUTION, GROUNDWATER RECHARGE, FLOODWATER STORAGE, AND NUTRIENT CYCLING.
7. CREATE A ROBUST RIPARIAN CORRIDOR TO INCREASE SHADE, PROVIDE OVERHEAD COVER, STABILIZE BANKS, PROVIDE IN-STREAM STRUCTURE, AND INCREASE WOODY DEBRIS RECRUITMENT POTENTIAL.
8. FORCE SURFACE/GROUNDWATER INTERCHANGE TO MODERATE IN-STREAM TEMPERATURE AND PROVIDE AREAS OF ISOLATED TEMPERATURE REFUGE.

VICINITY MAP
NOT TO SCALE

LOCATION MAP
NOT TO SCALE

SHEET INDEX		
SHEET COUNT	DRAWING NUMBER	DRAWING TITLE
1	G1	COVER
2	G2	GENERAL NOTES 1
3	G3	GENERAL NOTES 2
4	G4	CONSERVATION MEASURES 1
5	G5	CONSERVATION MEASURES 2
6	G6	CONSERVATION MEASURES 3
7	G7	MASTER LEGEND
8	G8	QUANTITIES
9	C1	EXISTING OVERVIEW
10	C2	OVERVIEW
11	C3	PLAN 1
12	C4	PLAN 2
13	C5	PLAN 3
14	C6	PLAN 4
15	C7	ACCESS AND STAGING
16	D1	TYPICAL SECTIONS
17	D2	ACCESS AND EROSION CONTROL
18	D3	CONSTRUCTED RIFFLE
19	D4	2 LOG STRUCTURE
20	D5	SINGLE LOG STRUCTURE
21	D6	WHOLE TREE
22	D7	WILLOW ROOTBALL
23	D8	BLEEDER JAM
24	D9	SMALL APEX JAM
25	D10	LARGE APEX JAM
26	D11	RELIC BEAVER DAM ANALOUGE
27	D12	BRUSH BANK
28	D13	SHORT ROUGHENED EDGE
29	D14	WILLOW BAFFLES AND LIVE CUTTINGS
30	D15	BOULDERS & RACKING PLACEMENT

LOCATION:
LOCATED WITHIN SECTIONS 14, 23, 24, AND 25 OF TOWNSHIP 17N, RANGE 23E LEMHI COUNTY, IDAHO

Rio Applied Science & Engineering

Perpetua Resources

LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

PRELIMINARY DESIGN DRAWINGS

FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO

WORKING DRAFT FOR REVIEW AND REVISION

DATE: JUNE 2022
DESIGNED: —
APPROVED: —

DRAWING NAME
GENERALS

COVER

Figure D-1

ABBREVIATIONS

AC	ACRE
BMP	BEST MANAGEMENT PRACTICES
BO	BIOLOGICAL OPINION
BPA	BONNEVILLE POWER ADMINISTRATION
CFS	CUBIC FEET PER SECOND
CO/C.O.	CONTRACTING OFFICER
CP	CONTROL POINT
CSRO	COLUMBIA-SNAKE SALMON RECOVERY OFFICE
CWA	CLEAN WATER ACT
CY	CUBIC YARDS
DBH	DIAMETER AT BREAST HEIGHT
DEQ	DEPARTMENT ENVIRONMENTAL QUALITY
DSL	DEPARTMENT OF STATE LANDS
EA	EACH
E.	EAST
EL	ELEVATION
EPA	ENVIRONMENTAL PROTECTION AGENCY
ESA	ENDANGERED SPECIES ACT
FCRPS	FEDERAL COLUMBIA RIVER POWER SYSTEM
F.G.	FINISHED GRADE
HIP	HABITAT IMPROVEMENT PROGRAM
HWY	HIGHWAY
I	INTERSTATE
IDFG	IDAHO FISH & GAME
LWM	LARGE WOODY MATERIAL
MC	MAIN CHANNEL
MW	MONITORING WELL
N.	NORTH
NAD	NORTH AMERICAN DATUM
NAVD	NORTH AMERICAN VERTICAL DATUM
NEPA	NATIONAL ENVIRONMENTAL POLICY ACT
NMFS	NATIONAL MARINE FISHERIES SERVICE
NPDES	NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM
OC	ON CENTER
O.G.	ORIGINAL GRADE
OHW	ORDINARY HIGH WATER
OR	OREGON
OSHA	OCCUPATIONAL SAFTEY AND HEALTH ADMINISTRATION
PH	PHONE
PLS	PURE LIVE SEED
PLS/AC	PURE LIVE SEED PER ACRE
PP	PLAN AND PROFILE
R	RANGE
S.	SOUTH
SC	SIDE CHANNEL
SEC	SECTION
SHPO	STATE HISTORIC PRESERVATION OFFICE
STA	STATION
SWPPP	STORM WATER POLLUTION PREVENTION PLAN
SY	SQUARE YARDS
T	TOWNSHIP
TESC	TEMPORARY EROSION & SEDIMENT CONTROL
TOB	TOP OF BANK
TYP	TYPICAL
U.S.	UNITED STATES
USACE	UNITED STATES ARMY CORPS OF ENGINEERS
USBR	UNITED STATE BUREAU OF RECLAMATION
USFS	UNITED STATES FOREST SERVICE
USFWS	UNITED STATES FISH & WILDLIFE SERVICE
V	VOLTS
W.	WEST
WSE	WATER SURFACE ELEVATION
YR	YEAR

LEGEND

EXISTING FENCE
PROPERTY LINE, APPROXIMATE
RM 18 RIVER MILE
EXISTING IRRIGATION DITCH
EXISTING ORDINARY HIGH WATER (OHW)
EXISTING CONTOUR (1-FT INTERVAL)
CONSTRUCTED RIFFLE
WOOD HABITAT STRUCTURE
WILLOW ROOTBALL STRUCTURE
RELIC BEAVER DAM ANALOGUE
BRUSH BANK TREATMENT
SHORT ROUGHENED EDGE
WILLOW BAFFLE
EXCAVATED CHANNEL
CHANNEL PLUG/FILL
NON-PERENNIAL SIDE CHANNEL
TEMPORARY ACCESS ROUTE
STOCKPILE AND REFUELING AREA

Perpetua Resources

LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

PRELIMINARY DESIGN DRAWINGS

FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO

WORKING DRAFT FOR REVIEW AND REVISION

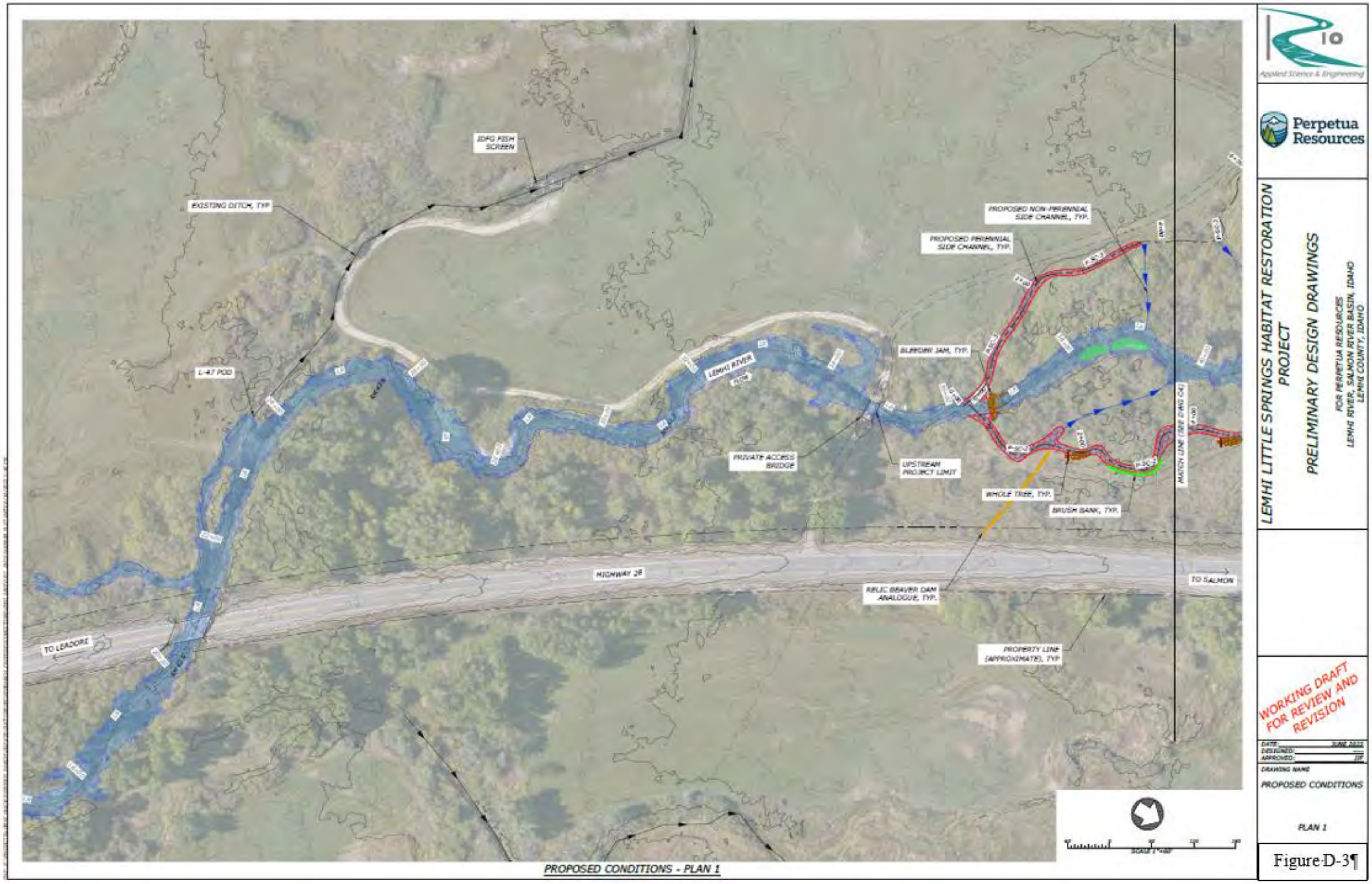
DATE:
DESIGNED:
APPROVED:

DRAWING NAME

GENERALS

MASTER LEGEND

Figure D-2¶


IDFG FISH SCREEN
EXISTING DITCH, TYP
L-47 POD
LEMHI RIVER
FLOW
PROPOSED NON-PERENNIAL SIDE CHANNEL, TYP.
PROPOSED PERENNIAL SIDE CHANNEL, TYP.
BLEEDER JAM, TYP.
PRIVATE ACCESS BRIDGE
UPSTREAM PROJECT LIMIT
WHOLE TREE, TYP.
BRUSH BANK, TYP.
MATCH LINE (SEE DWG C4)
HIGHWAY 28
TO SALMON
TO LEADORE
RELIC BEAVER DAM ANALOGUE, TYP.
PROPERTY LINE (APPROXIMATE), TYP
PROPOSED CONDITIONS - PLAN 1
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PRELIMINARY DESIGN DRAWINGS
FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO
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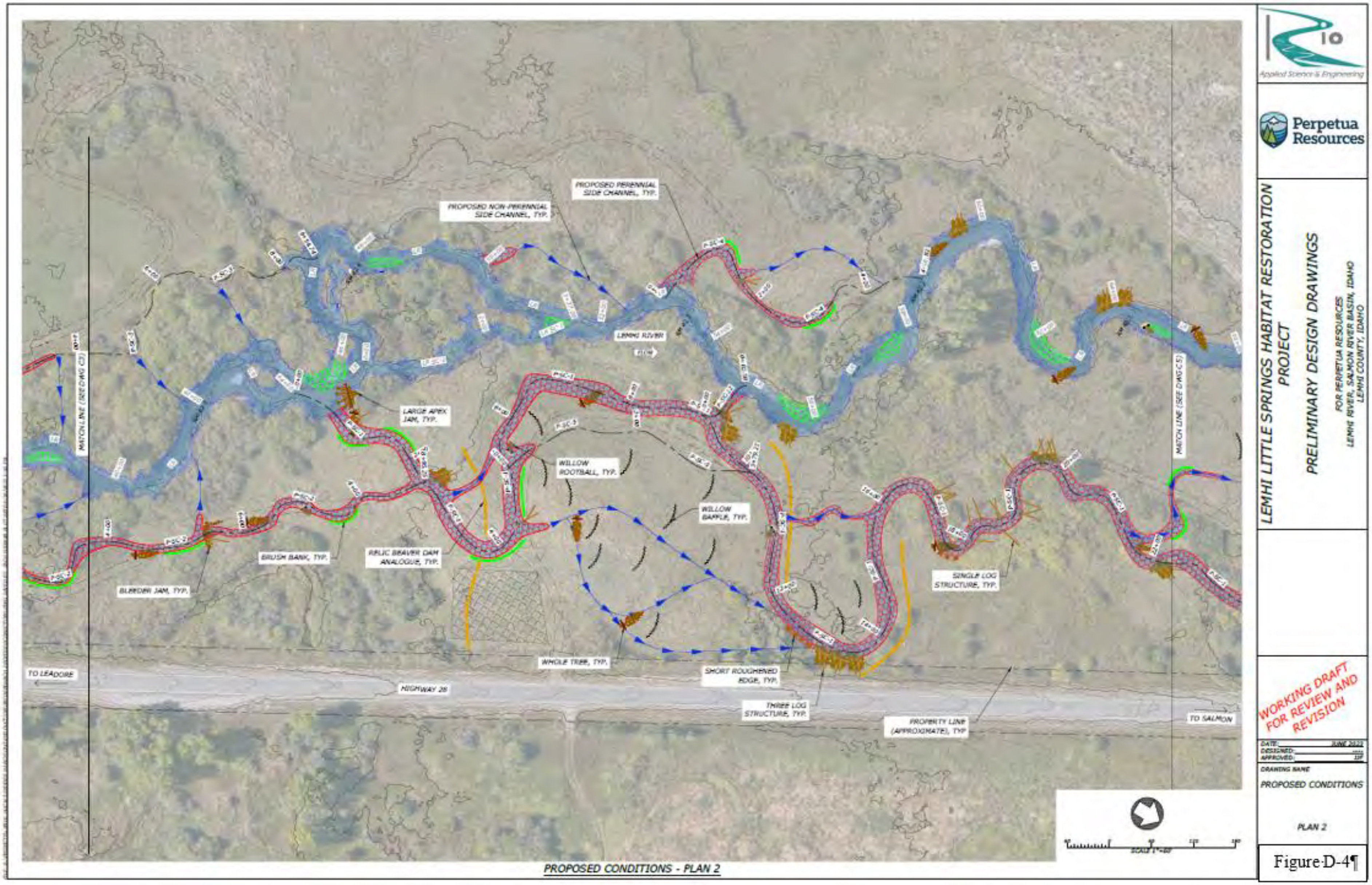
APPROVED:
DRAWING NAME
PROPOSED CONDITIONS
PLAN 1
Figure D-3


PROPOSED PERENNIAL SIDE CHANNEL, TYP.
PROPOSED NON-PERENNIAL SIDE CHANNEL, TYP.
LEMHI RIVER
LARGE APEX JAM, TYP.
WILLOW ROOTBALL, TYP.
WILLOW BAFFLE, TYP.
BRUSH BANK, TYP.
RELIC BEAVER DAM ANALOGUE, TYP.
BLEEDER JAM, TYP.
SINGLE LOG STRUCTURE, TYP.
WHOLE TREE, TYP.
SHORT ROUGHENED EDGE, TYP.
THREE LOG STRUCTURE, TYP.
PROPERTY LINE (APPROXIMATE), TYP.
TO LEADORE
HIGHWAY 28
TO SALMON
MATCH LINE (SEE DWG C5)
PROPOSED CONDITIONS - PLAN 2
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FOR PERPETUA RESOURCES
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LEMHI COUNTY, IDAHO
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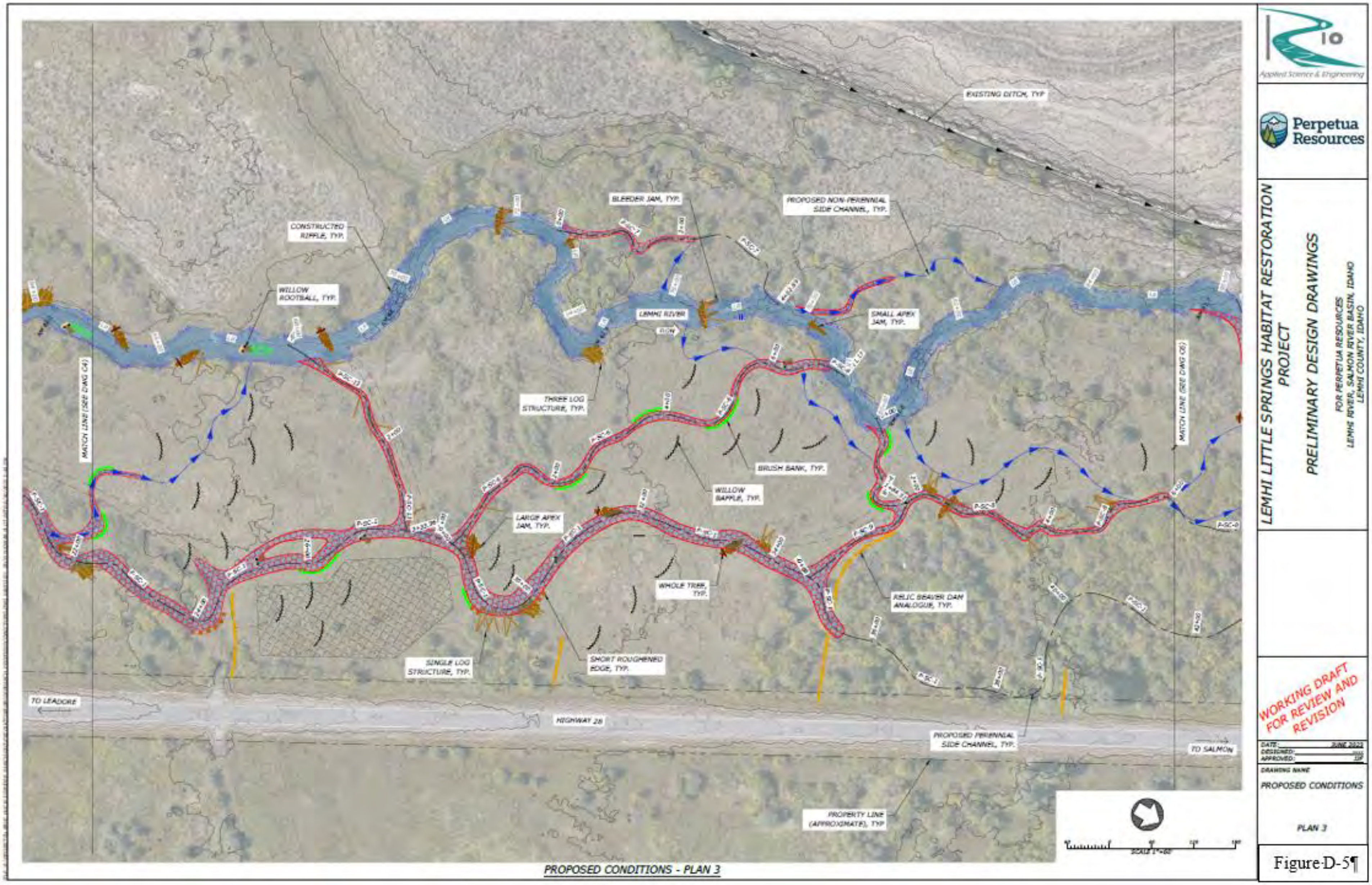
DESIGNED:
APPROVED:
DRAWING NAME
PROPOSED CONDITIONS
PLAN 2

Figure D-4



EXISTING DITCH, TYP
BLEEDER JAM, TYP.
PROPOSED NON-PERENNIAL SIDE CHANNEL, TYP.
CONSTRUCTED RIFFLE, TYP.
WILLOW ROOTBALL, TYP.
LEMHI RIVER
FLOW
SMALL APEX JAM, TYP.
THREE LOG STRUCTURE, TYP.
BRUSH BANK, TYP.
WILLOW BAFFLE, TYP.
LARGE APEX JAM, TYP.
WHOLE TREE, TYP.
RELIC BEAVER DAM ANALOGUE, TYP.
SINGLE LOG STRUCTURE, TYP.
SHORT ROUGHENED EDGE, TYP.
TO LEADORE
HIGHWAY 28
PROPOSED PERENNIAL SIDE CHANNEL, TYP.
TO SALMON
PROPERTY LINE (APPROXIMATE), TYP
MATCH LINE (SEE DWG C4)
PROPOSED CONDITIONS - PLAN 3
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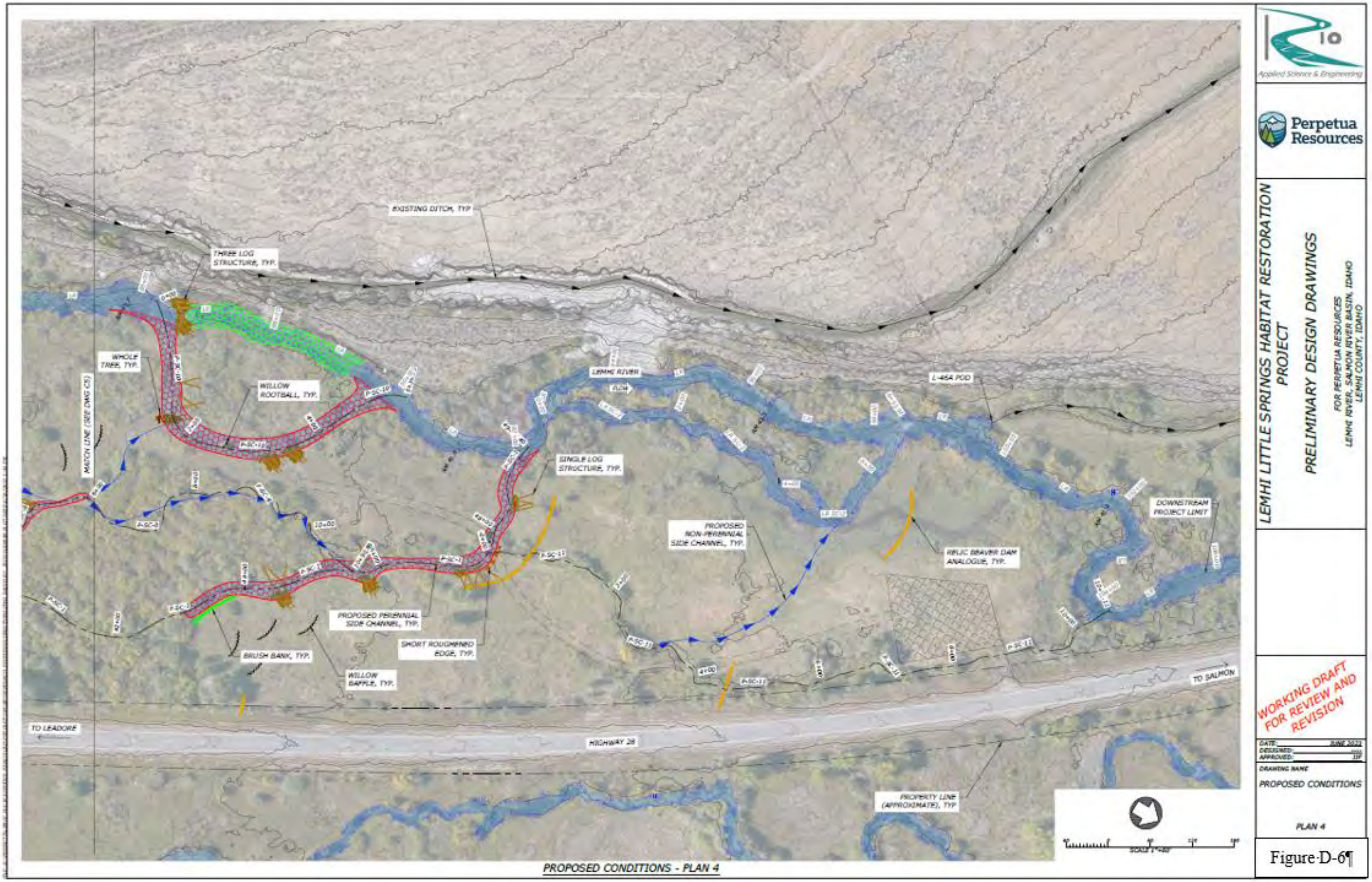
PRELIMINARY DESIGN DRAWINGS
FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO
WORKING DRAFT FOR REVIEW AND REVISION
DRAWING NAME
PROPOSED CONDITIONS
PLAN 3

Figure D-5



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PRELIMINARY DESIGN DRAWINGS
FOR PERPETUA RESOURCES
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LEMHI COUNTY, IDAHO
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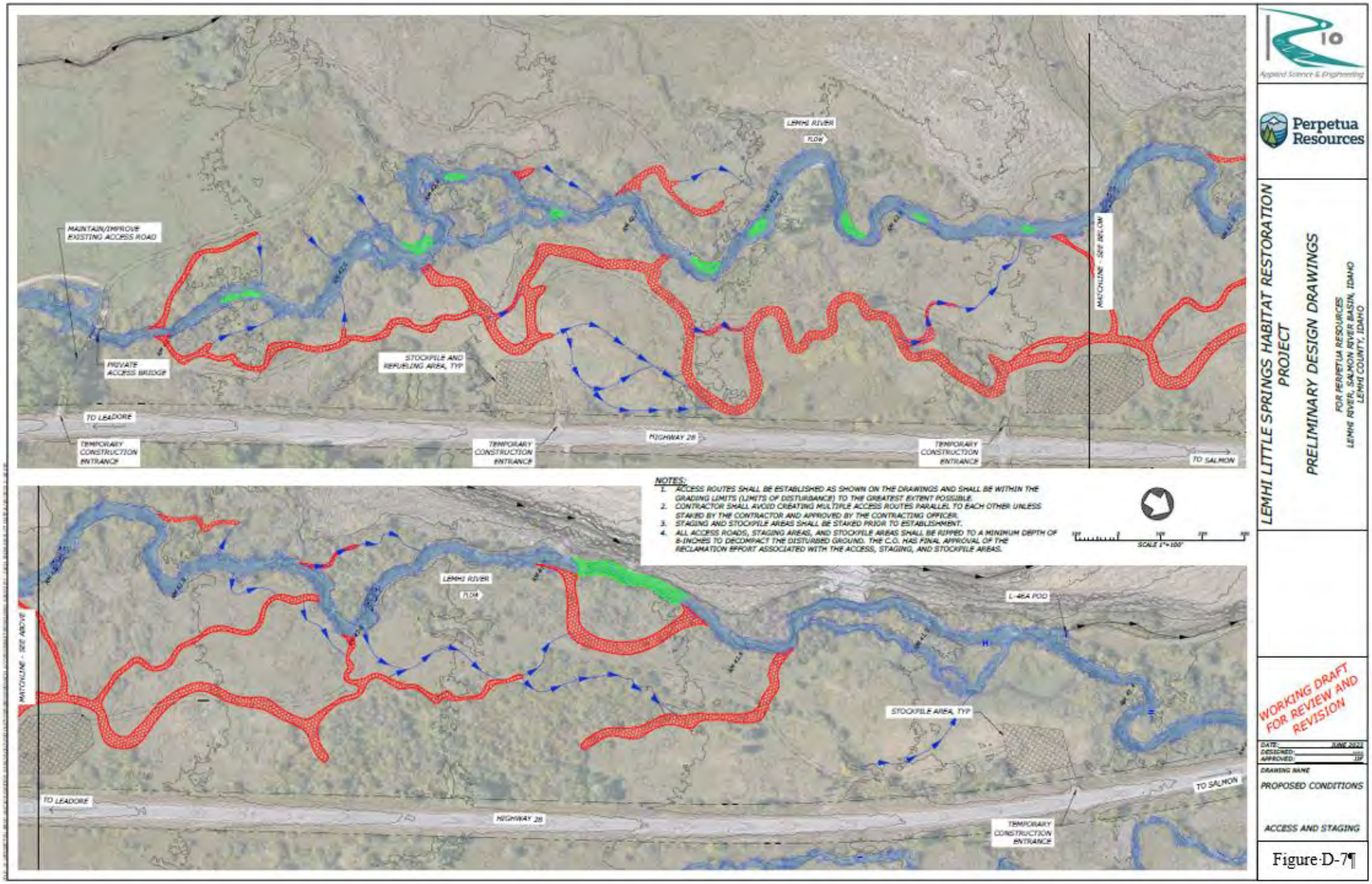
DRAWING NAME
PROPOSED CONDITIONS
PLAN 4
EXISTING DITCH, TYP
THREE LOG STRUCTURE, TYP.
WHOLE TREE, TYP.
WILLOW ROOTBALL, TYP.
MATCH LINE (SEE DWG C5)
SINGLE LOG STRUCTURE, TYP.
LEMHI RIVER
FLOW
L-464 POD
PROPOSED NON-PERENNIAL SIDE CHANNEL, TYP.
RELIC BEAVER DAM ANALOGUE, TYP.
DOWNSTREAM PROJECT LIMIT
PROPOSED PERENNIAL SIDE CHANNEL, TYP.
SHORT ROUGHENED EDGE, TYP.
BRUSH BANK, TYP.
WILLOW BAFFLE, TYP.
TO LEADORE
HIGHWAY 28
TO SALMON
PROPERTY LINE (APPROXIMATE), TYP
PROPOSED CONDITIONS - PLAN 4

Figure D-6¶


LEMHI RIVER
FLOW
MAINTAIN/IMPROVE EXISTING ACCESS ROAD
PRIVATE ACCESS BRIDGE
STOCKPILE AND REFUELING AREA, TYP
TO LEADORE
TEMPORARY CONSTRUCTION ENTRANCE
HIGHWAY 28
TO SALMON
MATCHLINE - SEE BELOW
MATCHLINE - SEE ABOVE
L-46A POD
STOCKPILE AREA, TYP
NOTES:
1. ACCESS ROUTES SHALL BE ESTABLISHED AS SHOWN ON THE DRAWINGS AND SHALL BE WITHIN THE GRADING LIMITS (LIMITS OF DISTURBANCE) TO THE GREATEST EXTENT POSSIBLE.
2. CONTRACTOR SHALL AVOID CREATING MULTIPLE ACCESS ROUTES PARALLEL TO EACH OTHER UNLESS STAKED BY THE CONTRACTOR AND APPROVED BY THE CONTRACTING OFFICER.
3. STAGING AND STOCKPILE AREAS SHALL BE STAKED PRIOR TO ESTABLISHMENT.
4. ALL ACCESS ROADS, STAGING AREAS, AND STOCKPILE AREAS SHALL BE RIPPED TO A MINIMUM DEPTH OF 8-INCHES TO DECOMPACT THE DISTURBED GROUND. THE C.O. HAS FINAL APPROVAL OF THE RECLAMATION EFFORT ASSOCIATED WITH THE ACCESS, STAGING, AND STOCKPILE AREAS.
SCALE 1"=100'
Rio
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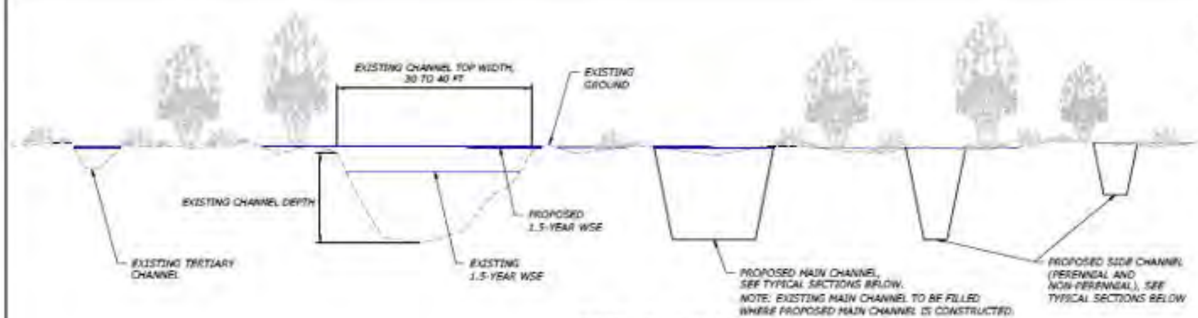
LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT
PRELIMINARY DESIGN DRAWINGS
FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO
WORKING DRAFT FOR REVIEW AND REVISION
DATE: JUNE 2022
DESIGNED:
APPROVED:
DRAWING NAME
PROPOSED CONDITIONS
ACCESS AND STAGING

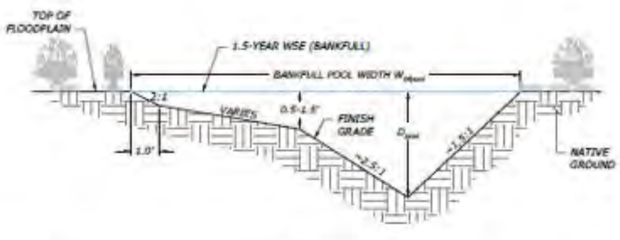
Figure D-7



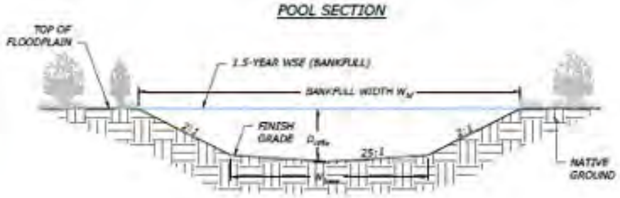
TYPICAL CHANNEL SECTION SUMMARY

NOTES:

1. NEW MAIN CHANNEL IS PROPOSED WHERE THE EXISTING CHANNEL IS TO BE ABANDONED, PARTIALLY OR FULLY FILLED, OR BLOCKED. MAIN CHANNELS ARE DESIGNED TO PROVIDE A HIGH DEGREE OF CERTAINTY OF CHANNEL FUNCTION.
2. PROPOSED SIDE CHANNELS WILL BE A MIX OF PERENNIAL AND NON-PERENNIAL PROVIDING A MODERATE DEGREE OF CERTAINTY OF OUTCOME/CHANNEL FUNCTION.
3. TERTIARY CHANNELS WILL BE CREATED AS A RESULT OF RESTORATION ACTIVITIES AND MAY BE ENHANCED WITH STRATEGIC PLACEMENTS OF STRUCTURE/ROUGHNESS ELEMENTS. THESE CHANNELS PROVIDE A LOW DEGREE OF CERTAINTY OF CHANNEL FUNCTION.
4. ALL PROPOSED EXCAVATED CHANNELS MAY INCLUDE POOL AND RIFFLE HABITAT UNITS AND ENGINEERED BANK STRUCTURE/ROUGHNESS ELEMENTS (BANK TREATMENTS USING NATURAL MATERIALS SUCH AS WOODY DEBRIS, COIR FABRIC, AND RIPARIAN PLANTINGS OR WOOD HABITAT STRUCTURES). REFER TO THE DETAILS ON DRAWINGS D2 TO D15 FOR PROPOSED ELEMENTS.



POOL SECTION



RIFFLE SECTION

Channel	Reach ID	Stationing			Length	% of Flow	Bankfull Q	Channel Slope	D_{riffle}	W_{bf}	Width/ Depth Ratio	D_{pool}	$W_{bf,pool}$
		Start Sta.	to	End Sta.	(ft)	(%)	(cfs)	(ft/ft)	(ft)	(ft)		(ft)	(ft)
Main Lemhi River	Main-A	0	to	3600	3,600	100%	336	0.0071	2.5	36	14.3	6.3 - 8.8	44 - 53
	Main-B	3600	to	4400	800	60%	269	0.0049	2.5	36	14.5	6.2 - 8.7	43 - 53
	Main-C	4400	to	4725	325	45%	151	0.0105	1.8	25	14.2	4.4 - 6.2	30 - 37
	Main-D	4725	to	5300	575	55%	185	0.0055	2.1	30	14.4	5.3 - 7.4	37 - 45
	Main-E	5300	to	5500	200	45%	151	0.0018	2.5	36	14.4	6.3 - 8.8	44 - 53
	Main-F	5500	to	5900	400	50%	168	0.0058	2.0	29	14.4	5 - 7.1	35 - 43
	Main-G	5900	to	6800	900	60%	202	0.0057	2.2	31	14.0	5.5 - 7.7	37 - 46
	Main-H	6800	to	7250	450	50%	168	0.0079	1.9	28	14.5	4.7 - 6.6	33 - 40
	Main-I	7250	to	7750	500	40%	134	0.0053	1.9	28	14.5	4.8 - 6.7	33 - 41
	Main-J	7750	to	7900	150	50%	168	0.0067	2.0	28	14.1	5 - 6.9	34 - 41
	Main-K	7900	to	8000	100	70%	235	0.0115	2.1	28	13.7	5.2 - 7.2	34 - 42
	Main-L	8000	to	8650	650	60%	202	0.0042	2.3	33	14.5	5.7 - 8	40 - 48
	Main-M	8650	to	9000	350	2%	7	0.0115	0.7	6	8.4	1.7 - 2.4	8 - 10
	Main-N	9000	to	9200	200	60%	202	0.0075	2.1	30	14.7	5.1 - 7.2	36 - 44
	Main-O	9200	to	10425	1,225	85%	286	0.0071	2.4	34	14.0	6 - 8.4	41 - 50
	Main-P	10425	to	10600	175	100%	336	0.0055	2.7	38	14.1	6.7 - 9.3	46 - 56
Side Channel 1	P-SC-1A	0+00	to	2+40	240	35%	118	0.0059	2.0	24	12.0	5 - 7	30 - 37
	P-SC-1B	2+40	to	5+25	285	45%	151	0.0059	2.2	27	12.3	5.4 - 7.6	33 - 41
	P-SC-1C	5+25	to	9+00	375	30%	101	0.0059	1.9	23	12.0	4.7 - 6.6	28 - 35
	P-SC-1D	9+00	to	10+25	125	25%	84	0.0052	1.8	21	11.7	4.5 - 6.4	27 - 34
	P-SC-1E	9+00	to	22+00	1,300	40%	134	0.0052	2.2	26	11.9	5.4 - 7.5	32 - 40
	P-SC-1F	22+00	to	27+50	550	40%	134	0.0041	2.2	27	12.0	5.6 - 7.8	34 - 42
	P-SC-1G	27+50	to	28+50	100	50%	168	0.0041	2.4	30	12.3	6 - 8.4	37 - 46
	P-SC-1H	28+50	to	34+50	600	30%	101	0.0041	2.0	24	11.9	5 - 7.1	30 - 38
	P-SC-1I	34+50	to	38+67	417	20%	67	0.0079	1.5	18	11.8	3.9 - 5.4	23 - 29
	P-SC-1J	38+67	to	45+50	683	20%	67	0.0076	1.6	18	11.7	3.9 - 5.4	23 - 29
	P-SC-1K	45+50	to	47+50	200	40%	134	0.0076	2.0	24	12.0	5 - 7	30 - 37
	P-SC-1L	47+50	to	49+07	157	25%	84	0.0076	1.7	20	11.7	4.2 - 5.9	25 - 31
Side Channel 2	P-SC-2	0+00	to	8+95	895	10%	34	0.0069	1.3	13	10.1	3.3 - 4.6	17 - 22
Side Channel 3	P-SC-3	0+00	to	8+55	855	10%	34	0.0083	1.2	13	10.4	3.1 - 4.4	17 - 21
Side Channel 4	P-SC-4	0+00	to	4+81	481	10%	34	0.0072	1.3	13	10.2	3.2 - 4.5	17 - 22
Side Channel 5	P-SC-5	0+00	to	3+79	379	15%	50	0.0076	1.6	14	9.1	3.9 - 5.5	19 - 25
Side Channel 6	P-SC-6	0+00	to	7+11	711	20%	67	0.0068	1.9	16	8.3	4.7 - 6.6	21 - 28
Side Channel 7	P-SC-7	0+00	to	4+03	403	10%	34	0.0095	1.2	13	10.7	3 - 4.2	16 - 21
Side Channel 8	P-SC-8A	0+00	to	1+70	170	10%	34	0.0066	1.3	13	10.1	3.3 - 4.6	17 - 22
	P-SC-8B	1+70	to	10+91	921	20%	67	0.0068	1.7	18	10.6	4.2 - 5.9	23 - 29
Side Channel 9	P-SC-9	0+00	to	1+85	185	10%	34	0.0150	1.2	11	8.8	3.1 - 4.3	15 - 19
Side Channel 10	P-SC-10	0+00	to	5+39	539	58%	195	0.0074	2.2	29	12.9	5.6 - 7.8	36 - 44
Side Channel 11	P-SC-11	0+00	to	10+51	1,051	15%	50	0.0098	1.5	14	9.4	3.7 - 5.2	18 - 24
Side Channel 12	P-SC-12	0+00	to	0+83	83	5%	17	0.0075	1.1	9	8.7	2.7 - 3.7	12 - 16
Side Channel 13	P-SC-13	0+00	to	3+34	334	10%	34	0.0077	1.4	12	9.2	3.4 - 4.7	16 - 22

Notes:
1. Main Lemhi River reaches are being used to target effective width at placement of islands, bankfills, large woody material structures, etc. The entire main channel will not be modified to achieve targets.
2. Side Channel 10 becomes the dominant channel in this location with minimum flow assumed to remain within existing main channel reach Main-M.
3. Tertiary channels, when excavated are sized as a small trapezoidal channel with a bottom width of 5-ft and side slopes 1.5:1.

1 TYPICAL CHANNEL SECTIONS
NTS

Perpetua Resources

LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

PRELIMINARY DESIGN DRAWINGS

FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO

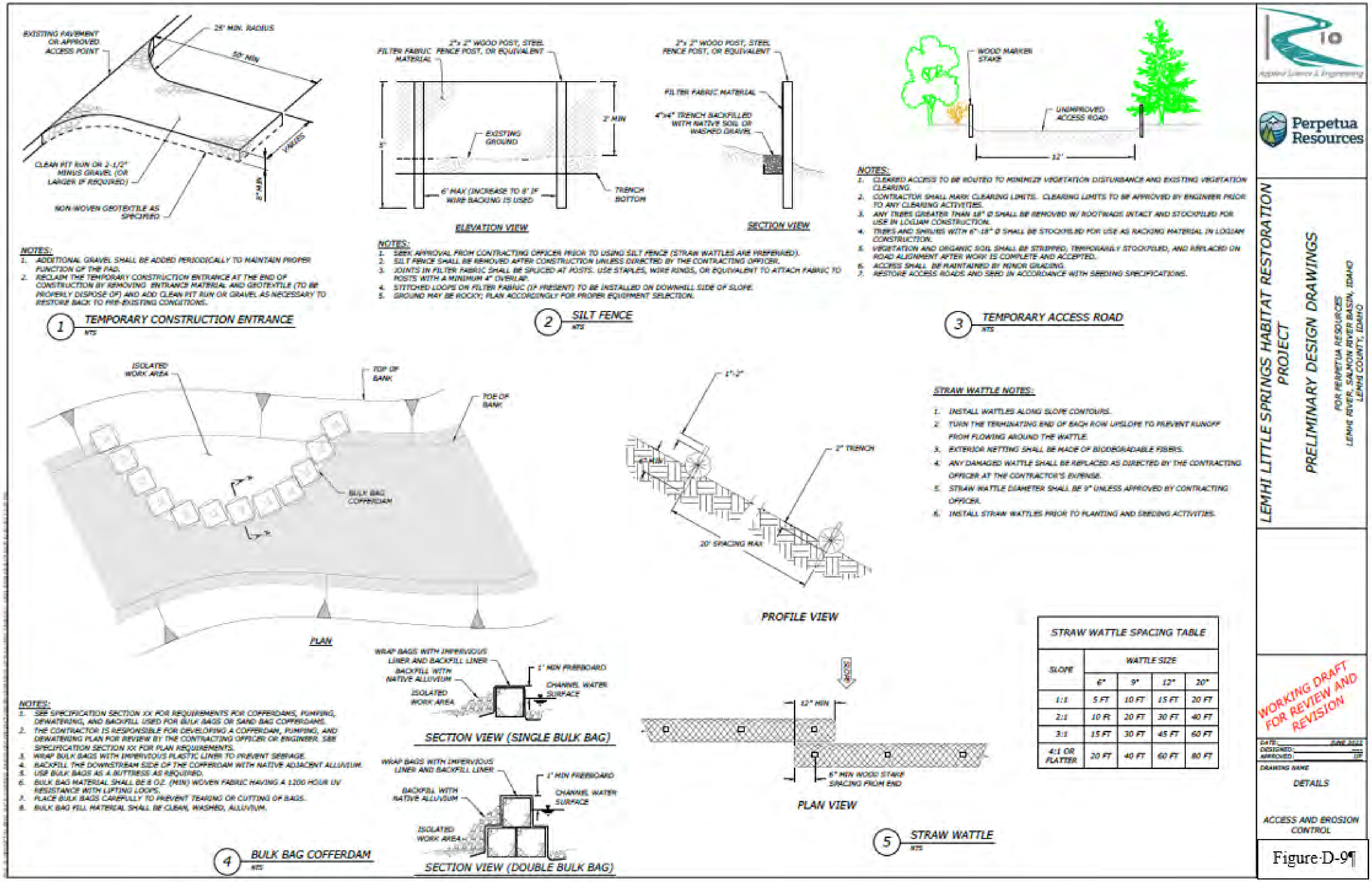
WORKING DRAFT FOR REVIEW AND REVISION

DATE: JUNE 2022
DESIGNED:
APPROVED:

DRAWING NAME
CROSS SECTIONS

TYPICAL SECTIONS

Figure D-8

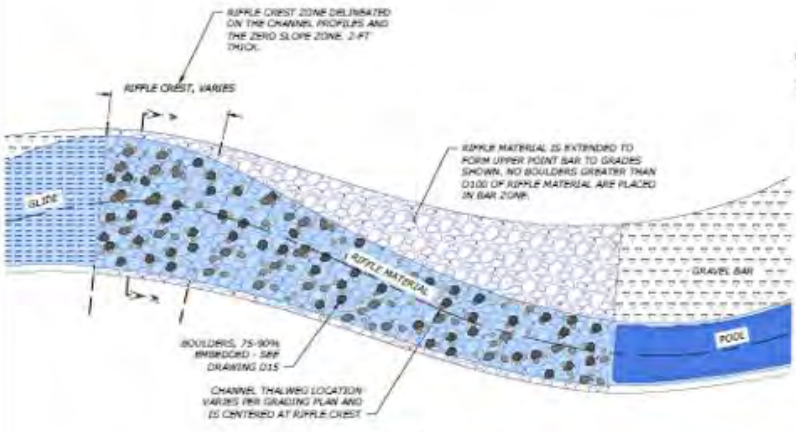


STRAW WATTLE SPACING TABLE

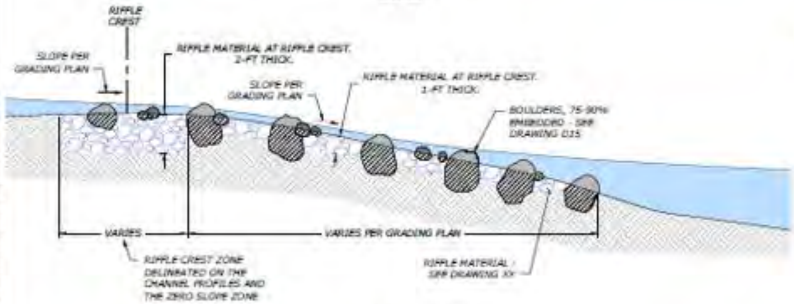
SLOPE	WATTLE SIZE			
	6"	9"	12"	20"
1:1	5 FT	10 FT	15 FT	20 FT
2:1	10 Ft	20 FT	30 FT	40 FT
3:1	15 FT	30 FT	45 FT	60 FT
4:1 OR FLATTER	20 FT	40 FT	60 FT	80 FT

Figure D-9

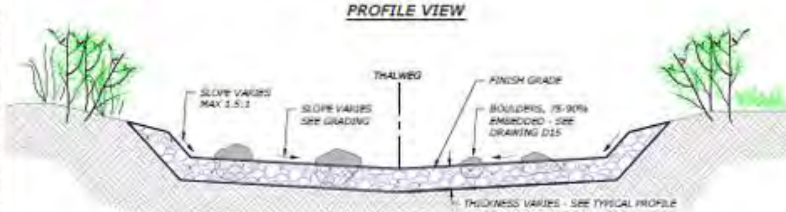
RIFFLE OVERVIEW NOTES:
CONSTRUCTED RIFFLES ARE TO BE INSTALLED AT LOCATIONS SHOW IN THE GRADING PLANS. CONSTRUCTED RIFFLES SHALL BE OVER EXCAVATED AND REPLACED UNLESS DIRECTED BY ENGINEER.



PLAN



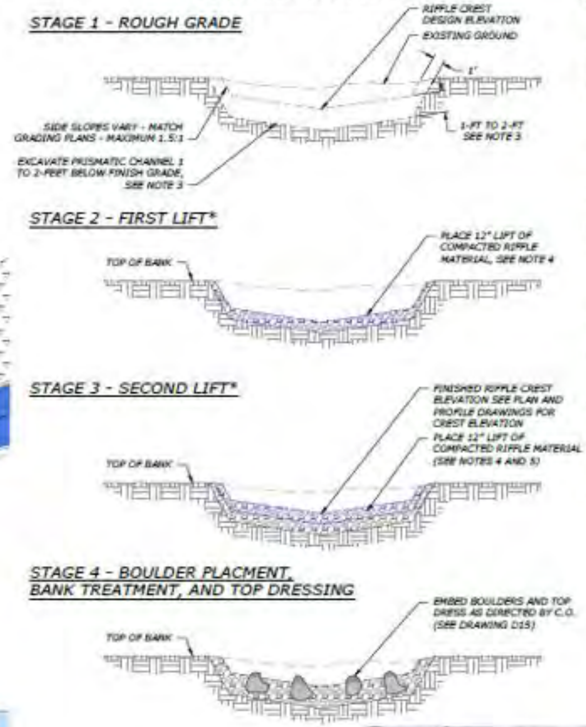
PROFILE VIEW

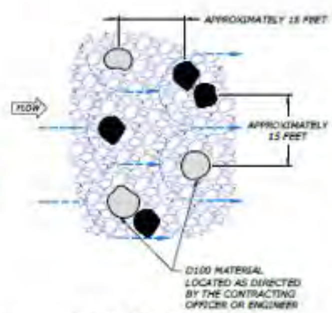


SECTION A-A'

(1) **CONSTRUCTED RIFFLE**
NTS

CONSTRUCTION SEQUENCING





BOULDER PLACEMENT

CONSTRUCTED RIFFLE NOTES:

1. STOCKPILE CHANNEL MATERIALS PER DESIGN SPECIFICATIONS. MATERIALS ARE TO BE STOCKPILED IN THE IMMEDIATE PROJECT AREA OR TRANSPORTED FROM THE SORTING AREA AS NEEDED.
2. THREE PLACEMENTS ARE REQUIRED AS FOLLOWS:
   - 2.1. CONSTRUCTED RIFFLE MATERIAL
   - 2.2. LARGE AND SMALL BOULDERS (FOR EMBEDMENT)
   - 2.3. ROUGHNESS ROCK (TOP DRESSING)
3. TREAT EXISTING CHANNEL BED BY REMOVING ORGANICS AND CREATING A PRISMATIC WORKING SURFACE FOLLOWING CHANNEL THALWEG AND DESIGN CONTOURS ON GRADING DRAWINGS. ROUGH GRADE FROM FINISH GRADE TO SPECIFIED RIFFLE MATERIAL DEPTH IN CHANNEL BED IN ACCORDANCE WITH PLAN AND PROFILE DRAWINGS. ROUGH GRADE BANKS BY 1-FT TO SLOPES SHOWN ON GRADING PLANS AND NOT EXCEEDING 1.5:1.
4. RIP EXISTING CHANNEL BED AT MINIMUM 1" DEEP TO CREATE A BETTER BONDING SURFACE BETWEEN THE TWO LAYERS.
5. IMPORT WELL-MIXED RIFFLE MATERIAL AND/OR CREATE MATERIAL FROM NATIVE ALLUVIUM FROM PROJECT EXCAVATIONS MEETING THE SPECIFICATIONS FOR CONSTRUCTED RIFFLE MATERIAL. COMPACT RIFFLE MATERIAL IN 12-INCH LIFTS USING TRACKED 300 SERIES EXCAVATOR, OR SIMILAR EQUIPMENT AS APPROVED BY C.O. TRACK ON MATRIX MATERIAL SUFFICIENTLY TO COMPACT MATERIAL.
6. REPEAT RIFFLE CONSTRUCTION BY PLACING ANOTHER 12-INCH LIFT WHERE REQUIRED TO MEET DESIGN GRADE AND CROSS SECTION SHAPE.
7. BOULDERS OF VARIOUS SIZES (LARGE AND SMALL - SEE RIFFLE MATERIALS DRAWING, DRAWING XX) ARE TO BE ADDED TO THE RIFFLE TO CREATE DIVERSE FLOW PATHS AND HABITAT, SEE DRAWING D15.
8. TOP DRESS WITH COARSE RIFFLE MATERIAL AS NEEDED AND DIRECTED BY C.O. TO ADD SOME INITIAL ROUGHNESS TO THE CHANNEL AND FORM A NATURAL APPEARANCE.
9. FOR THOSE AREAS WHERE HABITAT STRUCTURES OR BANK TREATMENTS ARE TO BE PLACED ADJACENT TO THE CONSTRUCTED RIFFLE, THE RIFFLE WILL BE CONSTRUCTED BEFORE PLACEMENT OF HABITAT STRUCTURES OR BANK TREATMENTS.
10. RIFFLES AND CHANNELS THAT ARE MARKED AS COMPLETE BY THE CONTRACTOR SHALL NOT BE DRIVEN ON BY MACHINERY TO PREVENT OVER COMPACTION OR MOVEMENT OF MATERIAL WITHOUT APPROVAL FROM C.O..

CONSTRUCTED RIFFLE ON THE LEMHI RIVER WITH BANK TREATMENTS - ONE YEAR AFTER CONSTRUCTION.

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LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

PRELIMINARY DESIGN DRAWINGS

FOR PERPETUA RESOURCES
LEMHI RIVER, SALMON RIVER BASIN, IDAHO
LEMHI COUNTY, IDAHO

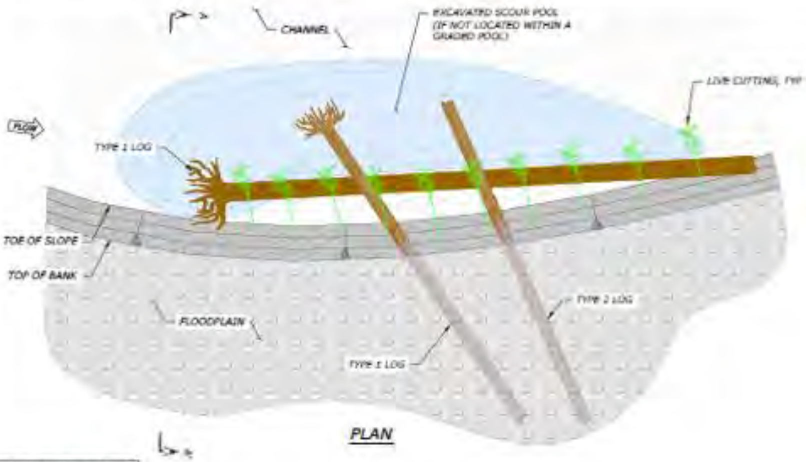
WORKING DRAFT FOR REVIEW AND REVISION

DATE: JUNE 2022
DESIGNED:
APPROVED:

DRAWING NAME
DETAILS

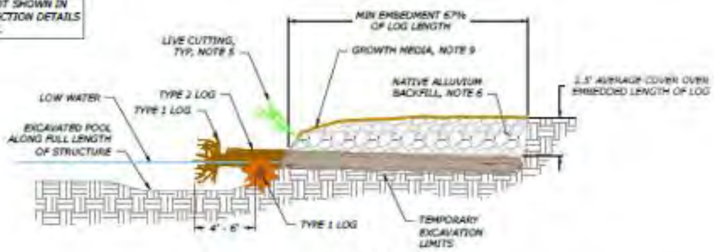
CONSTRUCTED RIFFLE

Fig. D-10



PLAN

NOTE: RACKING AND SLASH MATERIAL NOT SHOWN IN PLAN AND SECTION DETAILS FOR CLARITY.



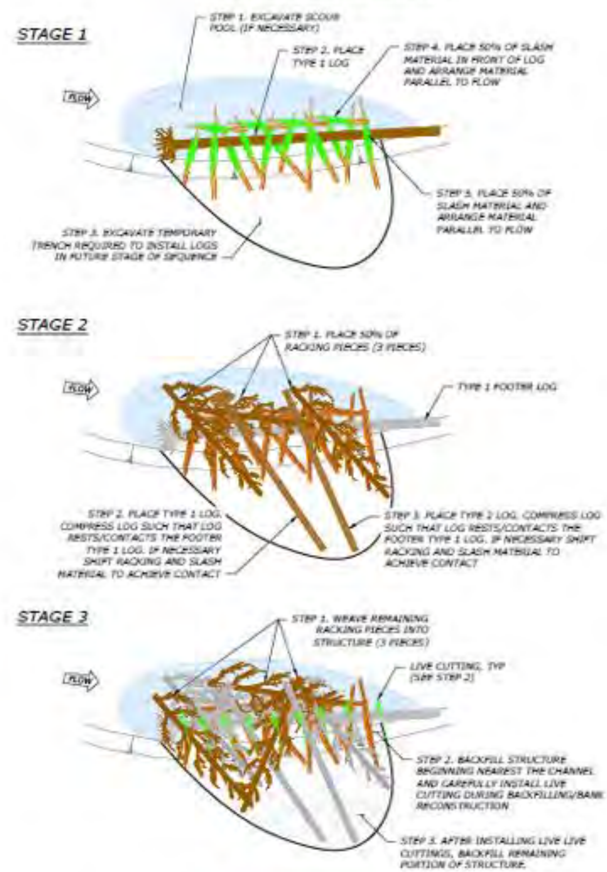
SECTION A-A'

NOTES:

1. INSTALL STRUCTURES AT LOCATIONS IDENTIFIED IN THE PLANS. THE EXACT LOCATION OF EACH STRUCTURE SHALL BE APPROVED BY THE CONTRACTING OFFICER PRIOR TO INSTALLATION.
2. IF POOL EXCAVATION IS NOT SPECIFIED IN THE GRADING PLAN, THE CONTRACTING OFFICER WILL DETERMINE IF A SCOUR POOL IS DESIRED. THE SCOUR POOL SHALL BE EXCAVATED TO A DEPTH OF 2' ADJACENT TO THE STRUCTURE AND EXTEND BEYOND ROOTWADS EXTENDING INTO CHANNEL PER THE DIRECTION OF THE CONTRACTING OFFICER.
3. ROUGH GRADING OF CHANNEL SHALL BE COMPLETE PRIOR TO CONSTRUCTION OF STRUCTURE INCLUDING CONSTRUCTION OF RIFFLES OR STREAMBED MATERIALS.
4. RACKING, SLASH, AND LIVE STAKES SHALL BE INCORPORATED INTO THE STRUCTURE BY WEAVING THE MATERIAL IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER. RACKING CAN BE PLACED FIRST TO LIFT THE LOG OFF CHANNEL BED AS DIRECTED BY THE CONTRACTING OFFICER. SEE STRUCTURE SEQUENCING FOR RACKING AND SLASH PLACEMENT.
5. LIVE STAKES SHALL BE INSTALLED PRIOR TO AND/OR DURING BACKFILLING TO ENSURE A MINIMUM OF 1-FT SUBMERGENCE IN GROUND WATER. LIVE STAKES SHALL HAVE CONTINUOUS CONTACT WITH SOIL ALONG THE LENGTH OF THE STAKE LEAVING NO VOIDS.
6. BACKFILL USING NATIVE EXCAVATED MATERIAL UNLESS NATIVE MATERIAL IS UNSUITABLE. UNSUITABLE IS DEFINED AS ANYTHING CLASSIFIED AS A CLAY, SILT, OR SAND. PLACE BACKFILL IN 1-FOOT MAXIMUM LIFTS. COMPACT EACH LIFT USING MECHANICAL EQUIPMENT SUCH AS AN EXCAVATOR BUCKET OR EQUIPMENT TRACKING MAKING CERTAIN TO NOT DAMAGE OR CHANGE THE ELEVATION OF THE STRUCTURE MATERIAL DURING COMPACTION.
7. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED PRIOR TO INSTALLATION. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.
8. LOG PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.
9. SEE DRAWING XX AND SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS.

1 THREE LOG STRUCTURE
NTS

STRUCTURE SEQUENCING



THREE-LOG STRUCTURE MATERIAL SCHEDULE						
LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 1	13" - 22"	30 - 40	YES	4.5	NO	2 EA
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	1 EA
RACKING - 1	4" - 12"	15 - 25	YES	2.5	YES	3 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	3 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	10 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	15 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

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LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

PRELIMINARY DESIGN DRAWINGS

FOR PERPETUA RESOURCES
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LEMHI COUNTY, IDAHO

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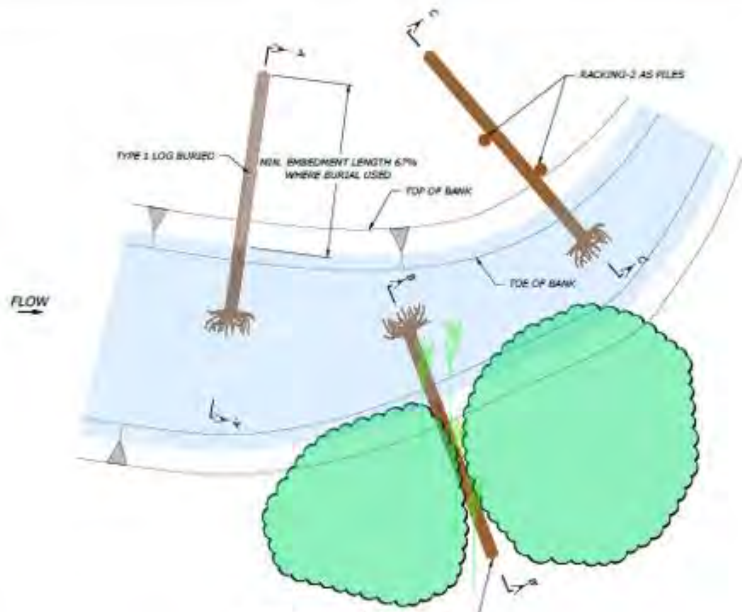
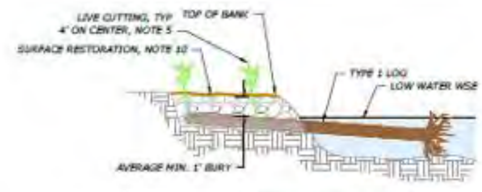
DETAILS

3 LOG STRUCTURE

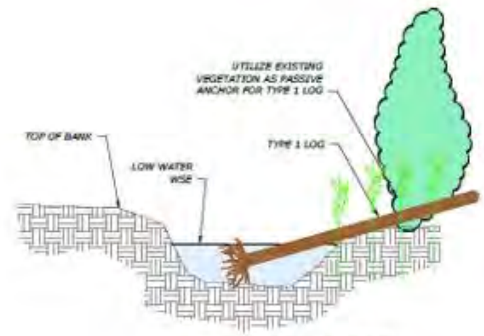
Fig. D-11¶



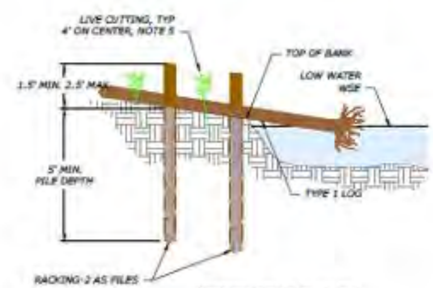
PLAN



SECTION VIEW A-A' (BURIED)



SECTION VIEW B-B' (ON SURFACE)



SECTION VIEW C-C' (PILES)

NOTES:

1. INSTALL STRUCTURES AT LOCATIONS IDENTIFIED ON PLAN AND PROFILE DRAWINGS.
2. THE EXACT LOCATION OF EACH STRUCTURE SHALL BE LOCATED PRIOR TO INSTALLATION FOR APPROVAL BY THE CONTRACTING OFFICER.
3. ROUGH GRADING OF CHANNEL SHALL BE COMPLETE PRIOR TO CONSTRUCTION OF STRUCTURE INCLUDING RIFFLE CONSTRUCTION AND PLACEMENT OF BAR MATERIAL.
4. SEE STRUCTURE SCHEDULE FOR NUMBER OF STRUCTURES, LOCATIONS, LOGS, AND ASSOCIATED MATERIAL QUANTITIES.
5. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED PRIOR TO INSTALLATION. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.
4. RACKING, SLASH, AND LIVE STAKES SHALL BE INCORPORATED INTO THE STRUCTURE WHILE PLACING LAYERS SUCH THAT IT IS WOVEN INTO STRUCTURE IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER.
5. WHEN EXCAVATED INTO GROUND, BACKFILL USING NATIVE EXCAVATED MATERIAL UNLESS NATIVE MATERIAL IS UNSUITABLE FOR BACKFILL. PLACE BACKFILL IN 1-FOOT MAXIMUM LIFTS. COMPACT EACH LIFT USING MECHANICAL EQUIPMENT SUCH AS AN EXCAVATOR BUCKET OR EQUIPMENT TRACKING.
6. WHEN UTILIZING EXISTING VEGETATION AS PASSIVE ANCHORS THERE SHALL BE AT A MINIMUM A WILLOW CLUMP ON THE DOWNSTREAM SIDE, BUT PREFERABLY ON THE UPSTREAM SIDE AS WELL. THE CONTRACTING OFFICER SHALL AGREE TO PLACEMENT AREAS OF STRUCTURES THAT ARE NOT BURIED.
7. LOG PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.
8. SEE DRAWING XX AND SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS.

SINGLE LOG STRUCTURE MATERIAL SCHEDULE

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 1	13" - 22"	30 - 40	YES	4.5	NO	1 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	3 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	3 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	6 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

(1) SINGLE LOG STRUCTURE
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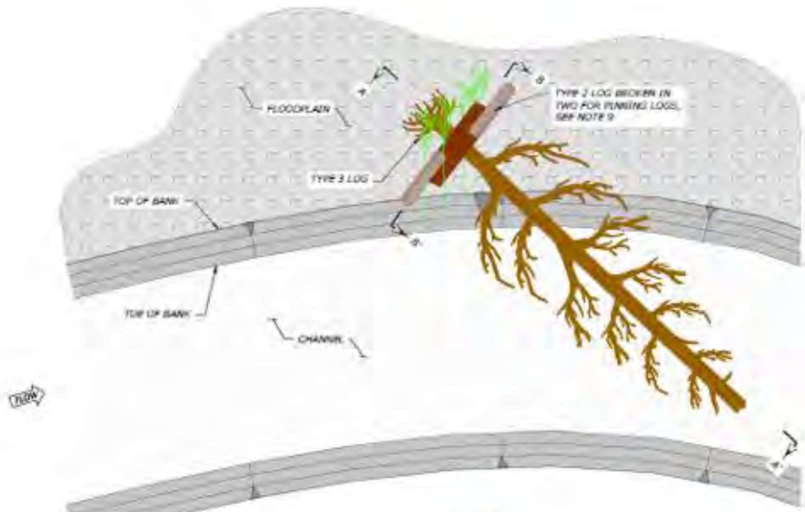
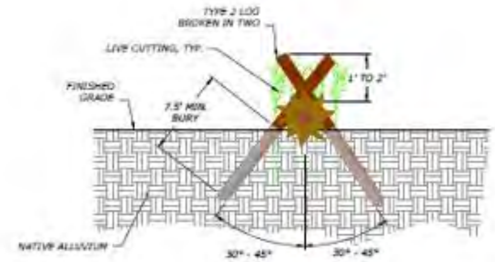
SINGLE LOG STRUCTURE

Fig. D-12¶

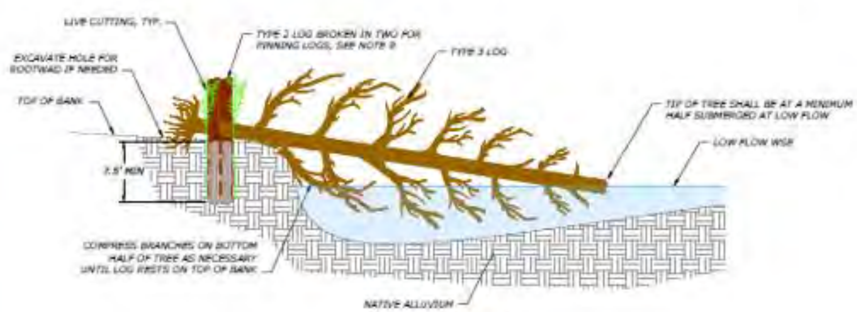


PLAN



SECTION B-B'

NOTES:
1. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.



SECTION A-A'

NOTES:
1. INSTALL STRUCTURES AT LOCATIONS IDENTIFIED IN THE PLANS. THE EXACT LOCATION OF EACH STRUCTURE SHALL BE LOCATED PRIOR TO INSTALLATION FOR APPROVAL BY THE CONTRACTING OFFICER.
2. ROUGH GRADING OF CHANNEL SHALL BE COMPLETE PRIOR TO CONSTRUCTION OF STRUCTURE INCLUDING RIFFLE CONSTRUCTION AND PLACEMENT OF BAR MATERIAL.
3. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED PRIOR TO INSTALLATION. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.
4. TYPE 3 LOG SHALL BE HANDLED A MINIMUM NUMBER OF TIMES TO REDUCE LOSS OF LIMBS, FOLIAGE, ETC.. IF MORE THAN 15% OF TREE BRANCHES ARE REMOVED OR DAMAGED DURING HANDLING THE CONTRACTOR SHALL REPLACE AT NO COST TO THE SPONSOR.
5. SLASH MATERIAL SHALL BE INCORPORATED INTO THE STRUCTURE BY PLACING IT UPSTREAM OR UNDER TYPE 3 LOG, AS DIRECTED BY THE CONTRACTING OFFICER.
6. LOG PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.
7. PINNING LOGS TO BE DRIVEN.

WHOLE TREE STRUCTURE MATERIAL SCHEDULE

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	1 EA
TYPE 3	13" - 22"	40 - 60	YES	4	YES	1 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	2 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	5 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	6 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBRR 10.

1 WHOLE TREE
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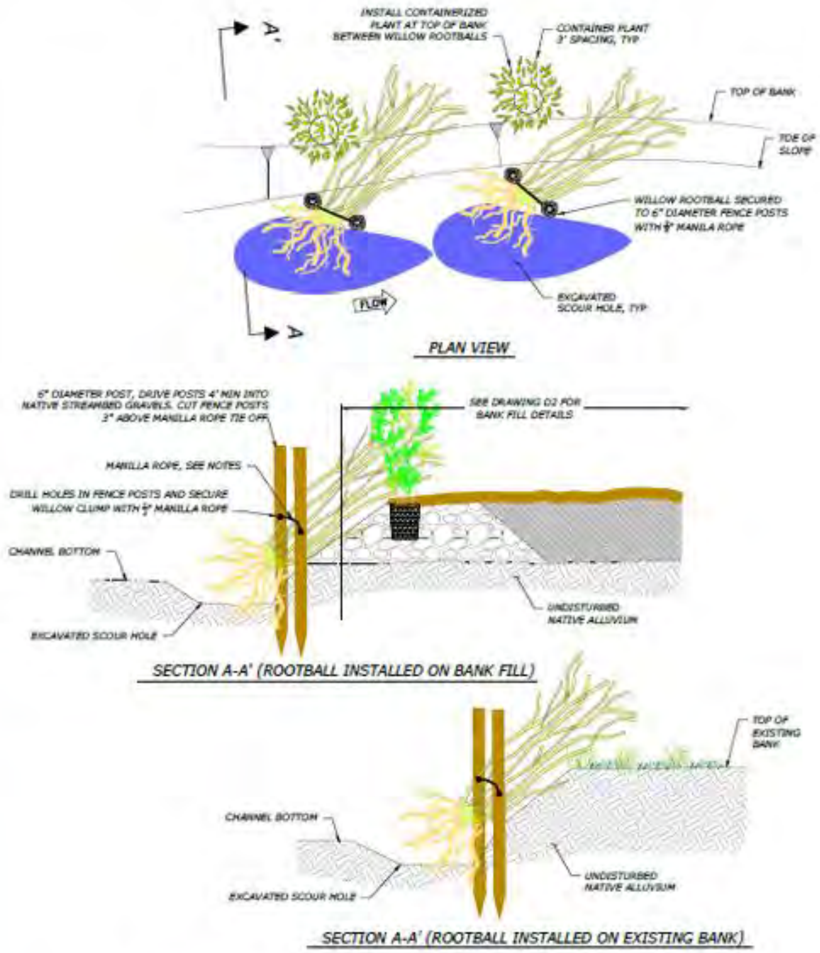
WHOLE TREE

Fig. D-13¶



NOTES:

1. 6" DIAMETER POSTS SHALL BE UNTREATED. POSTS MAY BE SUBSTITUTED WITH 6" DIAMETER LOGS CUT TO LENGTH. LOG MATERIAL SHALL BE INSPECTED AND MUST BE APPROVED BY THE CONTRACTING OFFICER OR ENGINEER.
2. WILLOW ROOTBALLS SHALL BE CONSTRUCTED AT LOCATIONS SHOWN IN THE PLAN AND PROFILE DRAWINGS.
3. FENCE POSTS SHSALL BE INSTALLED TO PINCH THE WILLOW CLUMP SECURING IT IN PLACE.
4. INSTALL MANILLA ROPE TIGHT AGAINST WILLOW CLUMP.
5. DRILL HOLES LOW ENOUGH SUCH THAT MANILLA ROPE PROVIDES DOWNWARD PRESSURE ON THE WILLOW ROOTBALL.

1 WILLOW ROOTBALL
NTS

WILLOW ROOTBALL MATERIAL SCHEDULE

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
WILLOW ROOTBALL	NA	10 - 20	YES	3.5	YES	1 EA
POST	6"	8	NA	NA	NA	2 EA
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	6 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

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LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

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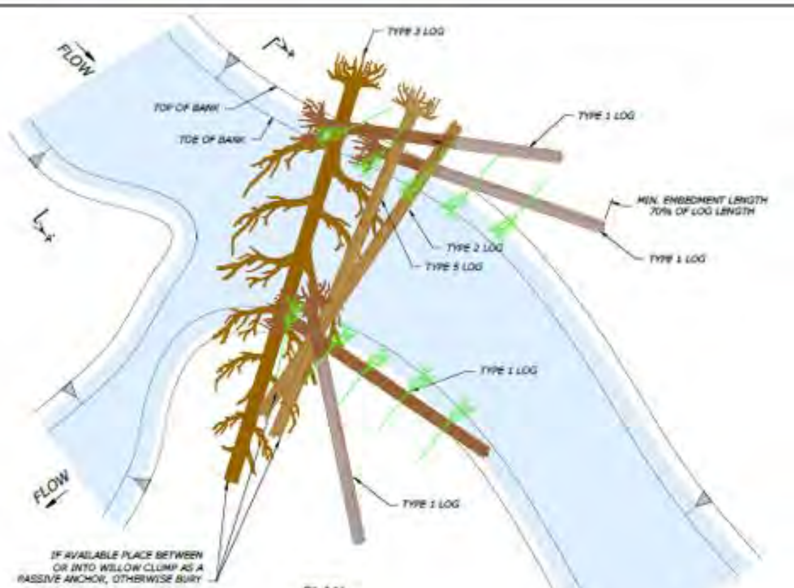
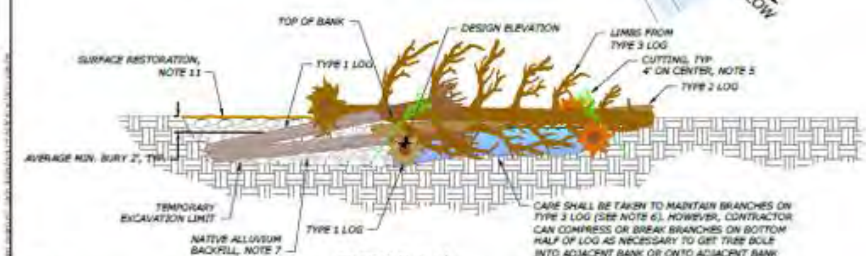
DETAILS

WILLOW ROOTBALL

Fig. D-14¶

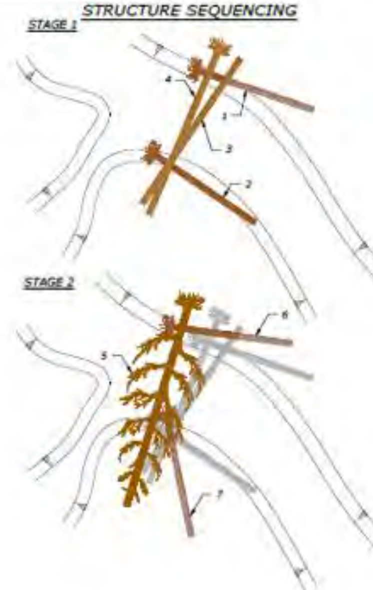


PLAN



SECTION A-A'

STRUCTURE SEQUENCING



NOTES:

1. INSTALL STRUCTURE AT LOCATION IDENTIFIED ON PLAN AND PROFILE DRAWINGS.
2. THE EXACT LOCATION OF STRUCTURE SHALL BE LOCATED PRIOR TO INSTALLATION FOR APPROVAL BY THE CONTRACTING OFFICER.
3. ROUGH GRADING OF CHANNEL SHALL BE COMPLETE PRIOR TO CONSTRUCTION OF STRUCTURE INCLUDING RIFFLE CONSTRUCTION AND PLACEMENT OF BAR MATERIAL.
4. SEE STRUCTURE SCHEDULE FOR NUMBER OF STRUCTURES, LOCATIONS, LOGS, AND ASSOCIATED MATERIAL QUANTITIES.
5. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED PRIOR TO OR UPON COMPLETION OF INSTALLATION. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.
6. TYPE 3 LOG SHALL BE HANDLE DIRECTLY TO REDUCE LOSS OF LIMBS, FOLIAGE, ETC.. IF MORE THAN 15% OF TREE BRANCHES ARE REMOVED OR DAMAGED DURING HANDLING THE CONTRACTOR SHALL REPLACE AT NOT COST TO THE CONTRACTING AGENCY.
7. RACKING AND SLASH MATERIAL SHALL BE INCORPORATED INTO THE STRUCTURE WHILE PLACING LAYERS SUCH THAT IT IS WOVEN INTO STRUCTURE IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER.
8. BACKFILL USING NATIVE EXCAVATED MATERIAL UNLESS NATIVE MATERIAL IS UNSUITABLE. UNSUITABLE MATERIAL CLASSIFIES AS A CLAY, SILT OR SAND. PLACE BACKFILL AS STRUCTURE IS CONSTRUCTED IN 1-FOOT MAXIMUM LIFTS. COMPACT EACH LIFT USING MECHANICAL EQUIPMENT SUCH AS AN EXCAVATOR BUCKET OR EQUIPMENT TRACKING MAKING CERTAIN TO NOT DAMAGE OR CHANGE THE ELEVATION OF THE STRUCTURE MATERIAL DURING COMPACTION.
9. WHEN UTILIZING EXISTING VEGETATION AS PASSIVE ANCHORS THERE SHALL BE AT A MINIMUM A WILLOW CLUMP ON THE DOWNSTREAM SIDE, BUT PREFERABLY ON THE UPSTREAM SIDE AS WELL.
10. LOG PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.
11. SEE DRAWING XX AND SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS.

1 BLEEDER JAM
NTS

BLEEDER JAM MATERIAL SCHEDULE						
LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 1	13" - 22"	30 - 40	YES	4.5	NO	4 EA
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	1 EA
TYPE 3	13" - 22"	40 - 60	YES	4	YES	1 EA
TYPE 5	13" - 22"	40 - 50	YES	4.5	NO	1 EA
RACKING - 1	4" - 12"	15 - 25	YES	2.5	YES	2 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	7 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	5 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	12 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

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LEMHI LITTLE SPRINGS HABITAT RESTORATION PROJECT

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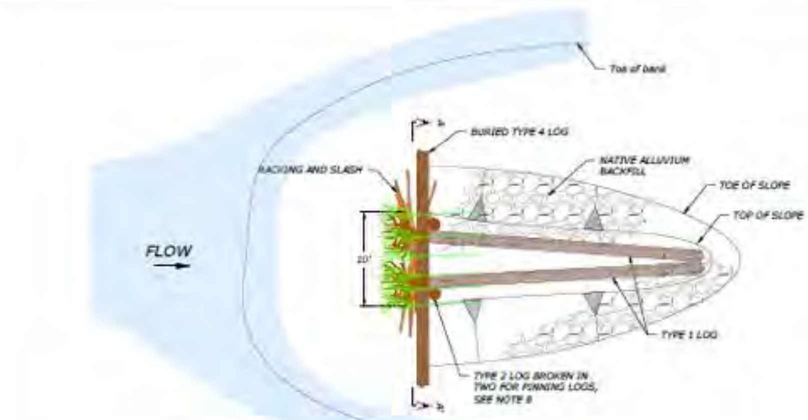
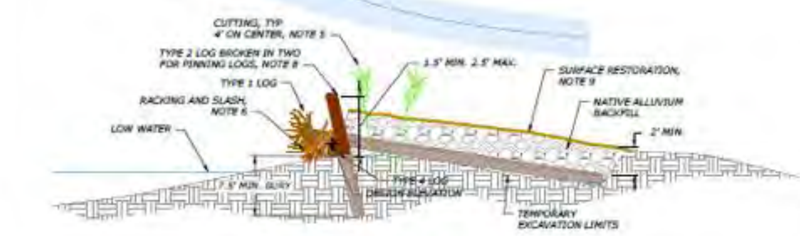
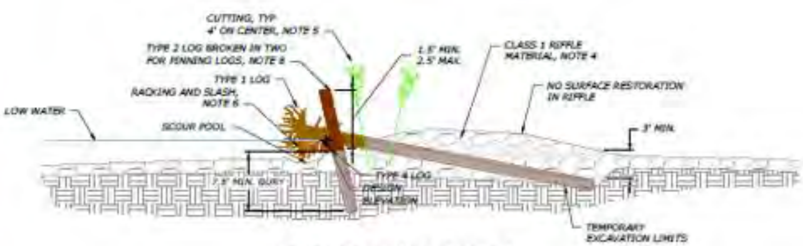
DETAILS
BLEEDER JAM

Fig. D-15¶





SECTION A-A' WHEN LOCATED ON BAR



SECTION A-A' WHEN LOCATED IN RIFFLE

STRUCTURE SEQUENCING

NOTES:

1. INSTALL STRUCTURES AT LOCATIONS IDENTIFIED ON PLAN AND PROFILE DRAWINGS. CONSTRUCTION WILL DIFFER WHEN STRUCTURE IS PLACED AT A FLOW SPLIT OR WITHIN A RIFFLE. SEE SECTIONS.
2. THE EXACT LOCATION OF EACH STRUCTURE SHALL BE STAKED PRIOR TO INSTALLATION FOR APPROVAL BY THE CONTRACTING OFFICER.
3. ROUGH GRADING OF CHANNEL SHALL BE COMPLETE PRIOR TO CONSTRUCTION OF STRUCTURE. WHEN BUILT IN RIFFLE, RIFFLE SHALL BE CONSTRUCTED PRIOR TO CONSTRUCTION OF STRUCTURE. FOR STRUCTURES IN RIFFLES, A SMALL SCOUR POOL SHALL BE PLACED UNDERNEATH THE TYPE 1 ROOTWADS, WHILE STILL MAINTAINING SPECIFIED MATERIAL DEPTH PER RIFFLE SPECIFICATIONS.
4. SEE STRUCTURE SCHEDULE FOR NUMBER OF STRUCTURES, LOCATIONS, LOGS, AND ASSOCIATED MATERIAL QUANTITIES. WHEN PLACED AT FLOW SPLITS THE TYPE 1 LOGS SHOULD HAVE A MINIMUM BURIAL DEPTH OF 2 FEET. WHEN PLACED IN RIFFLES, THE MINIMUM BURIAL DEPTH IS 3 FEET USING CLASS 1 RIFFLE MATERIAL PLACED BEHIND THE ROOTWAD, AS DIRECTED BY CONTRACTING OFFICER.
5. PLACE BACKFILL AS THE STRUCTURE IS CONSTRUCTED IN 1-FOOT MAXIMUM LIFTS. COMPACT EACH LIFT USING MECHANICAL EQUIPMENT SUCH AS AN EXCAVATOR BUCKET OR EQUIPMENT TRACKING MAKING CERTAIN TO NOT DAMAGE OR CHANGE THE ELEVATION OF THE STRUCTURE MATERIAL DURING COMPACTION. BACKFILL SHALL BE NATIVE MATERIAL UNLESS UNSUITABLE. UNSUITABLE MATERIAL IS ANYTHING THAT CLASSIFIES AS CLAY, SILT OR SAND.
6. ALL CUT ENDS OF LOGS THAT WILL BE EXPOSED UPON COMPLETION OF STRUCTURE SHALL BE MARRED PRIOR TO INSTALLATION. THE CONTRACTOR SHALL USE AN EXCAVATOR, OR OTHER HEAVY EQUIPMENT TO TEAR APART WOOD FIBERS AT THE CUT END OF THE LOG TO CREATE THE APPEARANCE OF A LOG THAT HAS NATURALLY BROKEN APART.
4. RACKING, SLASH, AND LIVE STAKES SHALL BE INCORPORATED INTO THE STRUCTURE WHILE PLACING LAYERS SUCH THAT IT IS WOVEN INTO STRUCTURE IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER.
5. LOG PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.
6. PINNING LOGS TO BE DRIVEN.
7. SEE DRAWING XX AND SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS. TOPSOIL AND PLANTING AND SEEDING ARE NOT REQUIRED WHEN PLACED IN RIFFLES.

SMALL APEX JAM MATERIAL SCHEDULE

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 1	13" - 22"	30 - 40	YES	4.5	NO	2 EA
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	1 EA
TYPE 4	12" - 14"	20 - 35	NO	NA	NO	1 EA
RACKING - 1	4" - 12"	15 - 25	YES	2.5	YES	2 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	8 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	10 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	8 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

1 SMALL APEX JAM
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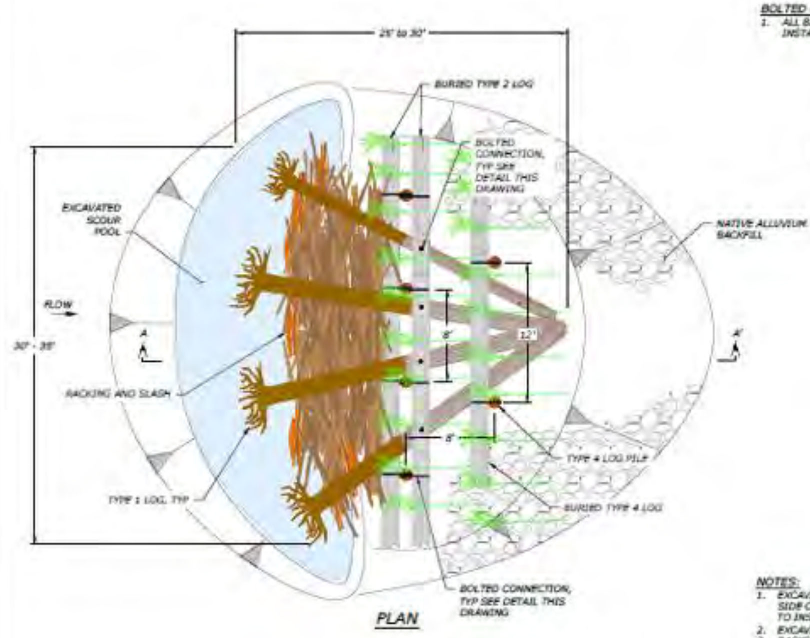
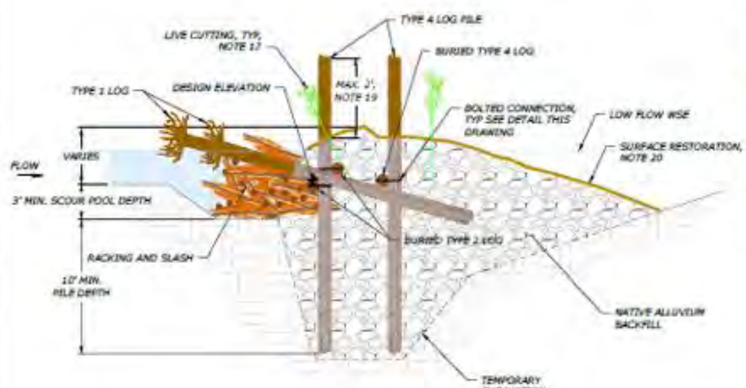
SMALL APEX JAM

Fig. D-16¶



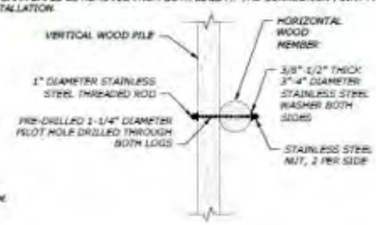
PLAN



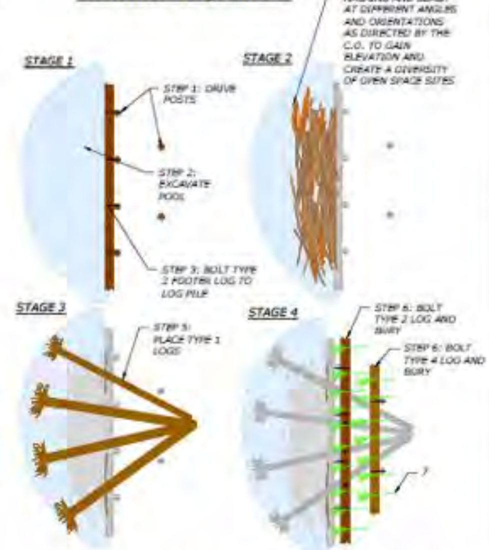
SECTION A-A'

BOLTED CONNECTION NOTES:

1. ALL BARK SHALL BE REMOVED FROM BOTH LOGS AT THE CONNECTION POINT PRIOR TO INSTALLATION.



STRUCTURE SEQUENCING



NOTES:

1. EXCAVATE IN FRONT OF LOGJAM FOR PLACEMENT OF RACKING MATERIAL. EXCAVATION AREA SHALL NOT BE BACKFILLED WITH ALLUVIUM, BUT LEFT AS A SCOUR HOLE OR PROPOSED SIDE CHANNEL PER GRADING PLANS OR AS DIRECTED BY C.O.. ADDITIONAL EXCAVATION WITHIN POOL MAY BE PERFORMED AS DIRECTED BY DESIGNER OR OWNER'S REPRESENTATIVE TO INSTALL RACKING MATERIAL AND/OR TO PULL BACK BANK TO ALLOW FLOW INTO SCOUR HOLE.
2. EXCAVATION SPOILS SHALL BE STAGED ACCORDING TO THE SWPPP. SPOILS SHALL ALSO BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. BACKFILL EXTENTS MAY VARY AND SHALL BE CONSTRUCTED WITH NATIVE ALLUVIUM FROM EXCAVATION SPOILS. PLACE ALLUVIUM IN 1-FT LIFTS AND COMPACT WITH BUCKET OR VIBRATORY PLATE COMPACTOR TO 85% MAX. DENSITY.
4. BACKFILL EACH STRUCTURE LAYER WITH NATIVE MATERIAL, UNLESS UNSUITABLE (UNSUITABLE MATERIAL CLASSIFIES AS A CLAY, SILT OR SAND), FLUSH WITH THE CURRENT LAYER PRIOR TO PLACEMENT OF THE SUBSEQUENT LAYER.
5. FINAL STRUCTURE HEIGHT TO BE ACHIEVED AS SPECIFIED REGARDLESS OF ACTUAL LOG DIAMETERS USED OR STACKING ARRANGEMENT.
6. ALL LARGE WOOD DIMENSIONS DO NOT INCLUDE BARK THICKNESS.
7. SET TOP OF FIRST FOOTER LOG EQUAL TO THE ELEVATION OF THE ADJACENT CHANNEL THALWEG. ALL OTHER ELEVATIONS SHALL MATCH DIMENSIONS FROM SIDE PROFILE.
8. RACKING AND SLASH PLACEMENT SHALL OCCUR WITH EACH LAYER PLACEMENT TO ENSURE MATERIAL EXTENDS THROUGH STRUCTURE AND PINNED IN PLACE BY SUBSEQUENT LAYERS.
9. THE CONTRACTOR SHALL FIELD VERIFY WITH THE DESIGNER OR OWNER'S REPRESENTATIVE ALL STRUCTURE LOCATIONS, PILE LOCATIONS, LENGTHS, WIDTHS AND ELEVATIONS PRIOR TO EXCAVATION, ASSEMBLY AND INSTALLATION OF EACH STRUCTURE.
10. LOCATIONS FOR ALL STRUCTURE PLACEMENTS SHALL BE STAKED IN FIELD FOR APPROVAL BY THE CONTRACTING OFFICER PRIOR TO START OF CONSTRUCTION.
11. LOG TYPE IDENTIFICATION SHALL BE PAINTED ON ALL LOGS. CONTRACTING OFFICER SHALL PROVIDE COLOR TO LOG TYPE KEY FOR CONTRACTOR.
12. PLACEMENT OF WOOD LAYERS SHALL BE FIELD VERIFIED FOR EACH STRUCTURE BY THE CONTRACTING OFFICER PRIOR TO BACKFILLING.
13. BACKFILL TO BE 1' OVER TOP LOG TO COVER ALL BOLTS AND BACKFILL WILL BE SET TO DESIGN GRADE ELEVATIONS UNLESS SPECIFIED BY THE CONTRACTING OFFICER TO BE LOWER FOR AESTHETICS. EXCESS MATERIAL TO BE HAULED TO A DESIGNATED SPOILS AREA.
14. EXCAVATION WILL BE REQUIRED TO ACHIEVE STRUCTURE BASE ELEVATION.
15. LOG PILES MAY BE INSTALLED AT AN ANGLE (UP TO 20 DEGREES). TOPS OF PILES TO BE CUT OR BROKEN FLUSH WITH BACKFILL TOP ELEVATION.
16. FRAME AND KEY LOG MEMBERS SHALL BE BOLTED AS SHOWN. THERE SHALL BE A TOTAL OF 14 BOLTED CONNECTIONS ON EACH STRUCTURE.
17. LIVE STAKES SHALL BE INSTALLED PRIOR TO AND/OR DURING BACKFILLING TO ENSURE A MINIMUM OF 1-FT SUBMERGENCE IN GROUND WATER OR ESTIMATED LOW WATER ELEVATION. LIVE STAKES SHALL HAVE CONTINUOUS CONTACT WITH SOIL ALONG THE LENGTH OF THE BURIED STAKE LEAVING NO VOIDS.
18. ALL EXPOSED ENDS OF LOGS SHALL BE BROKEN AND NOT SAW CUT TO APPEAR NATURAL.
19. TOP OF PILES SHALL BE BROKEN OFF APPROXIMATELY 2-FT ABOVE THE ADJACENT DESIGN GRADE.
20. SEE DRAWING XX AND SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS.

LARGE APEX JAM MATERIAL SCHEDULE

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 1	13" - 22"	30 - 40	YES	4.5	NO	4 EA
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	2 EA
TYPE 4	12" - 14"	20 - 35	NO	NA	NO	7 EA
RACKING - 1	4" - 12"	15 - 25	YES	2.5	YES	3 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	45 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	25 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	30 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

1 LARGE APEX JAM
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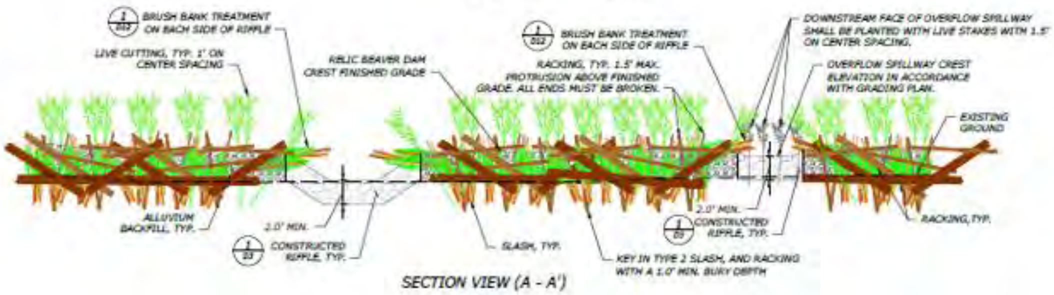
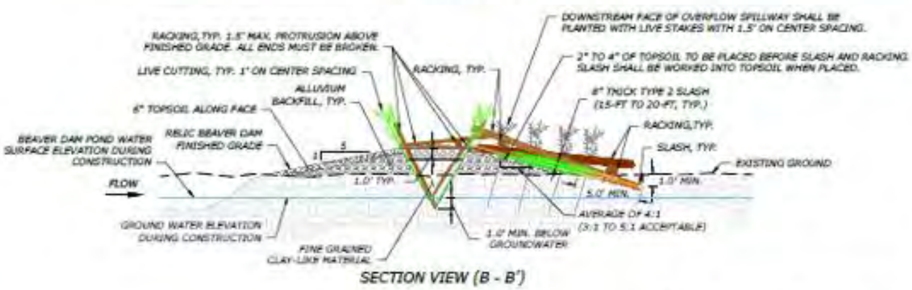
LARGE APEX JAM

Fig. D-17¶

EXAMPLE CONSTRUCTED RELIC BEAVER DAM.





1 RELIC BEAVER DAM ANALOGUE
NTS

INSTALLING RELIC BEAVER DAM AND SLASH AND POST STRUCTURES:

1. THE ENGINEER SHALL SUPERVISE THE INSTALLATION OF THE FIRST RELIC BEAVER DAM STRUCTURE TO INSURE PROPER INSTALLATION. THE CONTRACTOR MAY PROCEED WITH UNSUPERVISED INSTALLATION OF THE REST OF THE STRUCTURES, ONCE THE ENGINEER HAS SIGNED OFF THAT THEY ARE PROPERLY TRAINED.
2. ALL STRUCTURES SHALL BE PLACED AS SHOWN ON THE DRAWINGS.

SLASH AND RACKING:

1. PLACE SLASH AND RACKING SUCH THAT PIECES ARE INTERLACED WITH PARTIALLY BURIED MEMBERS. NO RACKING AND SLASH SHALL BE PLACED LOOSELY ON THE GROUND SUCH THAT IT WOULD FLOAT AWAY IN THE EVENT OF HIGH WATER.
2. RACKING PIECES SHALL NOT EXTEND BEYOND 1.5' ABOVE FINISHED GRADE.

RELIC BEAVER DAM BACKFILL MATERIAL:

1. BEAVER DAM CORE BACKFILL MATERIAL SHALL CONSIST OF FINE GRAINED CLAY-LIKE MATERIAL LARGELY FREE OF GRAVELS AND COBBLES TO REDUCE PERMEABILITY AND TO ALLOW INFILLING OF VOID SPACE BETWEEN RACKING AND SLASH MATERIAL.
2. BEAVER DAM GENERAL BACKFILL MATERIAL SHALL BE A MIX OF COBBLES, GRAVELS, AND FINES TO REDUCE PERMEABILITY. MATERIAL SHALL BE GENERATED FROM STOCKPILES OF EXCAVATED MATERIAL FROM PROJECT EXCAVATIONS.
3. BACKFILL MATERIALS SHALL BE APPROVED BY THE CONTRACTING OFFICER OR ENGINEER PRIOR TO PLACEMENT.

RELIC BEAVER DAM STRUCTURE SCHEDULE (PER 10 LF)

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
RACKING - 1 OR 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	10 EA
SLASH	1" - 4"	5 - 15	NA	NA	YES	9 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	21 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

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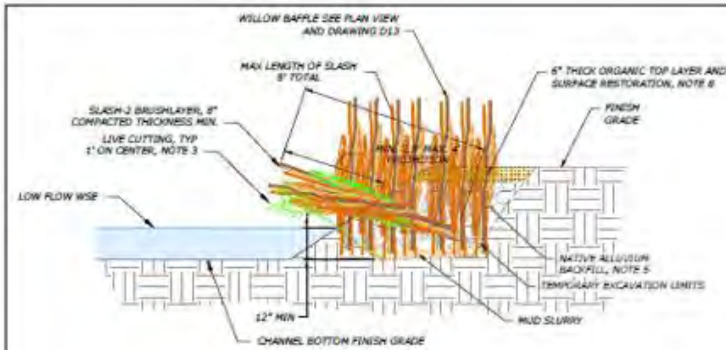
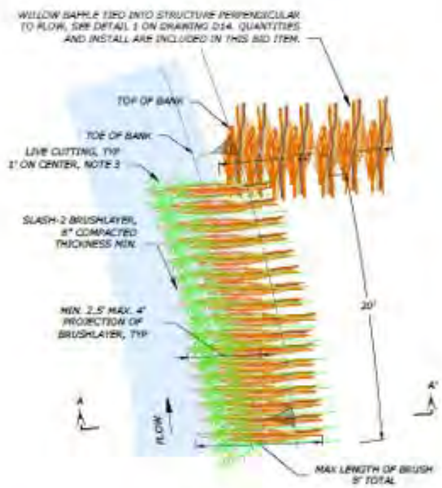
RELIC BEAVER DAM ANALOUGE

Fig. D-18¶

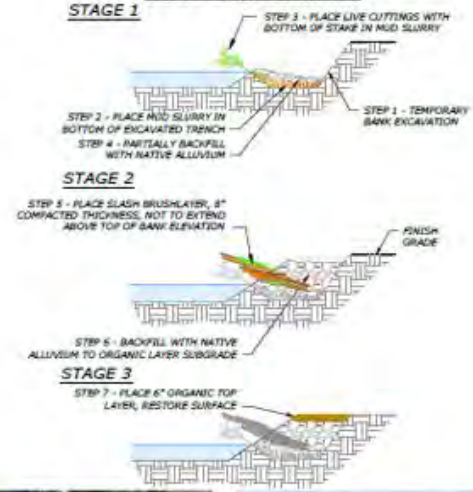


SECTION A-A'



PLAN VIEW

STRUCTURE SEQUENCING



STAGE 1: MUD SLURRY IN BOTTOM OF EXCAVATED TRENCH WITH LIVE CUTTINGS PLACED.

EXAMPLE: COMPLETED BRUSH BANK

NOTES:
1. COMPLETE FINISH GRADING OF CHANNEL BOTTOM AND ROUGH GRADING OF BANK INCLUDING RIFFLE CONSTRUCTION AND PLACEMENT OF BAR MATERIALS PRIOR TO INSTALLING BRUSH BANK.
2. LOCATE TOE OF SLOPE AND EXCAVATE TEMPORARY TRENCH STARTING AT THE ANTICIPATED LOW FLOW WATER SURFACE (SEE PLAN AND PROFILES FOR WATER SURFACE ELEVATIONS).
3. INSTALL LIVE CUTTINGS AT A SPACING OF 1' ON CENTER A MINIMUM OF 1' BELOW GROUNDWATER OR ADJACENT CHANNEL INVERT WHICHEVER IS SHALLOWER. LIVE CUTTINGS SHALL HAVE CONTINUOUS SOIL TO STEM CONTACT ALONG THE LENGTH OF THE CUTTING LEAVING NO VOIDS.
4. PLACE A 6-12" THICK MUD SLURRY INTO TRENCH TO PROVIDE GOOD MATERIAL FOR SOIL TO STEM CONTACT.
5. PLACE SLASH-2 MATERIAL FROM THE ELEVATION OF THE LOW WATER SURFACE ELEVATION TO FORM A COMPACTED 8" THICK LAYER. PLACE SLASH MATERIAL IN LAYERS WITH GREATER THAN 50% OF INDIVIDUAL PIECES ALIGNED PERPENDICULAR TO FLOW WITH A MINIMUM OF 2.5' EMBEDMENT.
6. FILL VOIDS OF SLASH MATERIAL BY SPRINKLING NATIVE ALLUVIUM BACKFILL OVER THE BURIED PORTION OF SLASH MATERIAL PER THE DETAIL AND LIGHTLY TAMP USING EXCAVATOR BUCKET AND WATER.
5. BACKFILL OVER LIVE CUTTINGS AND SLASH MATERIAL BY PLACING NATIVE ALLUVIUM FILL IN 6" LIFTS AND TAMP WITH EXCAVATOR BUCKET TO FILL ANY ADDITIONAL VOIDS IN SLASH MATERIAL AND TO ENSURE GOOD STEM TO SOIL CONTACT OF LIVE CUTTINGS. CONTINUE TO PLACE ADDITIONAL NATIVE ALLUVIUM FILL AS NECESSARY TO ACHIEVE SUBGRADE OF ORGANIC LAYER TOP DRESSING.
6. INSTALL TOP 6" THICK LAYER OF ORGANIC MATERIAL, UNCOMPACTED.
7. SLASH GREATER THAN 8' SHALL BE BROKEN OR CUT TO MEET INSTALL INTENT WITHOUT RUNNING OVER VOLUME OF SLASH ESTIMATE.
8. SEE SPECIFICATIONS FOR PLANTING AND SEEDING REQUIREMENTS.

BRUSH BANK MATERIAL SCHEDULE (PER 20 LF OF BANK TREATMENT)

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
RACKING - 2	4"-12"	15-25	OPTIONAL	NA	YES	3 EA
SLASH	1" - 4"	5-15	NA	NA	YES	12 CY
LIVE CUTTINGS	> 3/4"	6-8	NA	NA	NO	32 EA

1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

1 BRUSH BANK
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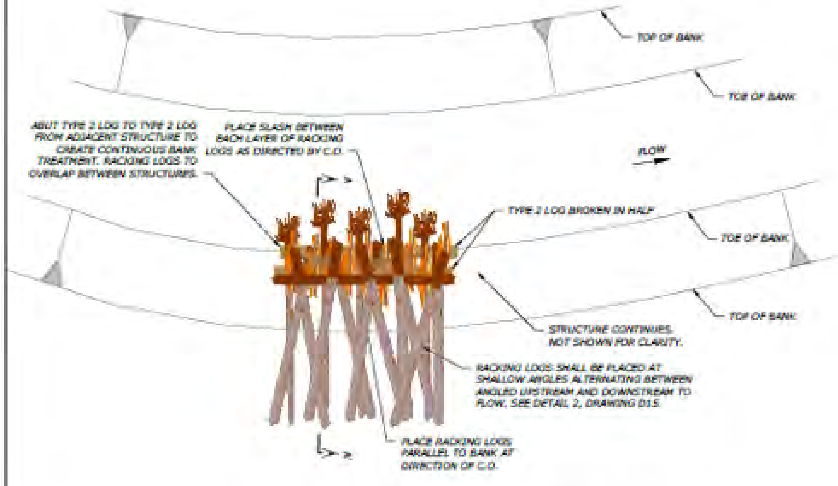
DETAILS
BRUSH BANK

Fig. D-19

SHORT AND TALL ROUGHENED EDGE STRUCTURE SEQUENCING

STAGE 1

STAGE 2
After Step 4 install Brush Bank treatment.



PLAN

STEPS:
1. TYPE 2 LOG (FOOTER) SHALL BE PLACED SO ITS UPSTREAM END RESTS ON THE STREAM BED (UP TO ½ DIAMETER BURIED TO ACCOMODATE VARIED BANK HEIGHTS) ALONG THE TOP OF THE BANK. BACKFILL AND COMPACT AROUND FOOTER LOG WITH COMPACTED FILL.
2. RACKING-1 LOGS (WITH ROOTWADS) SHALL BE INSTALLED ON TOP OF THE TYPE 2 LOG. ROOTWADS SHALL BE PLACED OVER TOP OF FOOTER LOG WITH ROOTWAD AS CLOSE TO BANK AS POSSIBLE AND AS DIRECTED BY C.O. IF BUILDING SHORT ROUGHENED EDGE, SKIP TO STEP 4.
3. REPEAT STEPS 1 AND 2 AT THE DIRECTION OF C.O. TO BUILD TALL ROUGHENED EDGE.
4. PLACE GENERAL FILL OVER PLACED MATERIALS AND COMPACT TO CREATE AN APPROXIMATE 45-DEGREE SURFACE FOR INSTALLATION OF BRUSH BANK TREATMENT AT THE ANTICIPATED LOW WATER ELEVATION. LOW WATER ELEVATION CAN BE ESTIMATED FROM PLAN AND PROFILE DRAWINGS. A PROPOSED LOW WATER ELEVATION SURFACE CAN BE PROVIDED TO THE CONTRACTOR UPON REQUEST FOR GPS USE.
5. INSTALL BRUSH BANK PER DETAIL 1 ON DRAWING D12.
6. PLACE RACKING LOGS PARALLEL TO BANK AND ALONG BANK AT TOP OF STRUCTURE, PIN WITH TWO RACKING LOGS WITH EXPOSED ENDS DOWNSTREAM TO FLOW. ENSURE THAT RACKING LOGS ARE NOT TOO STEEPLY VERTICALLY ANGLED FROM FRONT TO BACK BY PLACING FILL AT BACKSIDE AS NECESSARY.
7. BACKFILL TO TOP OF ANGLED LOGS WITH COMPACTED FILL.
8. PLACE SLASH ALONG TOP OF BACKFILL AT BANK EDGE AS DIRECTED BY C.O.
9. BACKFILL TO FINISH. BACKFILL SHALL BE PLACED IN MAXIMUM 1-FT LIFTS AND COMPACTED.

NOTES:
1. ROUGHENED EDGE BANK TREATMENT SHALL BE CONSTRUCTED AT LOCATIONS AS SHOWN ON THE PLANS. THE EXACT LOCATION OF EACH OCCURRENCE OF BANK ROUGHNESS SHALL BE LOCATED BY THE CONTRACTOR AND APPROVED BY THE C.O. PRIOR TO CONSTRUCTING A PARTICULAR OCCURRENCE.
2. ALL EXPOSED ENDS OF KEY LOGS AND RACKING LOGS SHALL BE BROKEN. ALL EXPOSED CLEAN CUT ENDS OF LOGS WILL REQUIRE THE CONTRACTOR TO REPLACE WITH A BROKEN END AT NO ADDITIONAL EXPENSE.

SHORT ROUGHENED EDGE MATERIAL SCHEDULE (PER 15 LF OF BANK TREATMENT)

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
TYPE 2	13" - 22"	30 - 40	NO	NA	NO	1 EA
RACKING - 1	4" - 12"	15 - 25	YES	2.5	YES	5 EA
RACKING - 2	4" - 12"	15 - 25	OPTIONAL	NA	YES	4 EA
SLASH	1" - 4"	5-15	NA	NA	YES	15 CY
LIVE CUTTINGS	> 3/4"	6 - 8	NA	NA	NO	16 EA

1. QUANTITIES SHOWN IN THE TABLES INCLUDE QUANTITIES ASSOCIATED WITH THE BRUSH BANK PORTION OF THESE TREATMENTS.
2. C.O. MAY REQUEST PLACEMENT OF ADDITIONAL MATERIAL BASED ON BANK HEIGHT AND EXPOSURE OF UNSUITABLE MATERIAL.
3. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

SECTION VIEW (A - A') SHORT ROUGHENED EDGE

1 SHORT ROUGHENED EDGE
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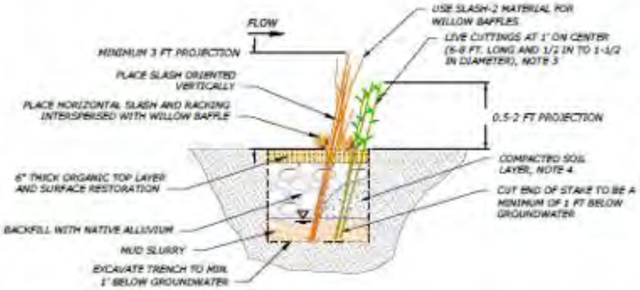
SHORT ROUGHENED EDGE

Fig. D-20



NOTES:

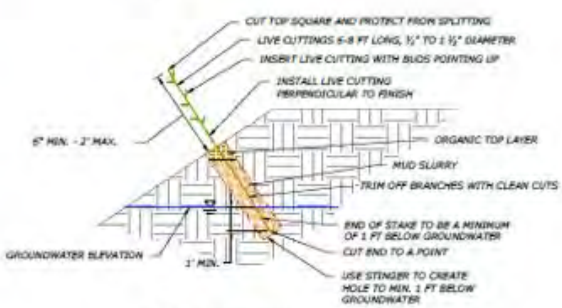
1. INSTALL WILLOW BAFFLE AT LOCATIONS SHOWN IN THE PLANS OR AS DIRECTED BY CONTRACTING OFFICER.
2. EXCAVATE TEMPORARY TRENCH TO 1' BELOW LOCAL GROUNDWATER.
3. INSTALL LIVE CUTTINGS WITH CUT ENDS AT 1 FT ON CENTER IN TOE OF TRENCH.
4. PLACE MUD SLURRY IN BOTTOM OF TRENCH TO AID IN STEM TO SOIL CONTACT.
5. COMPACT A SMALL LAYER OF SOIL TO ENSURE STEM TO SOIL CONTACT.
6. PLACE 4.5 C.Y. SLASH-2 MATERIAL (PER 20' OF TRENCH) IN TRENCH ORIENTED VERTICALLY AND ANGLED IN THE DOWNSTREAM DIRECTION. PLACED SLASH FORM A CONTINUOUS 6-8" THICK WALL OF "STEMS" PROTRUDING FROM THE GROUND THE ENTIRE LENGTH OF THE TRENCH.
7. BACKFILL TRENCH WITH NATIVE ALLUVIUM MATERIAL AND COMPACT IN MAXIMUM LIFTS OF 1'. USE WATER TO WASH MATERIAL INTO VOIDS IN SLASH AND CUTTINGS AT EACH LIFT.
8. INSTALL RACKING BETWEEN CUTTINGS AND VERTICAL SLASH LARGELY PARALLEL TO THE TRENCH.
9. INSTALL TOP 1.5 C.Y. OF SLASH-2 (PER 20' TRENCH) ON TOP OF THE BACKFILLED TRENCH ORIENTED PARALLEL TO THE TRENCH AND INTERSPERSED AMONGST THE VERTICAL SLASH AND CUTTINGS.
10. LENGTHS OF WILLOW BAFFLES ARE 20 OR 40 FEET AS SHOWN ON PLANS, OR AS DIRECTED BY C.O. WHILE QUANTITIES SHOWN IN THE SCHEDULE ARE FOR A 20 FOOT SEGMENT.

WILLOW BAFFLE MATERIAL SCHEDULE (PER 20 LF OF BANK TREATMENT)

LOG TYPE	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	MIN ROOTWAD DIAMETER (FT)	BRANCHES	QUANTITY/ STRUCTURE
SLASH	1" - 4"	5-15	NA	NA	YES	8 CY
LIVE CUTTINGS	> 3/4"	6-8	NA	NA	NA	21 EA

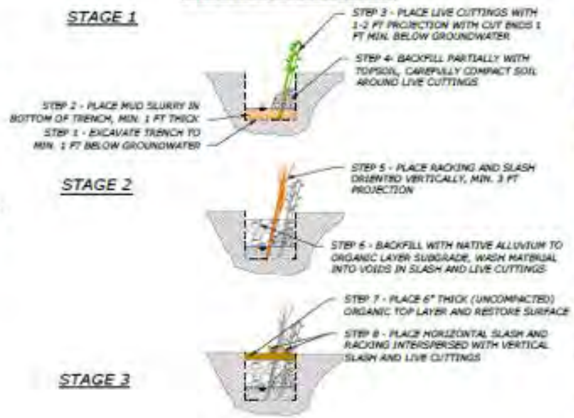
1. IF LIVE CUTTINGS QUANTITY IS FOR DORMANT INSTALLATION, QUANTITY SHALL BE DOUBLED IF INSTALLED APRIL 21 TO OCTOBER 10.

(1) WILLOW BAFFLE
NTS



(2) LIVE CUTTINGS
NTS

STRUCTURE SEQUENCING




STAGE 1: MUD SLURRY IN BOTTOM OF EXCAVATED TRENCH WITH LIVE CUTTINGS PLACED WITH BOTTOM END EXTENDING BELOW GROUNDWATER.


STAGE 2: VERTICAL SLASH/RACKING PLACED AND BACKFILLING TRENCH WITH NATIVE ALLUVIUM.


STAGE 3: TRENCH BACKFILLED WITH NATIVE ALLUVIUM AND ORGANIC TOP LAYER BEING PLACED.

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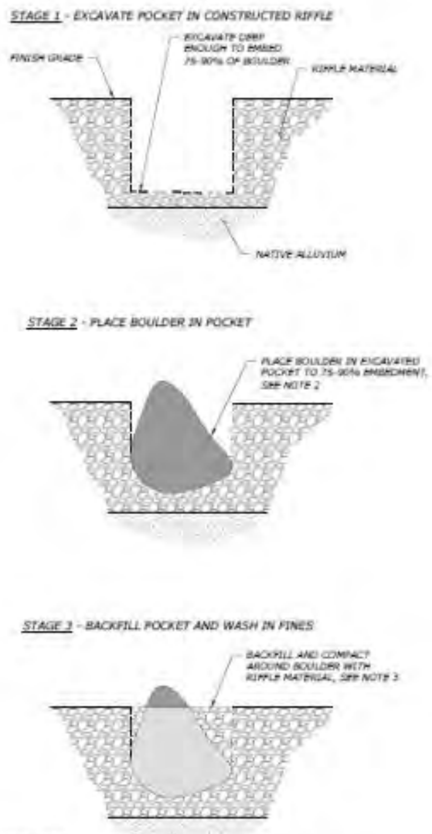
WILLOW BAFFLES AND LIVE CUTTINGS

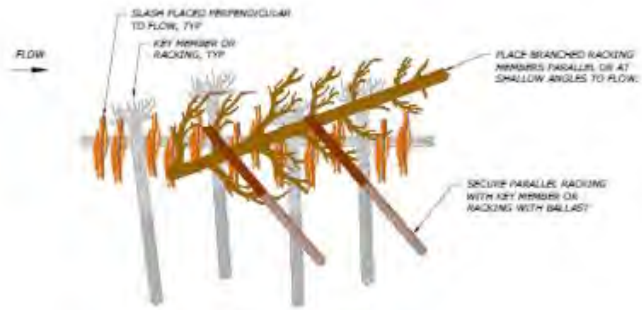
Fig. D-21



BOULDER PLACEMENT NOTES:

1. AFTER INITIAL RIFFLE CONSTRUCTION (SEE RIFFLE CONSTRUCTION NOTES IN DRAWING D3), POCKETS SHALL BE EXCAVATED IN RIFFLE MATERIAL, DEEP ENOUGH TO SET BOULDERS TO 75-90% EMBEDMENT. HABITAT BOULDERS SHALL BE SET WITH 50-70% EMBEDMENT AS DIRECTED BY C.O.
2. PLACE BOULDERS IN POCKETS, USING EXCAVATOR BUCKET TO FIRMLY SEAT THE BOULDER, WITHOUT BREAKING, INTO RIFFLE MATRIX AT A DEPTH THAT PRODUCES 75-90% EMBEDMENT (BASED ON APPROXIMATE DIAMETER IN VERTICAL DIRECTION NOT MASS). BOULDER SHOULD BE FIRMLY SEATED SO THAT THERE ARE NO VOID SPACES UNDERNEATH THE BOULDER.
3. BACKFILL POCKET WITH RIFFLE MATERIAL TO AND COMPACT TO FINAL GRADE, FILLING ALL VOIDS AROUND THE BOULDER. WASH ADDITIONAL FINES INTO MATRIX SURROUNDING BOULDERS AND COMPACT WITH EXCAVATOR BUCKET, AS DIRECTED BY C.O.
4. TOP DRESS WITH COARSE RIFFLE MATERIAL AS NEEDED AND DIRECTED BY C.O. TO ADD INITIAL ROUGHNESS AND FORM A NATURAL APPEARANCE. THIS SHOULD BE DONE AT THE SAME TIME AS THE ENTIRE RIFFLE IS TOP DRESSED WITH COARSE MATERIAL.

(1) BOULDER PLACEMENT
NTS



BRANCHED RACKING MEMBERS

NOTES:

1. 2/3 OF BRANCHED RACKING MEMBERS SHALL BE PLACED IN PARALLEL OR AT SHALLOW ANGLES TO FLOW.
2. BRANCHED RACKING MEMBERS SHALL BE SECURED BY KEY MEMBER OR RACKING MEMBER WITH BALLAST.

PARALLEL RACKING MEMBERS

NOTES:

1. RACKING MEMBER PLACED IN PARALLEL OR AT SHALLOW ANGLES TO FLOW SHALL BE SECURED BY KEY MEMBER OR RACKING MEMBER WITH BALLAST.
2. APPROXIMATE RATIO OF PERPENDICULAR TO PARALLEL RACKING MEMBERS SHALL BE 2:1.
3. PARALLEL RACKING MEMBERS SHALL BE VARIED IN VERTICAL PLANE BY WEAVING IT IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER.

GENERAL RACKING AND SLASH NOTES:

1. RACKING, SLASH, AND LIVE CUTTINGS SHALL BE INCORPORATED INTO THE STRUCTURE BY WEAVING IT IN BETWEEN PLACED LOGS, FILLING VOIDS, ETC. AT EACH STEP THROUGHOUT CONSTRUCTION AS DIRECTED BY THE CONTRACTING OFFICER.
2. ALL EXPOSED ENDS OF RACKING SHALL BE BROKEN AND NOT SAW CUT TO APPEAR NATURAL.
3. RACKING AND SLASH PLACEMENT MAY BE ADJUSTED IN THE FIELD BY THE CONTRACTING OFFICER TO PROVIDE VARIABILITY FROM STRUCTURE TO STRUCTURE.

(2) RACKING PLACEMENT
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BOULDERS & RACKING PLACEMENT

Fig. D-22

REFERENCES

Rio ASE. 2023. Lemhi Little Springs Habitat Restoration Project, Draft Basis of Design Report (Preliminary Design). Prepared for Perpetua Resources Idaho, Inc. 28pp. June.

APPENDIX E

SITE-WIDE WATER CHEMISTRY MODEL SUMMARY

In order to predict instream concentrations, modeling was first performed to estimate contaminant contributions from the mine facilities (i.e., tailings storage facility (TSF) buttress and embankment, TSF, backfilled pits, and the West End pit lake). These source estimates were then coupled with the hydrologic model, and the wastewater treatment plant effluent in a site-wide water chemistry (SWWC) model to estimate instream concentrations. For context, a brief summary of the modeling is provided in this appendix. Additional detail can be found in the SWWC modeling report (SRK 2021a) and the SWWC sensitivity analysis report (SRK 2021b).

To minimize the volumes of contact water requiring treatment, upstream non-contact water will be diverted to prevent it from interacting with mine facilities during operations. Table E-1 identifies the non-contact diversion channels that are considered in the SWWC model. At closure, the diversion channels will be decommissioned, and non-contact water will follow its natural drainage pathways.

Table E-1. Summary of diversion channels included in the site-wide surface water chemistry model.

Diversion Channel	Description
North Diversion	Diverts non-contact runoff from the north of the tailings storage facility (TSF) and TSF buttress to Meadow Creek
South Diversion	Diverts Meadow Creek and its tributaries from the south and west of the TSF around the TSF
Hennessy Diversion	Diverts water from Hennessy Creek away from the Yellow Pine Pit (YPP) to Fiddle Creek
Midnight Diversion	Diverts Midnight Creek away from the YPP to the EFSFSR
West End Diversion	Diverts upper West End Creek around the West End pit
East Fork South Fork Salmon River (EFSFSR) Tunnel	Diverts the EFSFSR around the YPP downstream of assessment node YP-SR-6 to upstream of assessment node YP-SR-4

Mine Facility Source Terms

Geochemical testing of mine material (e.g., development rock, ore, legacy facilities, and tailings) was performed (SRK 2021a). Based on humidity cell tested (SRK 2021a), the rock in the pit walls and the development rock deposited in the TSF buttress and pit backfills is expected to be largely non-acid generating. However, it will be capable of leaching aluminum, antimony, arsenic, cadmium, copper, manganese, mercury, zinc, sulfate, and total dissolved solids (TDS) into surface water and groundwater. Geochemical source terms were developed for various material groupings (e.g., development rock and ore by pit location, gold grade, and potentially acid generating [PAG] classification) and subsequently used to predict the chemical contributions of the mine facilities to the environment. In order to perform the modeling, a number of considerations and assumptions were made when assessing contaminant contribution over the life of the proposed action from these various sources. A detailed accounting of the considerations and assumptions made are included in the SWWC modeling report (SRK 2021a), with a select few summarized below.

TSF Buttress and Embankment/Ore Stockpiles.

None of the development rock storage facilities or ore stockpiles will be lined at their base. As a result, a portion of the rainfall and snowmelt coming into contact with these facilities infiltrate into the groundwater, creating a nonpoint source of pollution to surface water. Long-term infiltration and associated groundwater contamination are expected to be reduced during closure and reclamation as a result of capping the TSF embankment, buttress, and any remaining ore stockpiles. The upstream face of the TSF embankment will be fully lined in order to minimize leakage.

Conceptual models illustrating water flow paths associated with the TSF Buttress and Embankment during operations and closure are shown in Figure E-1. The predicted runoff water quality, toe/pop-out seepage chemistry, and groundwater chemistry under the TSF buttress and embankment during operations and post-mining (before and after cover placement) are summarized in Tables 3.5-7, 3.5-8, and 3.5-9 in the biological assessment (BA) (Stantec 2024), respectively. Select considerations and assumptions employed for predicting water quality are listed below.

- Any groundwater recharge from the buttress and embankment will interact with alluvial groundwater within the upper 10 meters of the water table underneath the footprint of the facility prior to reporting to surface water (i.e., groundwater flow to Meadow Creek) or the Hangar Flats pit. The specific yield within the alluvium is 15 percent.
- Solutes will not attenuate along the flowpath.
- Only a small fraction of (4 percent) of the total mass of material within the TSF embankment and buttress will be effectively contacted by meteoric waters. This based on the following assumptions:
    - Only 20 percent of the material will consist of fines and be available for chemical weathering reactions.
    - Infiltration will flow along preferential flow paths and contact only 20 percent of rock volume.
- No ore stockpiles will remain on the TSF buttress.
- Following cover placement on the TSF buttress and embankment, residual solution from the buttress materials will continue to infiltrate into the groundwater, though to a lesser degree as modeled during operations. Any toe/pop-out seepage will occur under the liner and will recharge groundwater.
    - Infiltration from rain and snowmelt will be reduced to 5 percent of the annual average precipitation.
    - The flow paths are assumed to be reduced by approximately 86 percent to account for reduction in infiltration and resulting decrease in the proportion of material contacted by infiltrating water.
- Reaction rates and solute release in the field will vary from laboratory predictions due to differences in ambient temperatures. In the field, the annual average temperature is 2.6°C whereas the laboratory studies were conducted at 25°C. A scaling factor (ratio of temperature in the field to temperature in the lab) was applied to account for this.
- The TSF embankment and buttress were assumed to be fully oxygenated and no additional scaling factor was applied.

- It is assumed that chemistry in the TSF embankment and buttress will be proportional to the type of material housed in the facilities.
- Mercury source terms were set to 0 since Phase 2 leachate tests were generally below a detection limit of 6 ng/L.

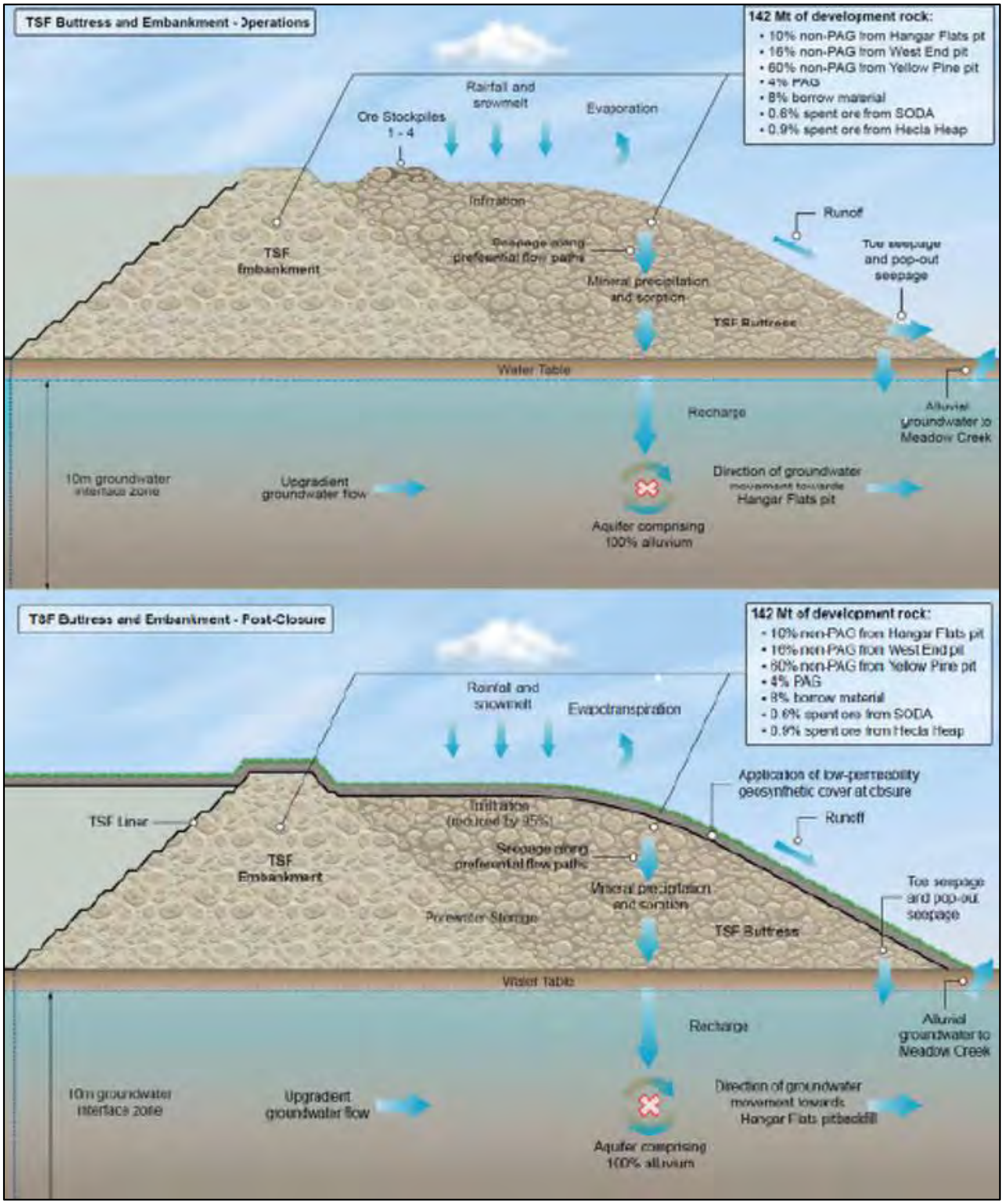

Figure E-1. Conceptual model for tailings storage facility buttress and embankment during operations and post closure (SRK 2021a).

Tailing Storage Favility

The TSF will be fully lined in order to minimize leakage. An underdrain groundwater collection and conveyance system will be installed beneath the TSF liner, TSF embankment, and TSF buttress. This conveyance system will facilitate detection of liner leakages as well as minimize the potential for groundwater to saturate the base of the embankment and buttress. During closure and reclamation, after the tailings have consolidated, the TSF will be capped in order to reduce long-term infiltration.

Figure E-2 provides conceptual models of water flow paths associated with the TSF during operations and post closure after placement of a cover. The predicted water quality of the TSF surface water and groundwater is summarized in Tables 6-7 and 6-8 of the SWWC modeling report (SRK 2021a), respectively. Select considerations and assumptions employed for predicting water quality include:

- Minor seepage from manufacturing defects and other larger holes in the liner or the seams developed during placement may occur, despite the best practice design. The model assumes one defect with an area of 99.9 mm^2 per acre. Seepage from these defects is assumed to interact with the uppermost 10 meters of the groundwater table below the TSF.
- Liner leakage will decrease from mine year 14 through mine year 41, when the tailings consolidation is expected to be complete (USFS 2023).
- Pore water within the TSF is primarily comprised of process water chemistry obtained from the metallurgical testwork program and weighted according to total tailings proportions over the life of the mine (SRK 2021a).
- Tailings reclamation will be completed within 9 years after ore processing operations cease. It is assumed that cover placement will begin 3 to 5 years after the end of tailings deposition and be completed by mine year 23.
- The low permeability geosynthetic cover will reduce infiltration to the TSF by 95% of the uncovered infiltration volume. Minor infiltration through the cover may contact the upper portion of the underlying tailings. It is assumed that this contact water will mix with clean runoff/run on water and consolidation water.
- Consolidation water from beneath the cover will be withdrawn using a combination of wells, wicks, and/or gravel drains and routed to water treatment.
- The quality of consolidation water is represented by decant solution chemistry from the metallurgical testwork program (Table 6-5 in SRK 2021a). This is conservative, as it does not account for dilution by precipitation that may infiltrate the TSF.
- Based on model results, treatment will no longer be required after about 25 years from the end of ore processing (mine year 40).

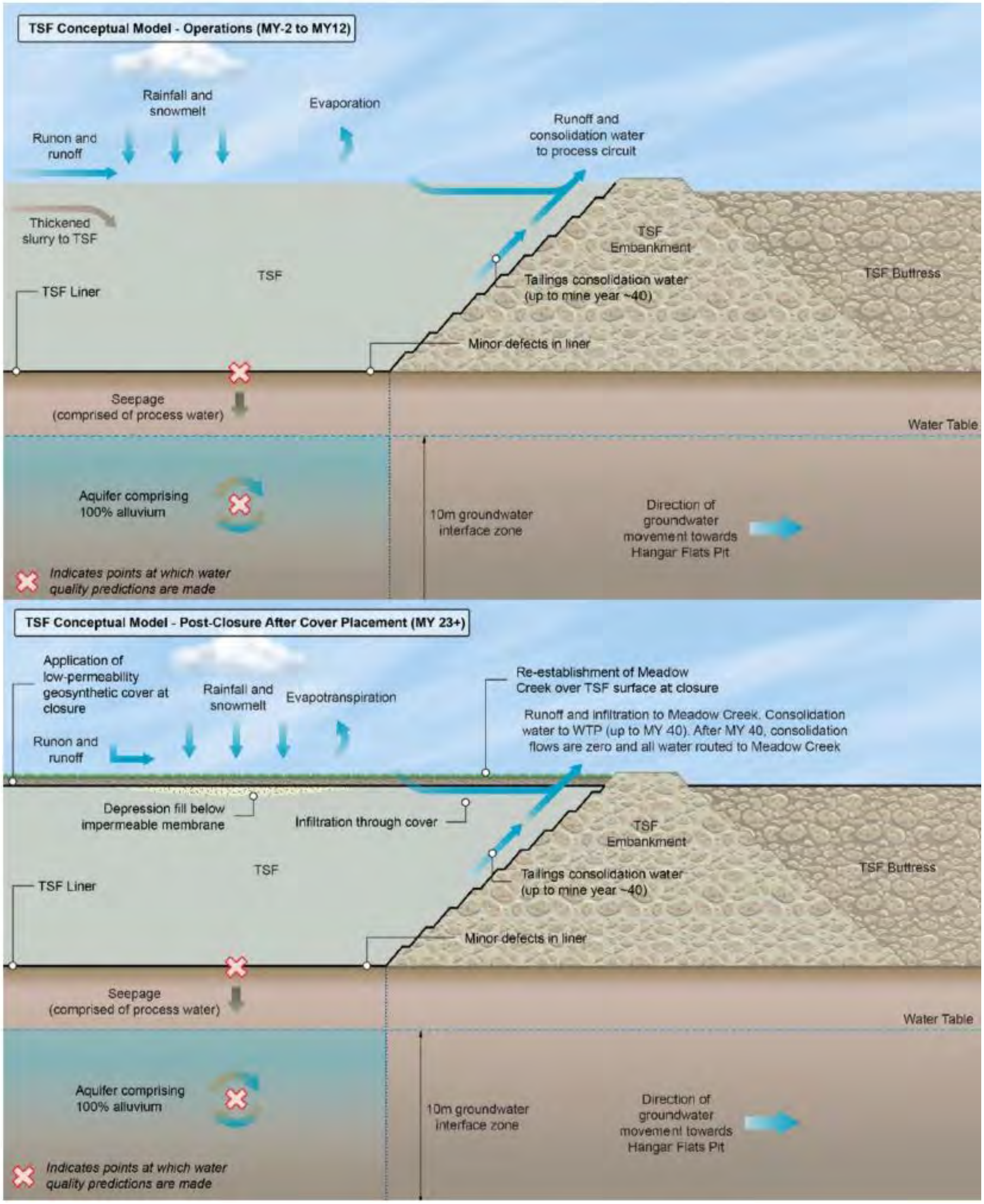

Figure E-2.TSF Conceptual model during operations and post closure after cover placement. Although not shown, the conceptual model for mine years 15 through 22 is similar to that for Mine Years -2 to 12, with the only difference being the removal of the "thickened slurry to TSF" element (SRK 2021a).

Hangar Flats Pit, YPP, and Midnight Pit.

During operations, groundwater (include water expressed along the pit walls) and any precipitation/snow melt will be pumped from the pits and used for ore processing. Upon closure, development rock placed in pit backfills will be inundated and contaminants are expected to leach from the backfilled material to alluvial and bedrock groundwater. Both the backfilled Yellow Pine Pit (YPP) and Hangar Flats pit will be covered with a low permeability geosynthetic liner, limiting infiltration of rainfall and snowmelt into the development rock and reducing potential groundwater impacts. The Midnight pit will not be covered with a liner.

Figures E-3 through E-5 illustrate the conceptual models of water flow paths associated with the YPP, Hangar Flats Pit, and Midnight Area Pit, respectively.

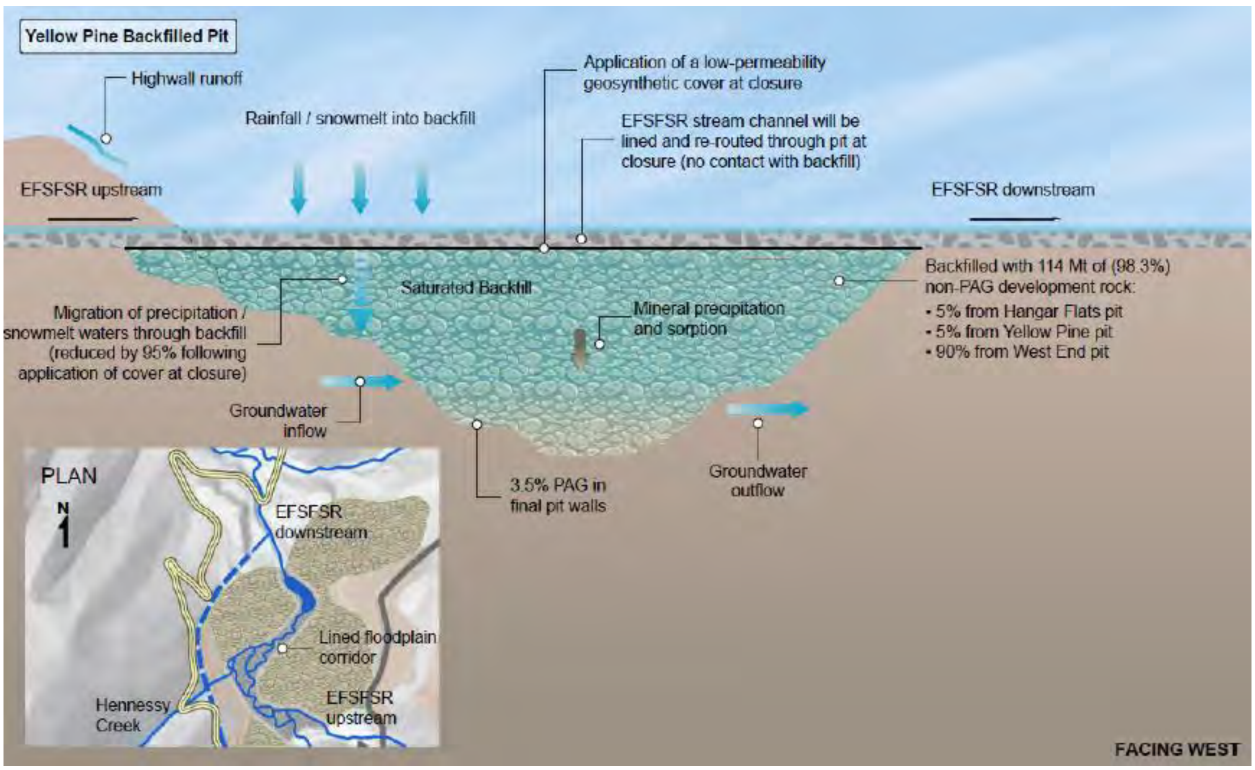

Figure E-3.Yellow Pine backfilled pit conceptual model (SRK 2021a).

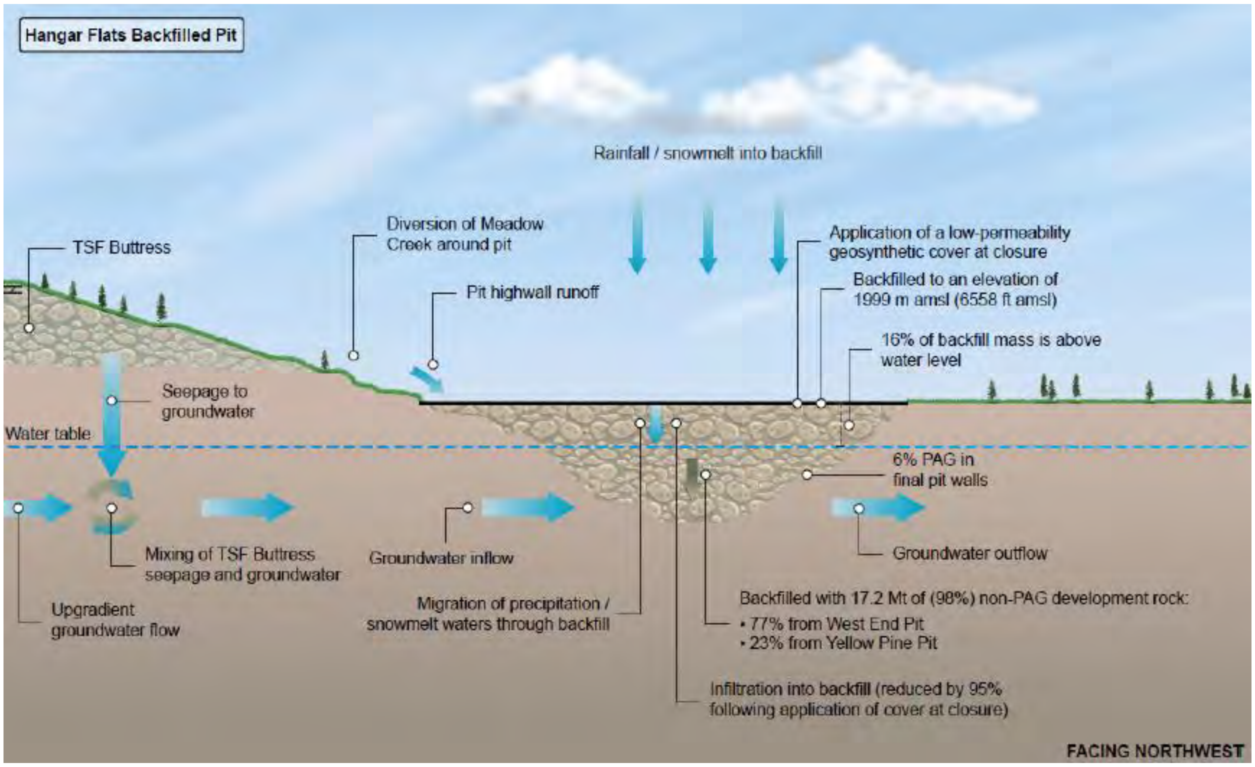

Figure E-4.Hangar Flats backfilled pit conceptual model (SRK 2021a)

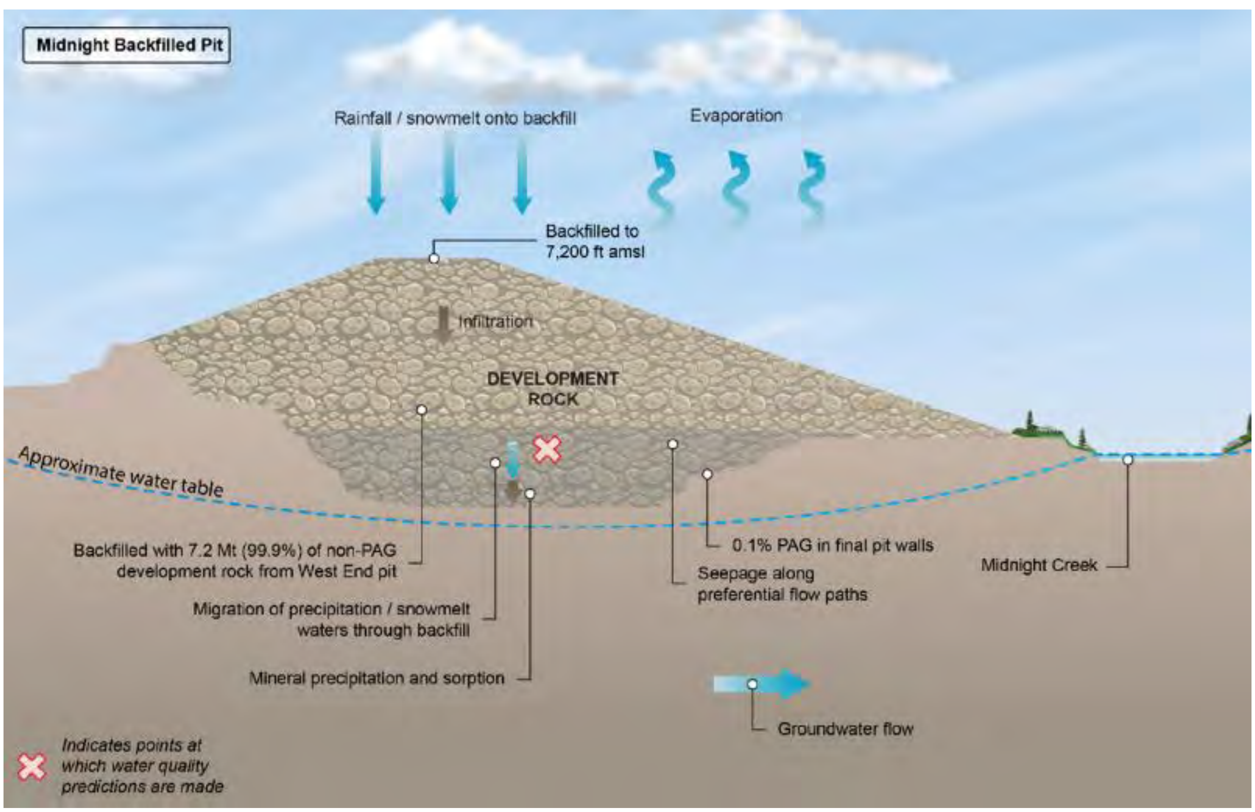

Figure E-5. Midnight Area backfilled pit conceptual model (SRK 2021a).

Contaminant loading within the backfilled pits will come from the backfill itself along with talus on the pit benches, groundwater, pit wall fractures, and precipitation that contacts exposed pit walls and backfill. The predicted water quality of backfilled Hangar Flats Pit and YPP, and Midnight Area pit is summarized in Tables 7-14, 7-16 and 7-17 of the SWWC modeling report (SRK 2021a), respectively. Select considerations and assumptions employed for predicting facility geochemistry include:

- The Midnight Area pit is above groundwater level; therefore, the backfill material and highwall will not be saturated.
- Limited water will pond within pit sumps in the YPP and Hangar Flats pit during operations.
- Pit backfill will be comprised of homogeneously mixed material types.
- The water table will rebound, partially flooding the backfill material within the YPP and Hangar Flats Pit.
- The low permeability geosynthetic cover on the YPP and Hanger Flats pit will reduce infiltration by 95% of the uncovered infiltration volume.
- Estimated proportional contribution of lithological units above or below water levels for the Hangars Flats pit and the YPP.
- Groundwater equilibrium occurs at Hangar Flats Pit by end of mine year 7; approximately 48 percent of the pit wall area will be submerged.
- Groundwater equilibrium occurs at the YPP by end of mine year 22; approximately 55 percent of the pit wall area will be submerged.
- Blast-induced fracturing of pit walls will occur, and it is assumed that fracturing will propagate to a depth of 3 feet and the density of fracturing will average 10 percent. Flushing os solutes from pit wall fractures by groundwater will only occur in the 'active' zone of groundwater inflow and will cease once pit walls become submerged.
- Only a small percentage of the talus remaining on pit benches will be contacted by runoff water entering the pit.
- The proportion of fines in the backfill is assumed to be 20 percent.
- The proportion of flow paths in unsaturated backfill is assumed to be 20 percent. This is reduced to 4 percent upon cover placement.
- Temperature scaling factor is 0.06.
- The overall contacted mass of backfill material contacted by water is 4 percent above the water table and 20 percent below the water table.
- Leaching of solutes below the water table is assumed to not occur due to minimal oxygen and flow.
- Groundwater quality entering the backfilled pits is influenced by the regional groundwater plus additional contaminants from upstream sources (e.g., TSF, TSF buttress and embankment, etc.).
- Water infiltrating the ore stockpile placed on the Hangar Flats backfill from mine year 7 to 12 is assumed to infiltrate into the backfill. It is assumed the stockpile will be removed by mine year 13.

West End Pit Lake

During operations, the West End pit is expected to be relatively dry. Water from precipitation or groundwater infiltration will be pumped to a contact water pond. When mining of the pit is complete (mine year 12), dewatering will cease, West End Creek will be diverted to the pit, and the lake will begin to fill slowly. It is expected to take 57 years to fill. Figure E-6 illustrates the conceptual model developed for the West End pit lake.

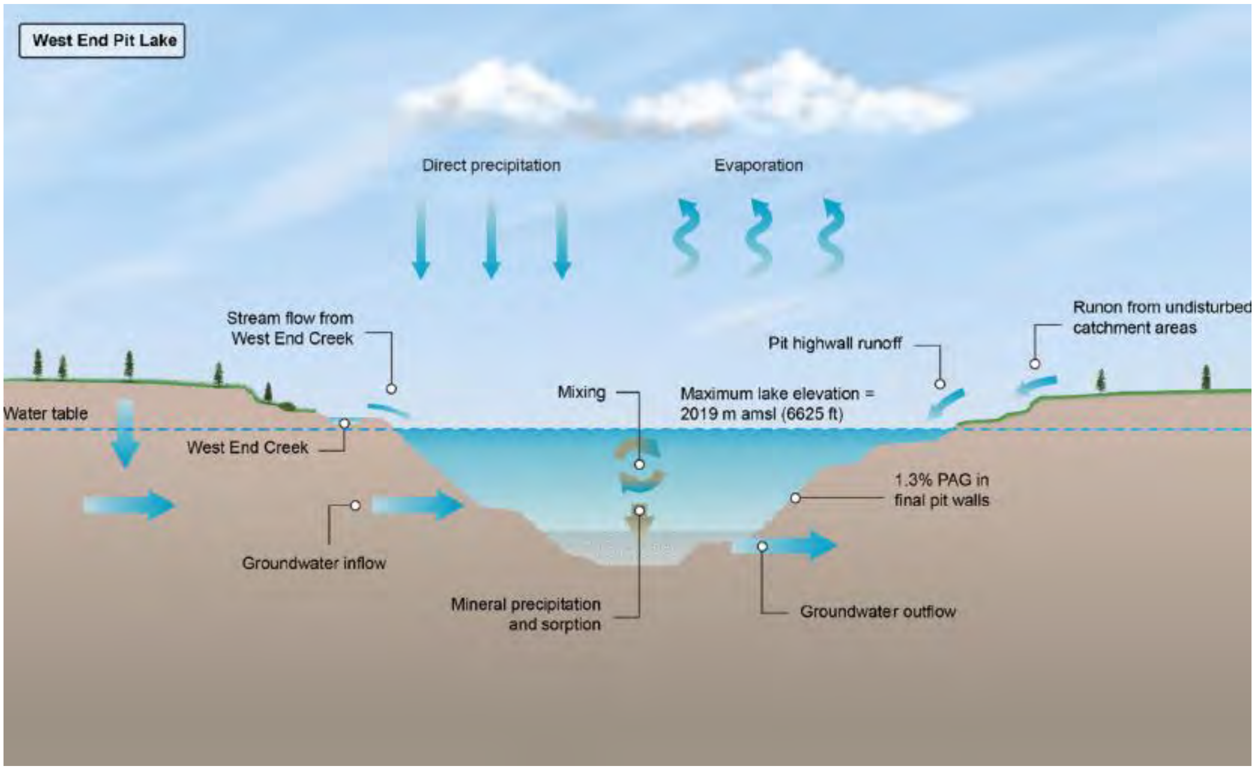

Figure E-6. West End pit lake conceptual model (SRK 2021a).

The predicted water quality of the West End Pit Lake is summarized in Table 8-3 of the SWWC modeling report (SRK 2021a). Select considerations and assumptions employed for predicting pit lake geochemistry include:

- Contaminant loading will come from groundwater and pit wall runoff. Additional contaminant loading will come from fractures in the pit wall and talus on the pit benches.
- Predicted chemical concentrations are based on mixing of groundwater, pit wall runoff, precipitation, and surface water in ratios defined by the hydrologic model.
- Predicted chemical composition is based on the estimated proportional contribution of lithological units above or below water levels.
- The lake is likely to experience seasonal stratification, turning over each spring and fall; however, the model predicts the lake chemistry under well-mixed, annual average conditions.
- Precipitates are assumed to sink to the bottom of the pit lake and be removed from future chemical interactions. These precipitated mineral phases are assumed to be unavailable for re-dissolution.

- Trace metals removed from solution via sorption onto mineral precipitates such as iron oxides are permanently removed from the system.
- Water is predicted to exit the pit lake via groundwater losses (65 percent) and evaporation (35 percent).

Site-Wide Water Chemistry Model

A SWWC model was developed in order to predict instream water quality as a number of assessment nodes in the project area (refer to Figure 29 in the opinion). The predicted chemical concentrations are a combination of natural and anthropogenic factors. Natural factors include the undisturbed mineralized orebody chemical contributions throughout the hydrologic system. Anthropogenic factors include legacy mining and the SGP. The natural and legacy mining constituent concentrations have been characterized by site-surface water monitoring data to establish constituent concentrations for the existing site condition. Contributions from the SGP are characterized by the individual facility geochemical models for the TSF, TSF buttress and embankment, the backfilled Hangar Flats, Yellow Pine and Midnight Pits, West End Pit lake, and water treatment plant (WTP) effluent quality. The SWWC model accounts for treated effluent as follows:

- Upstream of YP-T-27 from mine year -2 through mine year 12
- Upstream of YP-SR-10 from mine year 13 to mine year 23
- Upstream of YP-T-22 from mine year 23-40

The water chemistry models were coupled with surface and groundwater flow predictions from the site-wide water balance and hydrogeological model (Brown and Caldwell 2021; Perpetua 2021). Water quality was predicted on a monthly timestep for the following time periods:

- Existing conditions (Mine Year -37 to -3).
- Open pit mining (Mine Year -2 to 12), the last two years of operations where ore stockpiles are being processed is not included.
- Post-mining during water treatment (mine year 13 to 40)
- Post-mining when no water treatment is occurring (mine year 41 through 112).

The SWWC modeling report (SRK 2021a) and the Water Quality Specialist Report (Forest Service 2023, Section 7) provides details and references regarding the potential sources of chemical contaminants and predicted concentrations in surface waters during the construction, operations, and closure/post-closure periods.

Notable considerations and assumptions used in the SWWC model are listed below.

- There will be no runoff from the TSF discharged to Meadow Creek during operations.
- Following mine year 40, the model assumes there will be no contribution of consolidation water from the TSF to surface water.
- No surface outflow from the West End pit lake will occur.
- WTP effluent will be directed to Meadow Creek when flow augmentation is required through the end of mine year 12.
- WTP effluent will be directed to the EFSFSR (below Meadow Creek) the remainder of operations until the end of August of Mine Year 23.

- WTP effluent will be discharged to Meadow Creek upstream of YP-T-22 until Mine Year 40.
- Estimated surface and groundwater flow volumes contributing to each instream assessment node were based on information in the site-wide water balance and catchment wide hydrogeologic models. Catchment runoff volumes consisted of disturbed ground runoff (contact water) and undisturbed runoff and were proportional to estimated disturbed areas (refer to Table 10-1 of the SWWC model report (SRK 2021a)).
- Runoff from disturbed and undisturbed ground was assigned water chemistries associated with observed concentrations in water chemistry samples from the area.
- The model assumes existing impacts from the SODA/Bradley tailings and Hecla Heap will be completely removed and no residual flow from these facilities will remain following reclamation.
- The model accounted for losing stream reaches (i.e., reaches where surface water is lost to groundwater) by reducing inflows to surface water nodes by an equal volume. This was done to account for mass loss to groundwater prior to mixing at the next downstream location.
- The Bradley dumps are not removed and recharge estimates were assumed to remain the same as existing conditions during operations and post-closure. Infiltration from the Bradley dumps was predicted to comprise 44 and 16 percent of the groundwater flow reporting to instream assessment nodes YP-SR-4 (EFSFSR upstream of Sugar Creek confluence) and YP-SR-2 (EFSFSR below Sugar Creek confluence).
- Groundwater contributions from backfilled pits influence more than one instream assessment node:
    - Hangar Flats pit backfill: YP-T-22 (66 percent), YP-SR-10 (14 percent), and YP-SR-8 (6 percent);
    - YPP backfill: YP-SR-4 (68 percent), YP-T-1 (10 percent), and YP-SR-2 (2 percent); and
    - West End pit lake: YP-T-6 (25 percent) and YP-T-1 (36 percent).
- West End pit lake outflow is predicted to take 16 years to reach West End Creek and Sugar Creek. The SWWC model accounts for this delay.
- The site facility geochemical predictions were assumed to be constant for each month of the corresponding year.
- A load reduction source term was developed to account for mining of the YPP and diversion of the EFSFSR and the associated removal of an existing load contributing to the EFSFSR at assessment node YP-SR-4.

The predicted water quality at each assessment node is calculated by mass-balance mixing of the various contributing water sources. These sources of flow and geochemical information used for each assessment node for the existing conditions and operation and post-operations periods are summarized in Tables 10-5 and 10-6 of the SWWC model report, respectively (SRK 2021a). Monthly variability in the SWWC model outputs are driven by variation in monthly surface and groundwater source terms as well as monthly variability in the hydrological model (SRK 2021a, Brown and Caldwell 2021). The average, minimum, and maximum values for each assessment node were calculated based on the modeled monthly values for each of the time periods.

Modeling Sensitivity Analysis

The degree of potential predictive error from the geochemical model assumptions and SGP design features was evaluated through sensitivity analysis simulations (SRK 2021b). The sensitivity analysis addressed the model uncertainties associated with the potential for acid-generation and leaching reactions as well as the scaling assumptions related to the proportion of preferential flow paths and finer particle gradation in the TSF Buttress and pit backfills and pit wall fracture thickness and density. Findings from the sensitivity analysis include the following:

- Varying model input parameters for the sensitivity analysis had little effect on the model results during mine operations.
- Varying model input parameters (percentage of development rock fines, the percentage of rock contacted due to preferential flow paths through the TSF Embankment and Buttress, and increasing the reaction temperature) had a substantial effect on closure and post closure model results for some parameters. – effectively doubling or tripling the predicted instream concentrations.
    - When the bulk scaling factor of reactive rock is increased, concentrations of arsenic, antimony, sulfate, mercury, and aluminum are predicted to increase in contact water derived from the mined materials. The constituents exceeding surface water standards in contact water were the same as those predicted for the 2021 Modified Mine Plan, but the duration of contact water exceedances was affected in the model sensitivity runs and extended to the end of the mining period.
- In one of the model sensitivity runs, the neutralization potential ratio (NPR) cutoff for defining PAG material was increased to 2 (resulting in a greater percentage of pit wall rock and development rock lithology types being classified as PAG). The post-closure model results were not sensitive to increasing the NPR cutoff. The lack of model sensitivity to this parameter occurs because the mass loading rates for some constituents are lower in the PAG model source term input compared to some non-PAG units. Thus, increasing the percentage of PAG rock in the TSF Buttress and pit lake models does not lead to higher predicted post-closure concentrations.
- The model is not sensitive to varying the pit wall blast-damaged zone thickness.

Overall, the sensitivity analysis indicates the SWWC model is most sensitive to variations in the bulk scaling factor (e.g., reactive mass and temperature). Changing the NPR cutoff for defining PAG material or pit wall fracture depths do not substantially alter predicted instream concentrations during mine operational or post-closure periods. Incorporation of first-flush chemistry in the model predictions will slightly increase predicted analyte concentrations. Finally, effects of model uncertainty from simulating dissolved rather than total concentrations have not been evaluated, but total concentrations of analytes that appear in particulate form will be greater than the simulated dissolved concentrations.

Model Results

Meadow Creek (YP-T-27 and YP-T-22).

Meadow Creek assessment node YP-T-27 is located downstream of the TSF and TSF buttress/embankment and represents water quality conditions influenced by surface and groundwater inflow from upstream, TSF, TSF buttress and embankment, recharge from the SODA/Bradley tailings, and treated effluent. Meadow Creek assessment node YP-T-22 is located downstream of the Hangar Flats pit and represents water quality conditions influenced by upstream sources, Hecla Heap, Hangar Flats pit backfill, and EF Meadow Creek drainage. The modeled existing and predicted future surface water concentrations at nodes YP-T-27 and YP-T-22 are summarized in Tables E-2 and E-3, respectively. Predicted concentrations of pH, antimony, arsenic, and mercury for YP-T-22 are shown in Figure E-7.

Predicted concentrations of most metals are expected to increase during the open pit mining period; however, concentrations are expected to remain below applicable water quality criteria that have been deemed to be sufficiently protective. Arsenic, copper and antimony concentrations are predicted to decrease during open pit mining, though peak concentrations of arsenic and antimony will remain above applicable criteria. Mercury concentrations are predicted to increase, with predicted peak mercury concentrations exceeding the evaluation threshold of 2 ug/L.

During early closure, a number of metals concentrations will remain elevated relative to existing conditions; however, concentrations will remain below applicable water quality criteria. Antimony and arsenic concentrations are predicted to decrease, but will remain at levels higher than applicable criteria. Mercury concentrations are predicted to be similar to existing conditions, although peak concentrations will be slightly higher during early closure. By late closure, most metals concentrations are lower relative to existing conditions. Cadmium, chromium, and nickel are predicted to increase slightly, but concentrations are well below the evaluation thresholds. The predicted improvement in water quality of Meadow Creek is related to the removal of historical unlined mine waste disposal areas from the Meadow Creek drainage and the construction of lined and covered facilities as part of the SGP.

The exception to the reduced analyte concentrations are mercury concentrations which exhibit some variability during the operational and early closure periods attributable to predicted variations in effluent chemistry from the WTP. Predicted long-term surface water mercury concentrations are comparable to the existing conditions at the location.

Table E-2. Summary of site-wide water chemistry model predictions in Meadow Creek at node YP-T-27.

Parameter	Units	Evaluation Threshold[1]	Existing Condition Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH	mg/L	6.5 - 9	7.1	6.8	7.3	7.1	6.8	7.3	7.0	6.5	7.2	6.9	6.4	7.2
Ag[3,4]	ug/L	0.7	0.01	0.0099	0.011	0.012	0.0099	0.061	0.017	0.0100	0.046	0.021	0.0100	0.047
Al[5]	ug/L	385	11	6.7	26	12	7.4	27	12	6.0	27	11	5.9	24
As	ug/L	10	***35.0***	3.1	***83***	2.9	0.80	***23***	1.9	0.77	***17***	1.4	0.76	2.7
Cd[4]	ug/L	0.3	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.03	0.02	0.01	0.03
Cr[4]	ug/L	10.6	0.18	0.12	0.28	0.20	0.10	1.1	0.14	0.070	0.29	0.13	0.062	0.28
Cu[6]	ug/L	2	0.32	0.16	1.6	0.27	0.16	1.3	0.22	0.11	0.30	0.21	0.10	0.27
Hg[7]	ng/L	2	1.0	0.50	***2.2***	1.4	0.53	***5.1***	1.0	0.43	***2.3***	0.92	0.42	1.9
Ni[4]	ug/L	24	0.18	0.11	0.23	0.27	0.10	3.0	0.71	0.10	3.3	1.10	0.14	3.4
Pb[4]	ug/L	0.9	0.02	0.01	0.09	0.034	0.010	0.35	0.013	0.0067	0.060	0.011	0.0061	0.018
Sb	ug/L	5.2	***7.3***	1.0	***18***	0.94	0.24	***7.3***	0.61	0.20	***7.6***	0.40	0.20	1.0
Se	ug/L	3.1	0.50	0.50	0.50	0.50	0.38	0.65	0.46	0.30	0.50	0.44	0.29	0.50
SO_4	mg/L	250	6.7	2.4	13	3.8	1.5	15	2.7	1.4	4.5	2.6	1.4	3.8
Zn[4]	ug/L	54	0.79	0.46	1.9	1.1	0.46	7.1	0.65	0.31	2.0	0.60	0.28	1.8
TDS[8]	mg/L	500	57	26	80	38	20	89	33	19	44	32	18	41
$NO_2 + NO_3$	mg/L as N	-	0.50	0.30	0.58	0.75	0.26	14	0.43	0.22	0.58	0.40	0.20	0.54

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in IDEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

Table E-3.Summary of site-wide water chemistry model predictions in Meadow Creek at node YP-T-22.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH	mg/L	6.5 - 9	7.2	6.9	7.3	7.2	6.9	7.3	7.1	6.6	7.3	7.0	6.6	7.3
Ag[3,4]	ug/L	0.7	0.010	0.0099	0.011	0.012	0.0099	0.048	0.018	0.010	0.040	0.019	0.01	0.042
Al[5]	ug/L	385	11	6.0	26	12	6.9	27	12	6.2	27	11	6.1	25
As	ug/L	10	***32***	4.0	***75***	3.8	1.4	***18***	3.0	1.2	***13***	2.5	1.2	3.7
Cd[4]	ug/L	0.3	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.014	0.01	0.024
Cr[4]	ug/L	10.6	0.20	0.13	0.28	0.20	0.10	1.0	0.25	0.09	0.82	0.14	0.074	0.29
Cu[6]	ug/L	2	0.34	0.16	2.0	0.28	0.18	1.3	0.29	0.14	0.67	0.22	0.13	0.29
Hg[7]	ng/L	2	1.0	0.48	***2.3***	1.5	0.68	***4.9***	1.2	0.59	***2.3***	1.1	0.57	2
Ni[4]	ug/L	24	0.18	0.11	0.22	0.26	0.10	2.7	0.80	0.10	3.30	0.84	0.14	3
Pb[4]	ug/L	0.9	0.018	0.010	0.11	0.032	0.010	0.34	0.022	0.0093	0.071	0.012	0.0083	0.017
Sb	ug/L	5.2	***9.2***	1.4	***25***	1.20	0.29	***14***	0.74	0.29	***5.6***	0.55	0.29	1.02
Se	ug/L	3.1	0.50	0.50	0.51	0.50	0.38	0.61	0.50	0.32	0.67	0.46	0.32	0.5
SO_4	mg/L	250	6.3	2.1	12	3.6	1.4	12	3.2	1.4	7.0	2.6	1.4	3.7
Zn[4]	ug/L	54	0.81	0.46	1.8	1.0	0.48	6.7	1.15	0.38	3.9	0.63	0.34	1.8
TDS[8]	mg/L	500	57	27	80	40	21	82	37	20	51	34	20	43
$NO_2 + NO_3$	mg/L as N	-	0.50	0.32	0.58	0.70	0.30	11	0.44	0.26	0.58	0.42	0.25	0.56

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

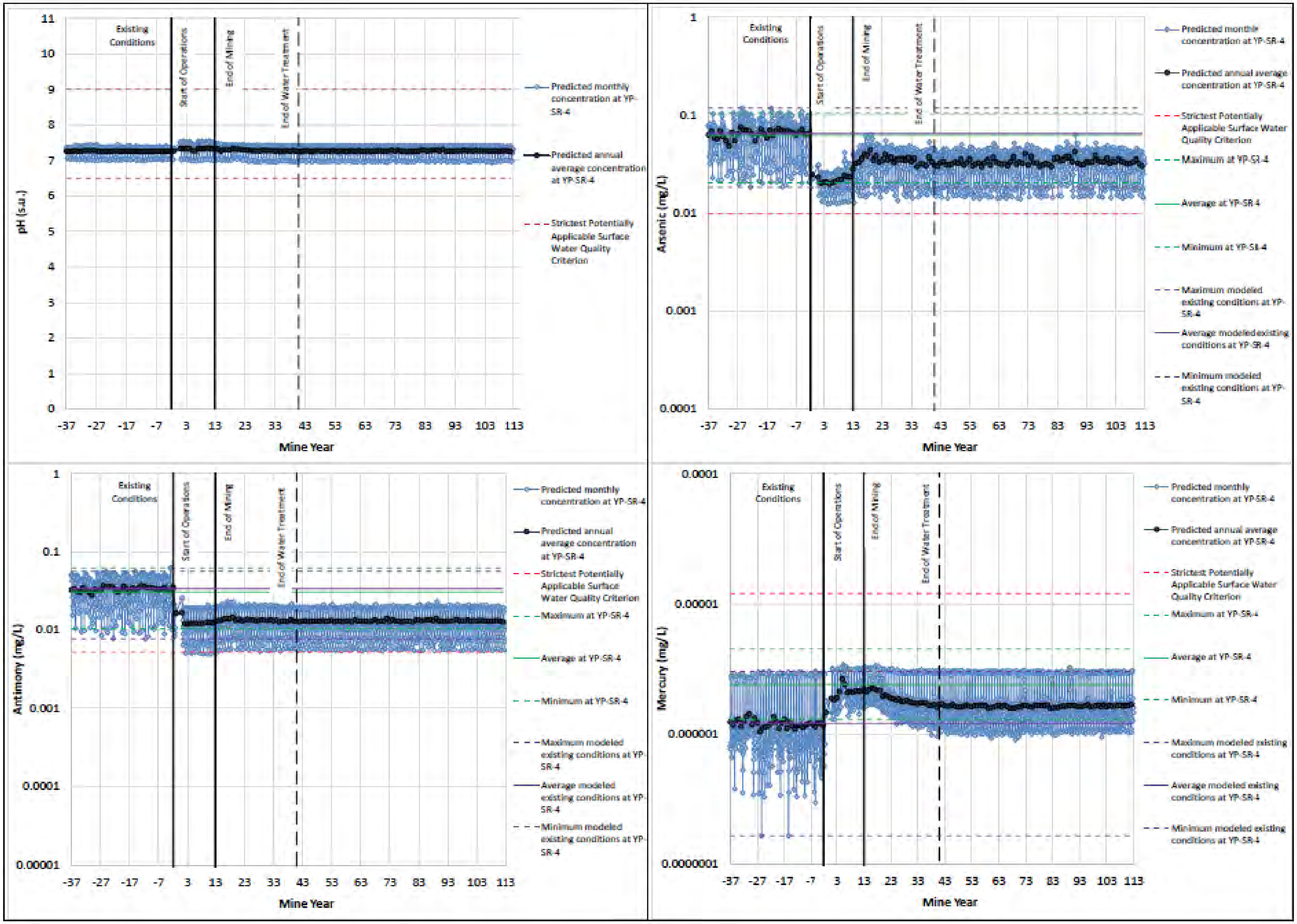

Figure E-7.Predicted surface water chemistry (i.e., pH, arsenic, antimony, and mercury) in Meadow Creek (YP-T-22) downstream of the tailing's storage facility, buttress, and Hangar Flats pit backfill (SRK 2021a).

West End Creek (YP-T-6).

The West End Creek assessment node YP-T-6 is located just upstream of the confluence with Sugar Creek and represents conditions associated with West End pit area mining and subsequently the West End pit lake. The modeled existing and predicted future surface water concentrations at node YP-T-6 during operations are summarized in Table E-4. Predicted concentrations of pH, antimony, arsenic, and mercury for YP-T-6 are shown in Figure E-8.

During operations, water quality at YP-T-6 is assumed to be the same as upstream water quality since the creek will be routed around the mining facilities and will comprise the majority of the flow at YP-T-6. As such, antimony and arsenic concentrations are expected to decrease relative to modeled existing conditions whereas mercury concentrations are predicted to increase. The changes in concentration for these metals from baseline conditions during this period is fairly substantial. Existing mercury concentrations in West End Creek above the West End Pit area are approximately 50 ng/L and are approximately 4 ng/L below the pit area. This suggests that mechanisms that retain particulate mercury reduce mercury concentrations in the creek between the sample locations upstream and downstream of the pit area. Routing the creek around the mine facilities is assumed to result in higher mercury concentrations near the mouth during operations. Mercury concentrations are predicted to be upwards of ten times greater and well above levels associated with detrimental bioaccumulation, assuming conditions conducive to methylation are present. Chromium concentrations are also predicted to increase, though predicted concentrations are well below the chronic criterion for chromium IV (the most toxic form).

Upon completion of open pit mining, upper West End Creek will flow to the West End pit and predicted concentrations at YP-T-6 during this period are calculated as mixture of outflow from the pit lake. During early- and late-closure periods, average concentrations of arsenic, antimony, and mercury are predicted to return to levels similar to existing conditions, though maximum predicted concentrations will increase. Under existing conditions and predicted future conditions, both predicted average and maximum concentrations of arsenic, antimony, and mercury exceed the evaluation thresholds.

Table E-4.Summary of site-wide water chemistry model predictions in West End Creek at node YP-T-6.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	8.2	8.0	8.4	7.7	7.4	7.9	8.2	8.0	8.4	8.2	8.0	8.4
Ag[3,4]	ug/L	0.7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.011	0.01	0.01	0.011
Al[5]	ug/L	385	2.2	1.3	5	3.3	1.4	4	2.4	1.3	5	2.2	1.3	5
As	ug/L	10	***79***	***64***	***88***	8.6	7.8	8.9	***79***	***64***	***94***	***79***	***64***	***95***
Cd[4]	ug/L	0.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.018	0.01	0.01	0.018
Cr[4]	ug/L	10.6	0.22	0.1	0.37	0.33	0.29	0.48	0.22	0.1	0.37	0.22	0.092	0.37
Cu[6]	ug/L	2	0.25	0.15	0.5	0.13	0.11	0.17	0.26	0.15	0.57	0.26	0.15	0.57
Hg[7]	ng/L	2	***4.3***	***3.7***	***5.6***	***53***	***37***	***63***	***4.4***	***3.7***	***9.7***	***4.3***	***3.7***	***9.5***
Ni[4]	ug/L	24	0.35	0.25	0.52	0.16	0.1	0.27	0.33	0.24	0.52	0.35	0.2	0.52
Pb[4]	ug/L	0.9	0.013	0.01	0.028	0.01	0.01	0.013	0.017	0.01	0.24	0.019	0.01	0.25
Sb	ug/L	5.2	***10***	***7.9***	***12***	2.1	1.8	2.2	***10***	***7.9***	***14***	***11***	***7.9***	***14***
Se	ug/L	3.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.43	0.5	0.5	0.39	0.5
SO_4	mg/L	250	55	38	94	0.82	0.65	0.9	56	36	94	54	30	94
Zn[4]	ug/L	54	0.59	0.48	0.85	0.56	0.44	0.8	0.63	0.48	2	0.62	0.48	2.1
TDS[8]	mg/L	500	192	158	250	119	105	129	194	152	251	191	140	251
$NO_2 + NO_3$	mg/L as N	-	0.69	0.53	0.89	1.0	0.28	6.0	0.69	0.5	0.89	0.69	0.43	0.89

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5^{th} percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5^{th} percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10^{th} percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

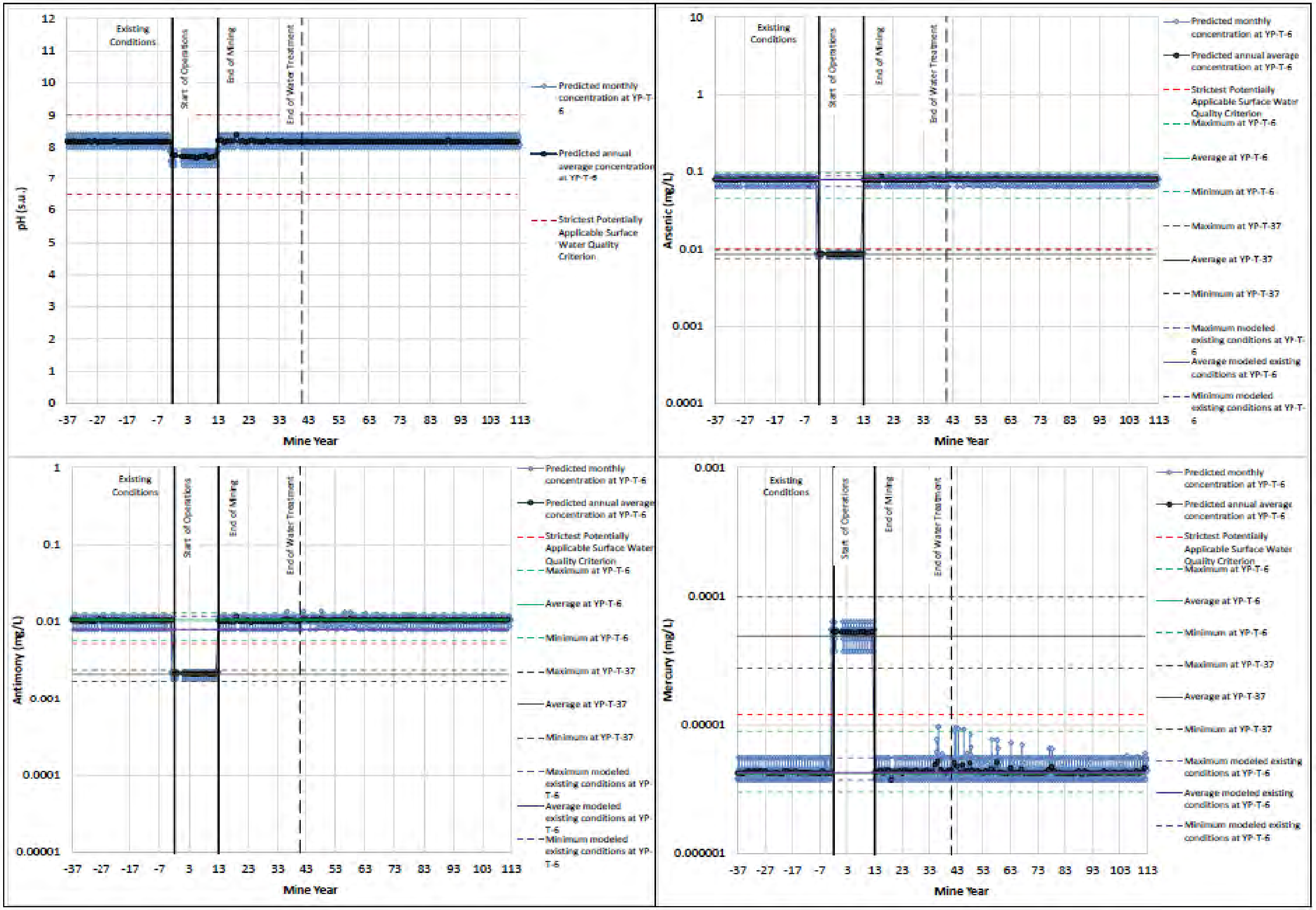

Figure E-8.Predicted surface water chemistry (i.e., pH, arsenic, antimony, and mercury) in West End Creek (YP-T-6) (SRK 2021a).

Sugar Creek (YP-T-1).

The Sugar Creek assessment node YP-T-1 is located just upstream of its confluence with the EFSFSR and represents conditions associated with upstream surface and groundwater quality, Bailey Tunnel adit seepage, and activities within the West End Creek drainage. The modeled existing and predicted future surface water concentrations at node YP-T-6 during operations are summarized in Table E-5. Predicted concentrations of pH, antimony, arsenic, and mercury for YP-T-6 are shown in Figure E-9.

During operations, most metals concentrations are predicted to remain the same or decrease. Mercury concentrations are predicted to increase slightly, and will continue to exceed the evaluation threshold of 2 μg/L. Lead is also predicted to increase; though concentrations are expected to be an order of magnitude lower than applicable criteria. Arsenic concentrations are predicted to be slightly lower than existing conditions; however, concentrations are expected to remain elevated above applicable criteria.

During early- and late-closure periods, predicted concentrations of arsenic, cadmium, copper, mercury and lead are expected to increase. Cadmium, copper and lead concentrations are expected to be well below their respective evaluation thresholds. Arsenic and mercury concentrations will remain above their respective evaluation thresholds.

Table E-5.Summary of site-wide water chemistry model predictions in Sugar Creek at node YP-T-1.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.4	7.2	7.6	7.4	7.2	7.6	7.4	7.2	7.6	7.4	7.3	7.6
Ag[3,4]	ug/L	0.7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Al[5]	ug/L	385	6	2.8	13	6	2.7	13	6	2.7	13	6	2.6	13
As	ug/L	10	***13***	7.4	***16***	***13***	6.6	***15***	***13***	6.8	***17***	***14***	7	***17***
Cd[4]	ug/L	0.3	0.0101	0.01	0.01	0.0101	0.01	0.01	0.0102	0.01	0.011	0.0103	0.01	0.011
Cr[4]	ug/L	10.6	0.13	0.1	0.2	0.13	0.1	0.2	0.13	0.1	0.2	0.13	0.1	0.2
Cu[6]	ug/L	2	0.27	0.2	0.6	0.27	0.21	0.6	0.27	0.2	0.6	0.28	0.2	0.6
Hg[7]	ng/L	2	***6.3***	***5.47***	***8.1***	***6.5***	***5.55***	***8.5***	***6.5***	***5.61***	***8.2***	***6.6***	***5.71***	***8.2***
Ni[4]	ug/L	24	0.22	0.11	0.26	0.21	0.11	0.25	0.21	0.11	0.25	0.21	0.11	0.25
Pb[4]	ug/L	0.9	0.018	0.01	0.05	0.019	0.01	0.051	0.022	0.0117	0.057	0.026	0.0145	0.057
Sb	ug/L	5.2	3.6	1.42	***6***	2.4	1.26	3	2.5	1.28	3	2.5	1.31	3
Se	ug/L	3.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.49	0.5
SO_4	mg/L	250	10.2	4.3	14	8.1	3.3	10	8.1	3.4	10	8.3	3.5	10
Zn[4]	ug/L	54	0.67	0.31	0.8	0.6	0.29	0.7	0.62	0.28	0.8	0.64	0.29	0.8
TDS[8]	mg/L	500	69	40	81	66	38	75	66	38	75	67	39	76
$NO_2 + NO_3$	mg/L as N	-	0.59	0.3	1.11	0.6	0.29	1.13	0.6	0.29	1.12	0.59	0.29	1.12

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

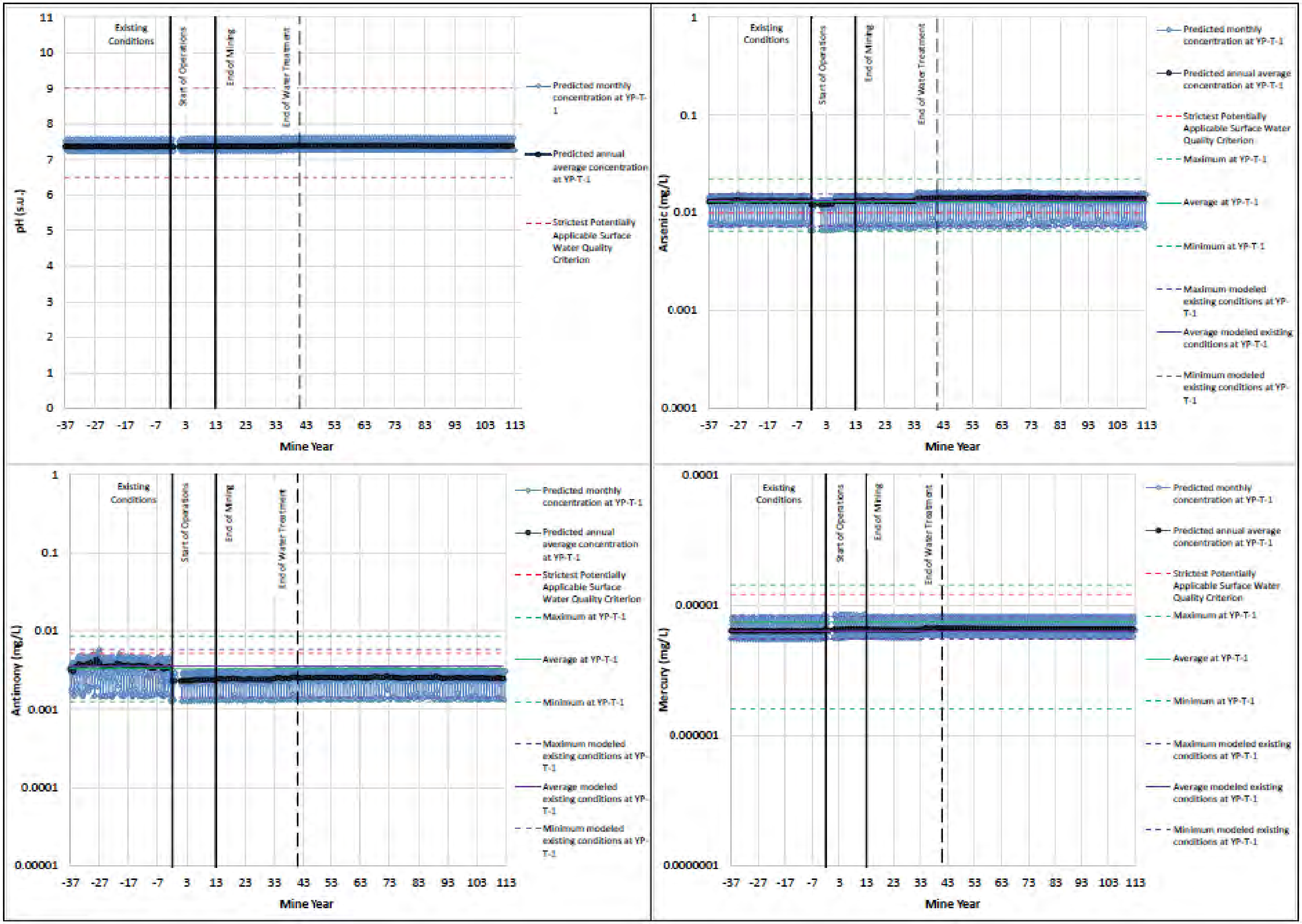

Figure E-9.Predicted surface water chemistry (i.e., pH, arsenic, antimony, and mercury) in Sugar Creek (YP-T-1) (SRK 2021a)

East Fork South Fork Salmon River Upstream of Sugar Creek

The following four assessment nodes were used to evaluate water quality conditions in the EFSFSR upstream of Sugar Creek:

- YP-SR-10 is located just downstream of the confluence with Meadow Creek.
- YP-SR-8 is located upstream of the Fiddle Creek confluence.
- YP-SR-6 is located downstream of the Fiddle Creek confluence and represents conditions in the lined stream channel across the YPP (USFS 2023).
- YP-SR-4 is located downstream of the YPP backfill.

Predicted water quality conditions for assessment nodes YP-SR-10, 8, 6, and 4 are summarized in Tables E-6 through E-9, respectively. Predicted concentrations of pH, antimony, arsenic, and mercury for YP-SR-4 are shown in Figure E-10. Similar graphs for YP-SR-10, 8, and 6 can be found in the SWWC report (SRK 2021a; Figures G-5, G-7, and G-9, respectively).

Under existing conditions, water quality at assessment nodes YP-SR-10, 8, and 6 are influenced by the spent ore disposal area (SODA), Bradley tailings, and Hecla Heap. As a result, concentrations of antimony, arsenic, and mercury are elevated above the evaluation thresholds. Reclamation of these facilities during the operations period will is expected to result in decreased concentrations of arsenic and antimony, though concentrations will remain above the evaluation thresholds. Concentrations of mercury and other contaminants are predicted to increase during operations, though only mercury is predicted to exceed its evaluation threshold. At YP-SR-4, removal of unlined legacy mine wastes results in decreases in antimony and arsenic during operations.

During early-closure, concentrations of most constituents are predicted to be higher than existing conditions, which may be attributable to discharge of treated mine contact water. Maximum predicted concentrations of mercury are expected to exceed the evaluation thresholds, while average concentrations are predicted to remain below. Concentrations of antimony and arsenic are predicted to continue to decrease at locations above the YPP, though predicated average and maximum concentrations remain above the evaluation thresholds at most assessment nodes. At assessment node YP-SR-4, concentrations of arsenic increase relative to operations, because discharging groundwater chemistry is modified by interaction with the YPP backfill.

During late-closure, when water treatment is no longer needed, concentrations of many contaminants in the EFSFSR above the YPP are expected to generally be below existing conditions. Exceptions to this include slight increases in predicted average concentrations of silver, cadmium, and nickel at assessment nodes upstream of the YPP. Although quantifiable, concentrations are very similar to existing conditions and none of the predicted concentrations will exceed the evaluation thresholds used. Of particular note is the predicted reductions in arsenic and antimony concentrations relative to existing conditions at all EFSFSR assessment nodes; although concentrations will remain above evaluation thresholds for these two parameters. Similarly, predicted mercury concentrations will remain the same or decrease slightly upstream of the YPP backfill; however, predicted maximum concentrations will remain above the evaluation threshold. Downstream of the YPP backfill, mercury concentrations will be slightly higher than existing concentrations and will be greater than the evaluation threshold.

Table E-6.Summary of site-wide water chemistry model predictions in the East Fork South Fork Salmon River at node YP-SR-10.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.2	7.0	7.3	7.2	7.0	7.3	7.2	6.3	7.3	7.1	6.8	7.3
Ag[3,4]	ug/L	0.7	0.01	0.0099	0.011	0.011	0.0099	0.032	0.016	0.0100	0.090	0.015	0.0100	0.036
Al[5]	ug/L	385	8.8	4.9	21	9	6	21	9	6	21	9	6	21
As	ug/L	10	***26***	7.4	***51***	8.2	3.2	***23.0***	6.3	3.0	***13.1***	5.8	2.8	7.6
Cd[4]	ug/L	0.33	0.01	0.0095	0.011	0.0110	0.0097	0.0250	0.0120	0.0093	0.0410	0.0120	0.0100	0.0210
Cr[4]	ug/L	10.6	0.18	0.12	0.34	0.18	0.11	0.70	0.22	0.11	0.91	0.14	0.10	0.35
Cu[6]	ug/L	2	0.3	0.14	1.5	0.3	0.14	1.0	0.3	0.14	0.7	0.2	0.1	0.5
Hg[7]	ng/L	2	1.8	1.2	***3.2***	***2.3***	1.5	***4.3***	1.9	0.9	***3.7***	1.8	0.9	***3.0***
Ni[4]	ug/L	24	0.17	0.11	0.22	0.22	0.10	1.80	0.60	0.10	2.50	0.58	0.13	2.40
Pb[4]	ug/L	0.9	0.016	0.0098	0.082	0.028	0.0100	0.250	0.022	0.0100	0.170	0.013	0.0097	0.030
Sb	ug/L	5.2	***13***	2.1	***30***	2.90	0.42	***18.0***	1.00	0.40	4.2	0.88	0.40	1.3
Se	ug/L	3.1	0.51	0.5	0.52	0.50	0.42	0.58	0.50	0.36	0.60	0.47	0.36	0.50
SO_4	mg/L	250	4.8	1.7	8.1	3.0	1.2	9	3.3	1.2	32	2.4	1.2	3
Zn[4]	ug/L	54	0.85	0.5	1.6	1.00	0.51	4.90	1.13	0.43	8.00	0.73	0.41	1.60
TDS[8]	mg/L	500	51	26	66	41	23	68	40	22	96	37	22	46
NO2 + NO3	mg/L as N	-	0.5	0.38	0.59	0.65	0.39	6.4	0.47	0.35	1.0	0.45	0.34	0.5

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

Table E-7.Summary of site-wide water chemistry model predictions in the East Fork South Fork Salmon River at nodeYP-SR-8.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.2	7.0	7.3	7.2	7.0	7.3	7.2	6.5	7.3	7.2	6.9	7.3
Ag[3,4]	ug/L	0.7	0.01	0.0099	0.011	0.011	0.010	0.027	0.015	0.010	0.072	0.014	0.010	0.031
Al[5]	ug/L	385	8.0	4.9	19	8.0	5.5	19	9.0	5.7	19	8.0	5.4	19
As	ug/L	10	**33**	**18**	**52**	**19**	**12.4**	**32**	***17***	***12.2***	***25***	***17***	***12.1***	***20***
Cd[4]	ug/L	0.33	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.01	0.01	0.019
Cr[4]	ug/L	10.6	0.18	0.12	0.33	0.19	0.12	0.59	0.22	0.12	0.75	0.16	0.11	0.34
Cu[6]	ug/L	2	0.31	0.15	1.5	0.29	0.15	1.1	0.29	0.15	0.80	0.25	0.14	0.80
Hg[7]	ng/L	2	1.7	1.2	**3.1**	**2.1**	1.4	**3.6**	1.8	0.92	***3.2***	1.7	0.92	***3.0***
Ni[4]	ug/L	24	0.17	0.11	0.21	0.21	0.10	1.5	0.51	0.10	2.03	0.50	0.14	1.9
Pb[4]	ug/L	0.9	0.016	0.0098	0.084	0.026	0.010	0.20	0.021	0.0098	0.14	0.014	0.0098	0.043
Sb	ug/L	5.2	**16.6**	**6.2**	**31**	**8.4**	4.5	**21**	***6.9***	4.4	***12***	***6.7***	4.3	***9.0***
Se	ug/L	3.1	0.51	0.50	0.52	0.50	0.43	0.56	0.50	0.39	0.58	0.48	0.39	0.50
SO_4	mg/L	250	5.0	2.0	8.0	3.6	1.6	8.0	3.8	1.6	26	3.1	1.6	4.0
Zn[4]	ug/L	54	0.84	0.52	1.5	0.98	0.52	4.0	1.1	0.51	6.4	0.75	0.45	1.4
TDS[8]	mg/L	500	52	29	66	44	26	67	44	25	89	41	25	51
NO2 + NO3	mg/L as N	-	0.49	0.41	0.61	0.62	0.42	5.0	0.47	0.38	0.85	0.46	0.38	0.56

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

Table E-8.Summary of site-wide water chemistry model predictions in the East Fork South Fork Salmon River at node YP-SR-6.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.3	7.0	7.6	7.3	7.0	7.6	7.3	6.9	7.5	7.3	6.9	7.6
Ag[3,4]	ug/L	0.7	0.01	0.0098	0.011	0.011	0.01	0.021	0.014	0.01	0.048	0.013	0.0102	0.024
Al[5]	ug/L	385	9	5.3	20	9	5.5	19	9	5.7	20	9	5.5	19
As	ug/L	10	***31***	***16.9***	***41***	***23***	***12.6***	***41***	***20***	***11.9***	***29***	***20***	***11.8***	***27***
Cd[4]	ug/L	0.33	0.0103	0.0098	0.011	0.0111	0.0099	0.018	0.0115	0.0094	0.025	0.0117	0.0103	0.016
Cr[4]	ug/L	10.6	0.22	0.15	0.31	0.22	0.14	0.48	0.24	0.14	0.57	0.2	0.13	0.32
Cu[6]	ug/L	2	0.36	0.18	1.6	0.35	0.18	1.3	0.35	0.18	1.1	0.31	0.17	1.1
Hg[7]	ng/L	2	1.8	1.22	***3.1***	***2.1***	1.26	***3.4***	1.8	1.01	***3.2***	1.8	1.02	***3***
Ni[4]	ug/L	24	0.3	0.11	0.45	0.33	0.11	1.2	0.54	0.11	1.57	0.53	0.21	1.51
Pb[4]	ug/L	0.9	0.023	0.0106	0.093	0.035	0.0108	0.144	0.026	0.0104	0.099	0.021	0.0101	0.065
Sb	ug/L	5.2	***18.7***	***5.94***	***30***	***13.4***	4.93	***27***	***11.9***	4.51	***20***	***11.8***	4.47	***19***
Se	ug/L	3.1	0.5	0.49	0.51	0.49	0.45	0.53	0.49	0.42	0.55	0.48	0.42	0.5
SO_4	mg/L	250	5.8	2.0	9	4.9	1.7	10	4.9	1.6	20	4.4	1.6	7
Zn[4]	ug/L	54	1.01	0.58	1.6	1.14	0.59	3.2	1.16	0.58	4.5	0.93	0.54	1.4
TDS[8]	mg/L	500	63	28	81	58	26	86	56	25	96	55	25	74
$NO_2 + NO_3$	mg/L as N	-	0.55	0.47	0.75	0.64	0.48	3.41	0.53	0.45	0.8	0.52	0.43	0.68

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

Table E-9.Summary of site-wide water chemistry model predictions in the East Fork South Fork Salmon River at node YP-SR-4.

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.3	7.0	7.5	7.3	7.0	7.5	7.3	7.0	7.5	7.3	6.9	7.4
Ag[3,4]	ug/L	0.7	0.010	0.0098	0.011	0.010	0.0063	0.012	0.011	0.0063	0.031	0.010	0.0057	0.017
Al[5]	ug/L	385	9.0	6.6	19	9.0	4.0	19	7.0	4.3	20	7.0	3.9	19
As	ug/L	10	***64***	***18.7***	***117***	***25***	***12.6***	***97***	***35***	***13***	***63***	***34***	***14.1***	***62***
Cd[4]	ug/L	0.3	0.01	0.01	0.01	0.01	0.006	0.02	0.01	0.008	0.02	0.01	0.007	0.02
Cr[4]	ug/L	10.6	0.20	0.15	0.29	0.22	0.11	0.48	0.20	0.13	0.45	0.16	0.12	0.31
Cu[6]	ug/L	2	0.34	0.21	1.4	0.34	0.17	1.2	0.30	0.17	0.90	0.27	0.17	0.80
Hg[7]	ng/L	2	1.2	0.17	***3.0***	2.0	0.46	***3.4***	1.9	0.96	***3.4***	1.6	0.91	***3.3***
Ni[4]	ug/L	24	0.27	0.11	0.40	0.32	0.11	1.2	0.42	0.11	1.1	0.40	0.21	1.0
Pb[4]	ug/L	0.9	0.018	0.011	0.080	0.034	0.011	0.14	0.055	0.013	0.20	0.040	0.011	0.18
Sb	ug/L	5.2	***33.4***	***7.7***	***56***	***14.5***	4.9	***63***	***13.3***	5.0	***23***	***13***	***5.4***	***23***
Se	ug/L	3.1	0.50	0.49	0.51	0.49	0.25	0.51	0.39	0.29	0.51	0.38	0.26	0.49
SO_4	mg/L	250	16.1	2.5	32	5.7	1.7	26	6.8	1.7	17	6.5	1.8	10
Zn[4]	ug/L	54	1.4	0.65	1.8	1.1	0.54	3.1	1.2	0.64	4.2	0.97	0.61	2.0
TDS[8]	mg/L	500	67	29	97	57	26	98	52	26	88	50	26	71
$NO_2 + NO_3$	mg/L as N	-	0.42	0.27	0.62	0.60	0.32	2.3	0.44	0.36	0.65	0.43	0.35	0.56

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

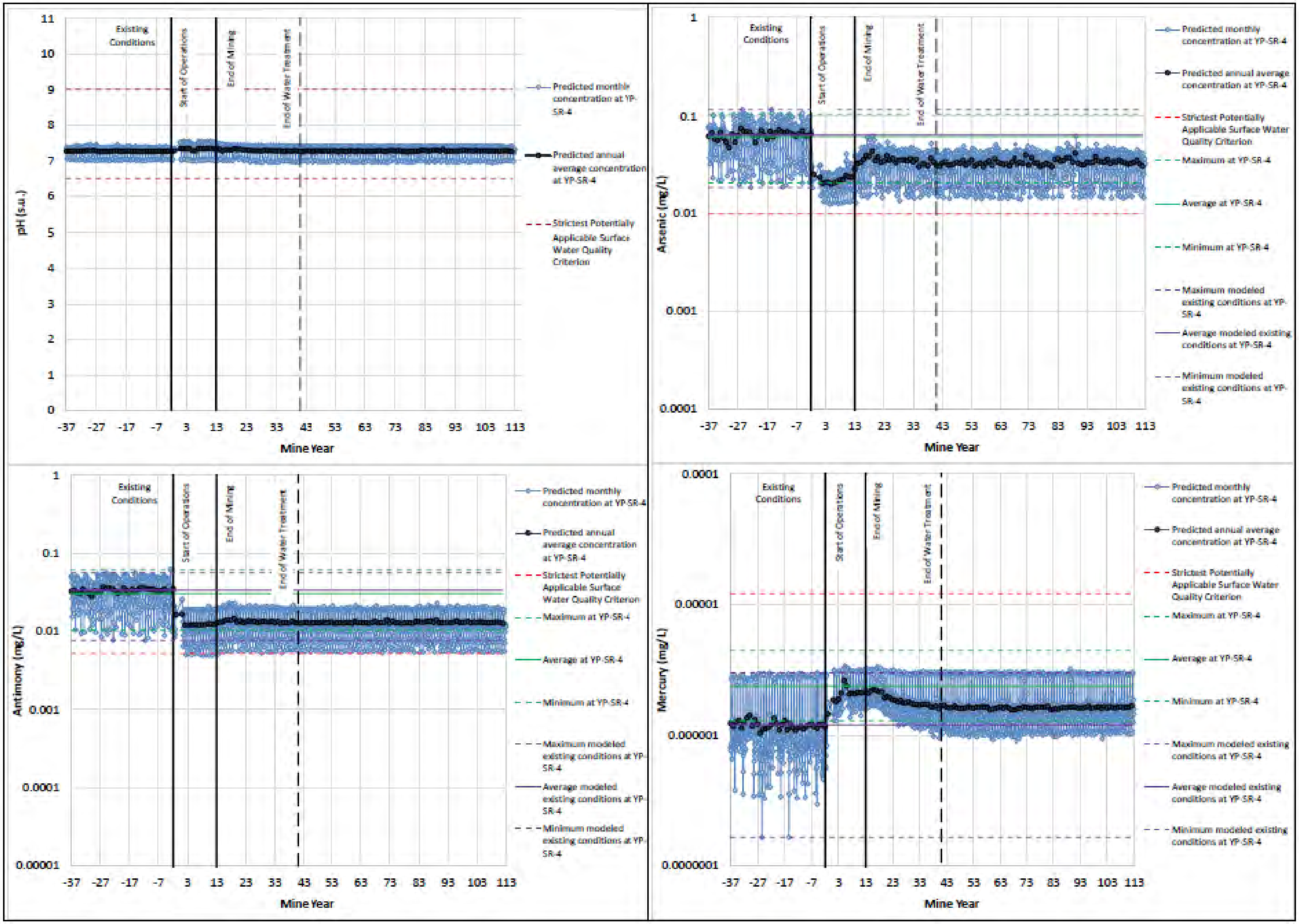

Figure E-10.Predicted surface water chemistry (i.e., pH, arsenic, antimony, and mercury) in the East Fork South Fork Salmon River (YP-SR-4), below the Yellow Pine Pit (SRK 2021a).

East Fork South Fork Salmon River downstream of Sugar Creek

The East Fork South Fork Salmon River assessment node (YP-SR-2) is downstream of Sugar Creek represents conditions associated with all proposed mine operation and closure activities. The modeled existing and predicted future surface water concentrations at node YP-SR-2 during operation, early-closure, and late-closure periods are summarized in Table E-10. Predicted concentrations of pH, antimony, arsenic, and mercury for YP-SR-2 are shown in Figure E-11.

During operations, predicted surface water chemistry is similar to existing conditions, with some variability in predicted antimony, arsenic, and mercury concentrations. Antimony and arsenic concentrations are expected to be lower during the operating period due to the removal of unlined legacy mine wastes. Mercury concentrations are slightly higher than existing conditions during the operating period, due to the predicted discharge from the mine contact water treatment plant.

During early closure, concentrations of antimony and arsenic are expected to increase (Figure E-11), but will remain above their respective evaluation thresholds. However, concentrations will be less than existing conditions. Mercury concentrations are expected to remain elevated above 2 ng/L; however, concentrations are expected to slightly decrease relative to the operations period.

During late closure, most contaminant concentrations will be lower than existing conditions, with the exception of mercury, nickel, and lead. These constituents are predicted to be slightly above existing conditions. Concentrations of nickel and lead will be well below their respective evaluation thresholds, whereas mercury is expected to be above 2 ng/L. Most of the mercury loading at this assessment node is due to legacy mining activities at the Cinnabar Mine Site in the Sugar Creek drainage.

Table E-10.Summary of site-wide water chemistry model predictions in the East Fork South Fork Salmon River at node YP-SR-2

Parameter	Units	Evaluation Threshold[1]	Existing Conditions Mine Year -37 to -3			Open Pit Mining Mine Year -2 to 12			Post-Mining during Water Treatment Mine Year 13 to 40			Post-Mining no Water Treatment Mine Year 41 to 112		
			Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]	Avg[2]	Min[2]	Max[2]
pH		6.5 - 9	7.3	7.1	7.5	7.3	7.1	7.5	7.3	7.0	7.5	7.3	7.0	7.5
Ag[3,4]	ug/L	0.7	0.01	0.0099	0.011	0.01	0.0077	0.012	0.011	0.0077	0.023	0.01	0.0074	0.015
Al[5]	ug/L	385	8	5.1	17	7	4.8	17	7	4	17	7	3.8	17
As	ug/L	10	***45***	***14.1***	***76***	***20***	***10.2***	***66***	***28***	***10.4***	***45***	***27***	***11.3***	***47***
Cd[4]	ug/L	0.3	0.0102	0.0099	0.01	0.0106	0.0075	0.016	0.0105	0.0086	0.018	0.0101	0.0082	0.013
Cr[4]	ug/L	10.6	0.17	0.14	0.23	0.18	0.12	0.37	0.17	0.13	0.33	0.15	0.12	0.25
Cu[6]	ug/L	2	0.32	0.23	1	0.31	0.2	0.8	0.29	0.2	0.6	0.28	0.2	0.6
Hg[7]	ng/L	2	***4.8***	***3.2***	***9.6***	***5.7***	***3.66***	***10***	***5.2***	***3.23***	***9.3***	***5.2***	***2.96***	***9.4***
Ni[4]	ug/L	24	0.25	0.11	0.35	0.28	0.11	0.89	0.35	0.11	0.87	0.33	0.18	0.84
Pb[4]	ug/L	0.9	0.018	0.011	0.056	0.028	0.0107	0.103	0.043	0.0211	0.139	0.035	0.0204	0.127
Sb	ug/L	5.2	***22.2***	5.2	***37***	***9.7***	3.51	***41***	***9.5***	3.45	***16***	***9.3***	3.82	***16***
Se	ug/L	3.1	0.5	0.49	0.51	0.49	0.35	0.5	0.43	0.36	0.51	0.42	0.35	0.49
SO_4	mg/L	250	13.8	3.2	23	6.7	2.3	20	7.3	2.4	15	7.1	2.5	10
Zn[4]	ug/L	54	1.11	0.64	1.4	0.93	0.57	2.3	1.02	0.63	2.9	0.86	0.6	1.5
TDS[8]	mg/L	500	67	33	87	61	31	88	57	30	82	56	30	71
$NO_2 + NO_3$	mg/L as N	-	0.49	0.32	0.71	0.6	0.31	1.68	0.5	0.34	0.72	0.49	0.33	0.72

Abbreviations: mg/L = milligrams per liter; ug/L = micrograms per liter; ng/L = nanograms per liter; Avg = average; min = minimum; max = maximum.

Notes: Yellow cells represent predicted increases in concentrations relative to the modeled existing conditions. Green cells represent predicted decreases in concentrations relative to the modeled existing conditions. Bold italic numerical values represent concentrations greater than surface water criteria/thresholds identified in the third column.

[1]Unless otherwise noted, the values presented here are the most stringent surface water quality criteria, reported as two significant digits.

[2]Average, minimum and maximum values are calculated based on the monthly predicted concentrations over the indicated time period.

[3]The evaluation threshold is based on the acute aquatic life criterion.

[4]Concentrations are based on a hardness value of 40 mg/L as calcium carbonate, which represents the 5th percentile hardness during the driest four months at EFSFSR node YP-SR-10.

[5]The aluminum threshold is based on EPA's nationally recommended criteria guidelines. Values for total hardness, pH, and dissolved organic carbon collected on the same day at USGS gaging stations EFSFSR above Sugar Creek (13311250) and EFSFSR at Stibnite (13311000) from 2014-2022 were used to calculate the chronic criterion. The 5th percentile value was selected as the evaluation threshold.

[6]The evaluation threshold was derived using the biotic ligand model per guidance contained in DEQ 2017, and was estimated by applying the lowest 10th percentile chronic aquatic life criterion based on regional classifications for the Salmon River Basin, Idaho Batholith, and third order streams.

[7]The evaluation threshold is based on recommendations by NMFS (2014).

[8]The evaluation threshold is based on a secondary drinking water standard.

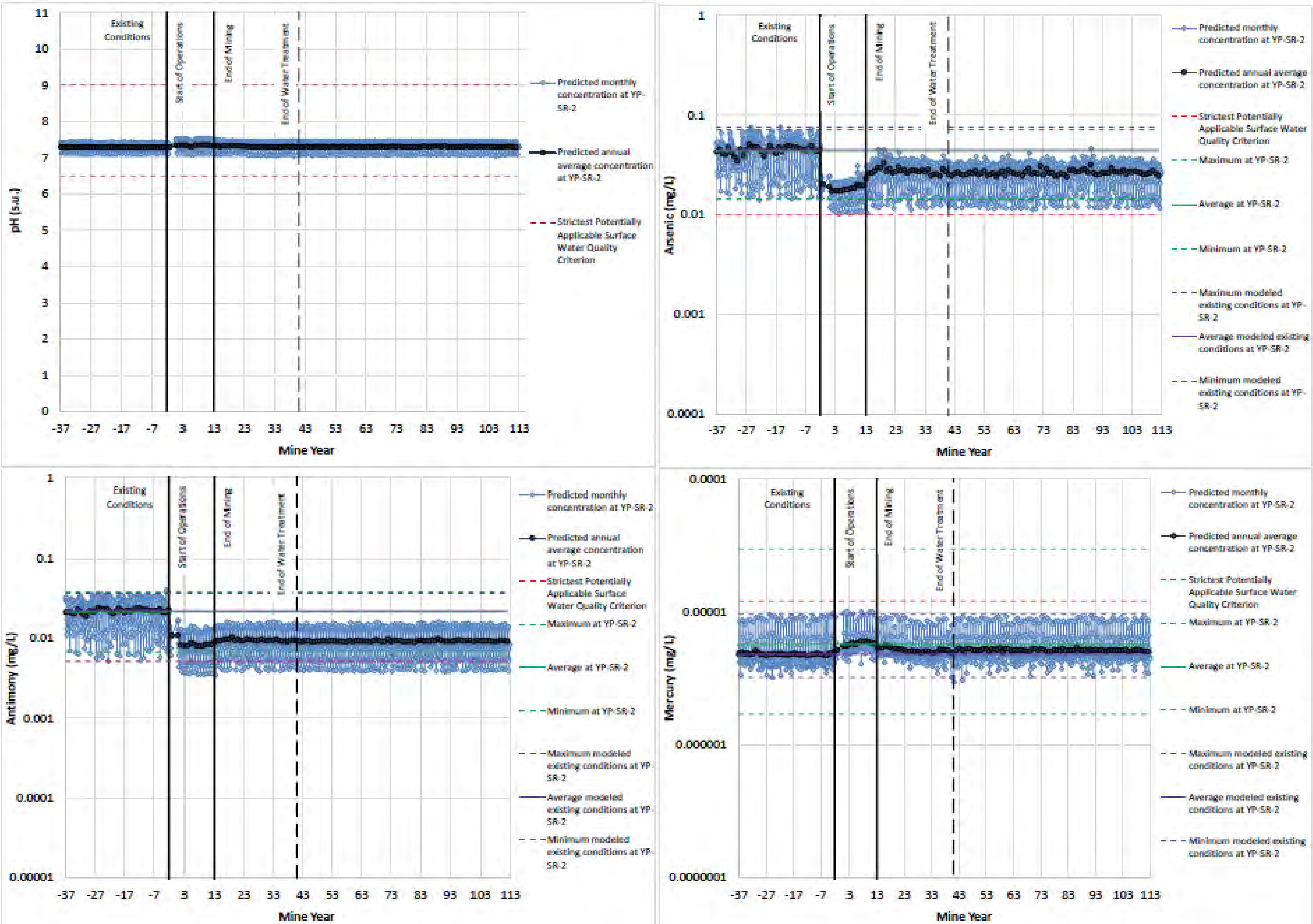

Figure E-11.Predicted surface water chemistry (i.e., pH, arsenic, antimony, and mercury) in the East Fork South Fork Salmon River (YP-SR-2), below the Sugar Creek confluence (SRK 2021a).

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APPENDIX F

SUMMARY OF TOXICOLOGICAL EFFECTS FOR SELECT CONSITUENTS

INTRODUCTION

This appendix summarizes toxicity information for constituents of potential concern associated with the Stibnite Gold Project. For each contaminant, a general discussion about its toxicity is followed by sections specific to fish and their prey. A discussion about prey items is included because aquatic macroinvertebrates serve as significant food sources for early life stages of Endangered Species Act (ESA)-listed fish, as well as for other aquatic organisms that are in turn prey items for salmon and steelhead. The toxicity for many constituents were examined as part of the consultation for Idaho water quality standards for toxics (NMFS 2014; WCRO-2000-1484), and much of that information has been incorporated here. We also incorporated best available science that has been published since 2014.

For ease of use, a general description of common toxicological terminology used in this section is provided for quick reference below. The terminology is organized alphabetically, by its respective acronym.

Bioaccumulation Factor (BAF). A measure of how readily a contaminant concentrates in biotic tissues relative to all potential exposure routes (e.g., waterborne and dietary exposures).

Bioconcentration Factor (BCF). A measure of how readily a contaminant concentrates in biotic tissues from waterborne exposures only. For aquatic toxicology, the BCF is the ratio of a contaminant concentration in biota (i.e., tissue concentrations) to its concentration in water.

Criterion Continuous Concentration (CCC). More commonly referred to as the "chronic criterion." Idaho water quality standards (WQS) (Idaho Administrative Procedures Act 58.01.02) contain chronic criteria for many of the23000 parameters of concern included in this biological opinion (Opinion). The CCC is established at a level (magnitude) that protects aquatic communities against long-term effects and that is not to be exceeded on average for longer than 4 days (duration) and more than once every 3 years (frequency).

Criterion Maximum Concentration (CMC). More commonly referred to as the "acute criterion," this is an enforceable criterion that is included in Idaho WQS for the protection of aquatic life. The concentration is established at a level that protects aquatic communities against short-term effects and that is not to be exceeded on average for longer than 1-hour and more than once every 3 years.

Effect Concentration (EC_x). The estimated concentration at which a specified proportion of the test organisms exhibit the endpoint (e.g., reduced growth, immobility, loss of equilibrium, etc.) of interest. For example, immobility was observed in 20 percent of the test organisms. Or, the estimated concentration at which an organism demonstrated a specified proportional reduction in a given endpoint (e.g., growth, reproduction, etc.). For example, test organisms experienced a

20 percent reduction in growth compared to controls. The later definition is synonymous with the inhibition concentration (IC) (listed below).

Genus Mean Acute Value (GMAV). The geometric mean of the species means acute values for an identified toxicity test statistic (most commonly the LC_{50}).

Inhibition Concentration (IC_x). The concentration estimated to cause a specified percent reduction in a biological test endpoint such as reproduction or growth.

Lethal Concentration (LC_x). The estimated concentration where a specified percentage of the test organisms die. The LC_x is estimated using a statistical distribution or regression model of the dose-response relationship based on toxicity testing. The most common test statistic used in acute studies is the LC_{50} (the lethal concentration where 50 percent of the organisms die).

Lowest Observed Effect Concentration (LOEC). The lowest tested concentration in which the measured endpoints are statistically significantly different from the controls. This is the first treatment that is greater than the No Observed Effect Concentration (NOEC) (defined below).

Maximum Acceptable Threshold Concentration (MATC). The geometric mean of the NOEC and the LOEC for the most sensitive endpoint (such as mortality, reproduction, or growth) for which data is available.

No Observed Effect Concentration. The highest tested concentration in which the measured endpoints are not statistically significantly different from the controls.

Species Mean Acute Value (SMAV). The geometric mean of individual toxicity test values (e.g., LC_{50}s) for a species.

ANTIMONY

Antimony (Sb) naturally occurs in soil and water and is generally present in low concentrations. Antimony is present in the environment in numerous oxidative states in both organic and inorganic forms (Bolan et al. 2022). The two oxidation states of environmental and biological importance include antimonite (i.e., Sb^{+3}, or Sb(III)) and antimonate (i.e., Sb^{+5} or Sb(V)) (Filella et al. 2009, 2002). Typical concentrations of Sb in uncontaminated freshwater are generally below 1 ug/L (Filella et al. 2009); observed background concentrations in Meadow Creek (upstream of historic mining impacts) have typically been well below 1 ug/L (Etheridge 2015).

Antimony is not an essential element, meaning it does not have any known biological function. The toxicity of Sb is not well studied, though it is thought to be less toxic than arsenic (Filella et al. 2009). Most toxicity studies involve Sb(III), which is not as prevalent as Sb(V) in oxic systems such as rivers and streams. Antimony mobility and bioavailability (and hence its toxicity), is dependent upon pH, redox potential, and organic matter (He et al. 2019, Bolan et al. 2022, Obiakor et al. 2017a). The mode of toxicity is not yet understood.

Most of the antimony toxicity research has focused on Sb(III). There is some disagreement in the literature regarding which oxidized state is more toxic, and many claims of Sb(III) being more toxic appear to be unfounded (Filella et al. 2009). Some authors suggest Sb(III) is more toxic than Sb(V); Kennedy (2023, as cited in B.C. Ministry of Water, Land and Resource Stewardship 2023) did not observe a significant difference in toxicity of Sb(III) and Sb(V), suggesting nearly equivalent toxicity. Sb(V) is the dominant oxidized state in Meadow Creek (Dovik et al. 2016).

Toxicity to Fish

Antimony toxicity is understudied relative to metals such as arsenic, copper, and mercury; and available information examines waterborne exposures. No studies regarding dietborne exposure were found. Recently, Canada published draft recommended chronic and acute water quality guidelines of 74 ug/L and 250 ug/L, respectively, to protect aquatic life (B.C. Ministry of Water, Land and Resource Stewardship 2023). These recommendations were derived from a species sensitivity distribution of toxicity data for chronic tests on aquatic organisms. The HC_5 estimation was 445 ug/L (upper and lower 95th percentile confidence intervals of 175 and 1,400 ug/L respectively), and divided by a selected adjustment factor of 6 (range from 29 to 233). In 1988, EPA reported a final acute value of 175 µg/L and after application of an adjustment factor of 2, recommended an acute criterion of 88 µg/L to protect aquatic life. An acute-to-chronic ratio from one test was applied to the final acute value (FAV) to derive a chronic criterion recommendation of 30 µg/L (EPA 1988). More recently, Obiakor et al. (2017a) examined acute toxicity of antimony to aquatic organisms and reported a predicted hazardous concentration (the concentration protective of 95 percent of species within the species sensitivity distribution) of 781 µg/L (lower- and upper-95 percent confidence intervals of 580 and 1,203 µg/L, respectively). In examined studies, insects were more sensitive to antimony than crustaceans and fish. Studies underlying one, or more, of the above recommendations are presented below.

MacPhee and Ruelle (1969) identify similarity in the toxicity (LC50 >10,000 ug/L) of Sb(III) and Sb(V) on steelhead, Chinook salmon, and coho salmon; although the authors used older juvenile fish (which are generally less sensitive) in their experiments. Brooke et al. (1986) exposed rainbow trout fry to two concentrations of antimony for 96 hours. While an LC_{50} could not be determined, deaths were observed after 24 hours and 45 percent of the fish died after a 96-hour exposure to 25,700 µg/L of antimony. No deaths were reported for the 11,400 µg/L exposure. The criteria recommendations previously mentioned are largely driven by non-salmonid species.

Doe et al. (1987) reported an LC_{50} of 16,000 µg/L for juvenile rainbow trout exposed to antimony for 30 days. A more recent study found similar results for sockeye salmon. Kennedy (2023, as cited in B.C. Ministry of Water, Land and Resource Stewardship 2023) exposed juvenile sockeye salmon to antimony for 30 days and reported a NOEC of 12,800 µg/L and a LOEC of 25,600 µg/L. Unfortunately, the details of this study were not available for critical review. Kennedy (2020, as cited in B.C. Ministry of Water, Land and Resource Stewardship 2023) also exposed larval rainbow trout to antimony for 30 days and reported a NOEC of 3,200 µg/L for both growth and survival endpoints.

Research suggests that early life stages (embryos and larvae) may be more susceptible to chronic antimony exposures than older juvenile stages. Birge (1978) exposed rainbow trout eggs from fertilization through 4 days post-hatch (28-day test) and reported an LC_{50} of 580 µg/L (upper- and lower-95 percent confidence intervals of 340 µg/L and 920 µg/L, respectively) and an LC_1 of 28.6 µg/L (upper- and lower-95 percent confidence intervals of 4.66 and 72.2 µg/L, respectively). LeBlanc and Dean (1984) reported a NOEC for mortality of fathead minnow (*Pimephales promelas*) embryos exposed to antimony at concentrations up to 7.5 µg/L in water. Similarly, when exposed to concentrations of up to 7.5 ug/L, larval fathead minnow survival and growth did not exhibit a consistent dose-response and the authors concluded the test concentrations were not toxic to fathead minnows. The authors did not test higher concentrations. In other aquatic toxicity tests with fathead minnow eggs, growth was the most sensitive endpoint (Kimball 1978). The 28-d LOEC for effects on growth (length) was 2,310 µg/L. There were no significant effects on growth at 1,130 µg/L. Xia et al (2021) examined developmental toxicity of antimony in zebrafish embryos. The authors exposed embryos (5 hours post fertilization) to high concentrations of antimony and evaluated mortality, development, and growth. Embryos exposed to all tested concentrations (73 to 292 mg/L) of antimony exhibited pericardial edema, cerebral hemorrhaging, uninflated swimming bladders, and/or a curved spine. There was no significant difference in survival 24 hours post fertilization. If these fish were to survive through hatching, such deformities would impact their fitness.

Data is limited on bioaccumulation and food web transfer of antimony; however, the current best available information indicates antimony does not biomagnify and bioaccumulation is limited in higher trophic organisms, such as fish (Obiakor et al. 2017b). Culioli et al (2009) found that trophic transfer of antimony from primary producers to trout was low; and there was not substantial accumulation of antimony in fish. Similarly, Dovick et al. (2016) studied antimony concentrations in biota at the Stibnite Mine site and found biodimunition of antimony with higher trophic levels. No studies relating bioaccumulation and adverse effects were found.

Toxicity to Aquatic Invertebrates

There is a large variation in toxicity of antimony to invertebrates, with LC_{50} values ranging from 687 to 29,600 ug/L (ECOTOX database; Olker et al. 2022). Brooke et al. (1986) investigated caddisfly susceptibility to antimony toxicity and was not able to establish a dose response because only 5 percent of the test organism died in the highest exposure concentration (25.7 mg/L). Estimated LC50 values for a midge (*Chironomus tentans*) were reported as 4.1 and 5.3 mg/L (ECOTOX database). In a life-cycle test with the cladoceran *Daphnia magna*, a 28-d LC_{50} of 4,510 µg/L was calculated for exposure to antimony trichloride in water of hardness 220 mg/L as CaCO3 (Kimball 1978). There were no effects on reproduction at 3,900 µg/L but there was a significant decrease in the number of progeny at 7,050 µg/L. Brooke et al. (1986) also investigated sublethal effects (clubbed tentacles or reduced growth) associated with antimony exposure. The authors reported an EC_{50} of 500 ug/L for adult *Hydra sp*.

Regarding bioaccumulation of antimony, Culioli et al (2009) observed differences among invertebrate functional feeding groups, with shredders accumulating the most antimony and predators accumulating the least. This indicates the dietary update route is a driver of antimony accumulation rather than water column concentrations.

Summary

Species response to antimony exposures vary drastically and the science remains scarce relative to other metals. For the purposes of this assessment, we have elected to utilize the EPA recommendations of 88 and 30 ug/L for characterizing the risk of adverse effects to ESA-listed species and their prey resulting from acute and chronic exposures, respectively. Considering Sb(V) is more prevalent in the aquatic environment and the recent work evaluating Sb(III) and Sb(V) toxicities, comparing concentrations of total dissolved Sb to toxicity thresholds developed from Sb(III) toxicity tests is deemed appropriate for our current assessment.

ARSENIC

Arsenic is ubiquitous; it is present in air, water, and soil. Usually, arsenic concentrations in surface waters are low, ranging from 0.1 to 2.0 μg/L. In a probabilistic study of arsenic in 55 Idaho rivers, the median total arsenic concentration was 2.0 μg/L, ranging from 0.06 to 17 μg/L, from unfiltered samples (Essig 2010).

The toxicity of arsenic is influenced by a number of factors including water temperature, pH, redox potential, organic matter, phosphate content, suspended solids, presence of other toxicants, and chemical speciation (Dabrowski 1976; Eisler 1988a; McGeachy and Dixon 1989; Sorensen 1991; Rankin and Dixon 1994; McIntyre and Linton 2011). Toxicity of arsenic does not appear to vary with hardness (Borgmann et al. 2005). Trivalent arsenic tends to be more toxic than other forms, and inorganic forms of arsenic are typically more toxic than organic forms (EPA 1985a; Eisler 1988a; Sorensen 1991).

Toxicity to Fish

Arsenic can enter fish through their diet or through absorption through the skin and gills. When ingested, arsenic can be converted to other forms such as the less toxic arsenocholine or arsenobetaine (Malik et al. 2023). Arsenic is a suspected carcinogen in fish and is known to bioaccumulate in fish tissue. It is associated with necrotic and fibrous tissues and cell damage, especially in the liver. At high enough concentrations, arsenic can result in immediate death through increased mucus production and suffocation. Other effects include anemia and gallbladder inflammation. Juvenile salmonids have been found to be more sensitive to arsenic toxicity than alevins (Buhl and Hamilton 1990; 1991). Arsenic does not readily bioconcentrate in aquatic species. Robinson et al. (1995, in EPA 1999) found no evidence of arsenic uptake or accumulation from water in both rainbow and brown trout (*Salmo trutta*). As described below, research suggests that adverse effects in fish from arsenic are most likely from dietary rather than waterborne exposures.

Arsenic is not very toxic in classic toxicity tests with exposures through water (McIntyre and Linton 2011). Acute toxicity appears to occur at concentrations that are significantly higher than the CMC of 340 μg/L (Buhl and Hamilton 1990). Erickson et al. (2011) observed very little difference in survival of juvenile rainbow trout exposed to 8 mg/L compared to controls. When testing higher concentrations of arsenic (i.e., 16 and 32 mg/L), most mortalities occurred within

2 days (32 mg/L exposure) and 6 days (16 mg/L exposure). A 96-hour LC_{50} of 10.8 mg/L was reported for rainbow trout (Hale 1977).

Birge et al. (1978; 1981) suggest that chronic arsenic toxicity from waterborne exposures occurs to developing embryos of listed salmonids at concentrations below Idaho's CCC of 150 µg/L. Rainbow trout embryos were exposed to arsenic for 28 days (4-days post-hatching) at 12°C (53.6°F) to 13°C (55.4°F) and a hardness of 93 mg/L to 105 mg/L $CaCO_3$ in static tests. Concentrations of 42 to 134 µg/L were estimated to be associated with the onset of mortality, as LC_1 and LC_{10} respectively (Birge *et al*. 1980). Studies reviewed in Eisler (1988a) and EPA (1985a) indicate that chronic effects do not occur in other life stages until concentrations are at least about an order of magnitude higher than the levels determined by Birge et al. (1978; 1981) to be detrimental to developing embryos. Nichols et al. (1984) described significant chronic effects to coho salmon (*O. kisutch*) from a 6-month exposure to 33 µg/L of arsenic trioxide, where the normal increase in plasma thyroxine was delayed, causing a transitory reduction in gill sodium-potassium ATPase activity. Although treated fish showed no direct effects in growth or survival, they were less successful in seaward migration than control fish. Rankin and Dixon (1994) observed significant reductions in growth (believed to be caused by reduced appetite and direct metabolic impacts) at chronic exposures to waterborne arsenite concentrations of 9.64 mg/L. In addition, trout exposed to this concentration also suffered 10 percent mortality and all fish exposed to this concentration showed inflammation of the gallbladder wall.

Studies have shown that inorganic arsenic in the diet of rainbow trout are associated with reduced growth, organ damage, and other physiological effects at concentrations in food items of about 20 milligrams/kilogram (mg/kg) dry weight (dw) and above (Cockell et al. 1991; Hansen et al. 2004; Erickson et al. 2010, Erickson et al. 2011). Hansen et al. (2004) collected metals-contaminated sediments (170 mg/kg arsenic) from the Clark Fork River, reared aquatic earthworms (*Lumbriculus*) in them, and fed the *Lumbriculus* (average arsenic concentrations of 129 micrograms per gram [µg/g] dw) to rainbow trout. Fish fed the *Lumbriculus* diet had reduced growth and physiological effects, and the presence of effects was strongly correlated with arsenic but not to other elevated metals in the sediments. Erickson et al. (2010) experimentally mixed arsenic into clean sediments, reared *Lumbriculus* in them, and fed the *Lumbriculus* to rainbow trout. The rainbow trout fed the worms contaminated with arsenic (26 to 77 µg/g dw) had reduced growth and disrupted digestion. These studies involved the trivalent form of arsenic.

Kiser et al. (2010) collected bull trout (*Salvelinus confluentus*) from Gold Creek (a mine-influenced stream in northern Idaho) and observed inflammation, necrosis, and cellular damage of the liver. The authors found fish tissue concentrations were correlated with elevated concentrations of arsenic in the sediments and macroinvertebrates. Damage to livers and gall bladders occurred in lake whitefish (*Coregonus clupeaformis*) fed arsenic contaminated diets as low as 1 mg/kg food dw (Pedlar et al. 2002). Cutthroat trout exhibited reduced growth and liver damage when fed contaminated invertebrates with arsenic concentrations between 14–51 mg/kg dw (Farag et al. 1999). While many studies focused mostly on the effects of arsenic on organs and growth, at least one study has shown that arsenic in zebrafish (*Danio rerio*) diets can reduce reproduction. The single dietary exposure tested for reproductive effects was higher (~135 mg/kg dw) than other dietary toxicity studies with salmonids (Boyle et al. 2008).

Recent attention has been given to assessing whether adverse effects are influenced by the various forms of arsenic that can occur in dietborne exposures, including inorganic arsenic (which has been the focus of most literature to date), monomethylarsonate, dimethylarsinate, and asrsenobetaine (Erickson et al. 2019). The authors documented growth rate reductions on the order of 41% and 18% when fish were fed inorganic arsenic feed containing 134 ug/g and 72 ug/g total arsenic. Of the 70 percent of measured species in the inorganic arsenic feed, 88 percent was inorganic As(III) and 12 percent was inorganic As(V). The authors did not observe growth rate reductions in juvenile rainbow trout fed the dimethylarsinate diet (total arsenic concentrations of 556 ug/g), indicating dimethylarsinate is far less toxic than inorganic As(III). Some reductions in growth rates occurred as a result of monomethylarsonate, though not to the extent as inorganic arsenic (III).

Bioaccumulation of arsenic in prey organisms to concentrations higher than 30 mg/kg dw has been documented in streams where concentrations of arsenic in the water were greater than background (<~ 5 µg/L) but significantly less than the chronic water quality criterion of 150 µg/L dissolved arsenic (NMFS 2014). These studies demonstrate that bioaccumulation of arsenic in invertebrate prey organisms harmful to salmonids can occur in streams with dissolved arsenic concentrations on the order of 10 µg/L or less. However, there has also been documentation of much lower levels of arsenic in invertebrate tissues (0.5 to 2 mg/kg dw) in waters with dissolved arsenic concentrations between 0.5 and 7 µg/L. Not surprisingly, a major difference between these streams was the concentration of arsenic in the sediments. Invertebrates from streams with higher arsenic concentrations in sediments had greater tissue concentrations. These studies did not examine arsenic speciation in invertebrate tissues.

Recently, Erikson et al. (2019) concluded that an understanding of the speciation of arsenic in the water and diet is critical for assessing risk to fish, and it is prudent to pay particular attention to inorganic arsenic. As part of their study, the authors examined the variability of arsenic species in macroinvertebrates collected from Panther Creek, Idaho. The macroinvertebrate species examined were a detritivorous stonefly (*Pteronarcys californica*), a filter-feeding caddisfly (*Arctopsyche grandis*) and a predatory stonefly (*Hesperoperla pacifica*). They found that the percentages of total extractable arsenic, inorganic arsenic, and organoarsenical species varied considerably among the species. They also found arsenic concentrations accumulated the most in the detritivore and the least in the predator.

Toxicity to Aquatic Invertebrates

The limited data available suggests that the risk of toxicity to salmonid food organisms is lower than the risk of toxicity to salmonids from eating arsenic exposed organisms. However, we did not locate any studies that tested invertebrates using environmentally relevant exposures through arsenic enriched periphyton or sediments, and conducted through full life exposures or obviously sensitive life stages. Although likely less relevant than exposures through diet, there are some data available regarding arsenic toxicity to aquatic invertebrates from water only exposures.

Irving et al. (2008) exposed mayfly (Ephemeroptera) nymphs to tri- and pentavalent arsenic in water-only exposures for 12 days. For trivalent arsenic, the threshold of growth effects was about 100 µg/L. However, arsenic levels accumulated by the mayfly nymphs in their study (1.2 to 4.6

μg/g dw) were far lower than those reported from stream locations with lower water concentrations of arsenic. In these stream locations, arsenic was elevated in the diet or sediments, suggesting that the water-only exposures may have underrepresented likely environmental exposures. Results reported in Eisler (1988a) suggest that gammarid amphipods may experience acute toxicity at concentrations of trivalent arsenic that are below the chronic criterion of 150 μg/L. Canivet et al. (2001) similarly found increased mortality of gammarid amphipods and heptageniid mayflies at about 100 μg/L.

Summary

Adverse effects to anadromous fish and aquatic invertebrates could occur from chronic exposure to arsenic when water column concentrations are lower than Idaho's CCC of 150 μg /L. The dietary exposure route is of most concern because bioaccumulation of arsenic in the food chain to levels that could adversely affect fish has been documented in streams with dissolved arsenic concentrations between 5 and 10 μg/L (NMFS 2014). These concentrations are far lower than concentrations found to cause adverse effects from waterborne exposure only (e.g., 100 μg/L for mayflies and about 40 μg/L for rainbow trout embryos).

COPPER

Copper is a naturally occurring trace element. Ambient monitoring studies by the U.S. Geological Survey at 811 sites across the United States have revealed background dissolved copper concentrations ranging from 1 to 51 μg/L, with a median of 1.2 μg/L (Hecht et al. 2007). In the Salmon River basin, dissolved copper concentrations are generally within the <0.5 to 4 μg/L range (NMFS 2014). At low concentrations, copper is an essential micronutrient to plants and animals; however, it becomes toxic at slightly higher concentrations. Copper is relatively insoluble in water; however, it becomes more soluble with decreasing pH (Nelson et al. 1991). It can dissolve or bind to organic and inorganic materials in suspension or within the sediments.

Copper toxicity is influenced by chemical speciation, hardness, pH, alkalinity, total and dissolved organic carbon (DOC) in the water, previous exposure and acclimation, fish species and life stage, water temperature, and presence of other metals and organic compounds. Idaho's current copper criteria are based on the biotic ligand model (BLM). This is a computer-based model that predicts copper toxicity based on its expected bioavailability to organisms, which is influenced by various water chemistry parameters (e.g., temperature, pH, dissolved organic carbon, etc.). In its evaluation of the BLM, NMFS identified that the BLM performed relatively well in predicting toxicity; however, it may underpredict acute toxicity in very soft waters. In addition, the BLM performed reasonably well in adequately protecting against sublethal effects such as reduced growth, neurological damage, or behavioral impairments.

Toxicity to Fish

Hecht et al. (2007), NMFS (2014), and EPA (2007) conducted literature reviews regarding copper and its effects on aquatic life. Table B-1 contains information excerpted from those publications, summarizing both acute and chronic effect concentrations reported in the literature. Mortality to fish occurs when insoluble copper-protein compounds form on gill surfaces, causing the sloughing of gill epithelia and eventual suffocation (Nelson et al. 1991). Acute mortality of various life stages of salmon and steelhead exposed to dissolved copper occur at low concentrations in soft waters (hardness between 9 and 42 mg/L), with 96-hour LC_{50} values ranging from 2.4 to 57 µg/L (Hecht et al. 2007; NMFS 2014).

In addition to direct mortality, adverse effects of copper to salmonids include reduced growth and reproductive impairment. Furthermore, exposure to low levels of dissolved copper can cause other sublethal physiological and behavioral effects such as interference with immune response and reduced disease resistance, reduced swimming stamina, damage to olfactory cellular tissue, and impaired olfactory function. These sublethal effects can lead to death through impairment of the ability of salmonids to avoid predators, find prey, and migrate from and to their natal streams (McIntyre et al. 2012, Puglis et al. 2019, Sommers et al. 2016, Thomas et al. 2016, Calfee et al. 2014, Lorz and McPherson 1976, 1977, Saucier et al. 1991, Saunders and Sprague 1967).

A common chronic effect observed with copper exposure has been reduced growth in laboratory toxicity tests with salmonids. In tests using soft water, copper concentrations of 3.6 ug/L were associated with a 4 to 7.5 percent reduction in the lengths of Chinook salmon and rainbow trout, depending on the statistical model used to analyze the toxicity data. Similarly, exposures to 2.1 µg/L corresponded to length reductions ranging from zero to 4.5 percent. To evaluate the relevance of reduced growth in a laboratory setting to natural-origin populations, Mebane and Arthaud (2010) used population modeling. The authors found that a size reduction of four percent as length was associated with survival reductions ranging from 12 to 38 percent for different migrant groups during their migration downstream to the Lower Granite Dam.

Reproductive impairment (measured as reduced fecundity) was a sensitive endpoint in some chronic tests with copper and fish (Mount 1968; Mount and Stephan 1969; McKim and Benoit 1971; Suter et al. 1987). However, with anadromous steelhead and salmon, presumably long-term exposure of adults to copper in freshwater would be unlikely, since adults are either only passing through migratory areas or are exposed on their spawning grounds for a few weeks or less. Thus, the risk of chronic effects from copper is higher for juvenile fish.

Reduced immune response and disease resistance is an effect of copper that appears to be understudied, considering its potential implications. Stevens (1977) reported that pre-exposure to sublethal levels of copper interfered with the immune response and reduced the disease resistance in yearling coho salmon.

Table F-67. Selected examples of adverse effects with copper to salmonids or their prey (Hecht 2007; NMFS 2014; EPA 2007; Mebane 2023)[a].

Species (life stage)	Effect	Effect Conc. (µg/L)[b]	Effect Statistic	Exposure Duration	Source
Chinook salmon (fry)	Death	19	LC_{50}	96 hr	Chapman 1978a
Coho salmon (fry)	Death	28–38	LC_{50}	96 hr	Lorz and McPherson 1976
Coho salmon (adult)	Death	46	LC_{50}	96 hr	Chapman and Stevens 1978
Steelhead/rainbow trout (fry)	Death	9–17	LC_{50}	96 hr	Chapman 1978a, Marr et al. 1999
Steelhead/rainbow trout (fry)	Death at pH 7	2.8	LC_{50}	96 hr	Cusimano et al. 1986
Steelhead (adult)	Death	57	LC_{50}	96 hr	Chapman and Stevens 1978
Coho salmon (juvenile)	Death	21–22	NOEC	60 d	Mudge et al. 1993
Steelhead (juvenile)	Death	24–28	NOEC	60 d	Mudge et al. 1993
Steelhead (egg-to-fry)	Death	11.9	EC_{10}	120 d	Chapman 1982
Rainbow trout (1 days post-hatch [dph])	Death	47.8	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (18 dph)	Death	43.4	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (32 dph)	Death	42.4	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (46 dph)	Death	37.8	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (60 dph)	Death	32.2	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (74 dph)	Death	44.3	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Rainbow trout (95 dph)	Death	15.2	LC_{50}	96 hr	Ingersoll and Mebane 2014[d]
Coho salmon (juvenile)	Reduced olfaction and compromised alarm response	0.18–2.1	EC_{10} to EC_{50}	3 hr	Sandahl et al. 2007
Chinook salmon (juvenile)	Avoidance in laboratory exposures	0.75	LOEC	20 min	Hansen et al. 1999
Chinook salmon (juvenile)	Avoidance (soft water)	0.91	EC_{20}	20 min	Hansen et al. 1999
Rainbow trout (juvenile)	Avoidance in laboratory exposures	1.6	LOEC	20 min	Hansen et al. 1999
Rainbow trout (juvenile)1	Avoidance (soft water)	0.84	EC_{20}	30 min	Hansen et al. 1999; Meyer and Adams 2010
Rainbow trout (juvenile)1	Avoidance (soft water)	2.4	EC_{20}	96 hr	Morris et al. 2019
Rainbow trout (juvenile)1	Avoidance (soft water)	1.6	EC_{20}		Giattina et al. 1982
Chinook salmon (juvenile)	Loss of avoidance ability	2.2	LOEC	21 d	Hansen et al. 1999
Atlantic salmon (juvenile)	Avoidance in laboratory exposures	2.4	LOEC	20 min	Sprague et al. 1965
Atlantic salmon (adult)	Spawning migrations in the wild interrupted	20	LOEC	Indefinite	Sprague et al. 1965
Chinook salmon (adult)	Spawning migrations in the wild apparently interrupted	10–25	LOEC	Indefinite	Mebane 2000

Species (life stage)	Effect	Effect Conc. (µg/L)[b]	Effect Statistic	Exposure Duration	Source
Coho salmon (juveniles)	Delays and reduced downstream migrations	5	LOEC	6 d	Lorz and McPherson 1976; 1977
Rainbow trout	Loss of homing ability	22	LOEC	40 wk	Saucier et al. 1991
Chinook salmon	Reduced growth (as weight)	1.9	EC10	120 d	Chapman 1982
Rainbow trout	Reduced growth (as weight)	2.8	EC10	120 d	Marr et al. 1996
Coho salmon	Reduced growth (as weight)	21–22	NOEC	60 d	Mudge et al. 1993
Steelhead (*O. mykiss*)	Reduced growth (as weight)	45 to >51	NOEC	60 d	Mudge et al. 1993
Caddisfly (*Clistoronia magnificas*)	Emergence (adult 1st generation)	7.7	EC_{20}	NR	Nebeker et al. 1984
Cladoceran (*D. pulex*)	Survival	2.8 9.16	EC_{20} EC_{20}	42 d	Winner 1985
Cladoceran (*D. pulex*)	Reproduction	12.6 19.9 6.1	EC_{20} EC_{20} EC_{20}	21 d	Chapman et al. unpublished manuscript in EPA 2007
Cladoceran (*C. dubia*)	Reproduction	NR	EC_{20}	7 d	Carlson et al. 1986
Cladoceran (*C. dubia*)	Reproduction	94.1	EC_{20}	7 d	Belanger et al. 1989
NA[f]	Ecosystem function: Reduced photosynthesis	2.5	LOEC	≈ 1 yr	Leland and Carter 1985
NA[f]	Ecosystem structure: loss of invertebrate taxa richness in a mountain stream	5	LOEC	≈ 1 yr	Leland et al. 1989

[a]Abbreviations: LOEC = Lowest observed adverse effect concentration (and most LOEC values given are not thresholds, but were simply the lowest concentration tested); NOEC = No observed adverse effect concentration; LC_{50} = the concentration that kills 50 percent of the test population; EC_p = effective concentration adversely affecting (p) percent of the test population or percent of measured response, e.g., 10 percent for an EC_{10}, etc.; and Indefinite = field exposures without defined starting and ending times. NA = not applicable; NR = not reported; d = days; hr = hours; min = minutes; yr = years; wk = weeks.
[b]Effects and exposure durations stem from laboratory and field experiments; therefore, in some experiments multiple routes of exposure may be present (i.e., aqueous and dietary) and water chemistry conditions will likely differ (see reference for details).
[c]Acute sensitivity of salmonids to copper varies by life stage, and the swim-up fry stage is probably more sensitive than older juvenile life stages such as parr and smolts or adults.
[d]Toxicity data from the test normalized for EPA's BLM standard water.
[e]The EC_{20} values were calculated by EPA (2007) using either a probability distribution analysis or a logistic regression analysis.
[f]This study examined ecosystems consisting of a number of species or unidentified species.

Reduction of sensory capabilities is another sublethal impact that can occur when fish are exposed to copper. Dissolved copper is a neurotoxicant that directly damages the sensory capabilities of salmonids at low concentrations (Hecht et al. 2007). These effects can manifest over a period of minutes to hours and can persist for weeks. To estimate toxicological effect thresholds for dissolved copper in surface waters, Hecht et al. (2007) calculated benchmark concentrations (BMCs) for juvenile salmonid olfactory function based on recent, available data. The BMCs ranged from increases of 0.18 to 2.1 µg/L above background copper concentrations (defined as being ≤ 3 µg/L) corresponding to reductions in predator avoidance behavior of approximately 8 to 57 percent. These BMCs for juvenile salmonid sensory and behavioral responses fall within the range of copper concentrations (0.75 to 2.5 µg/L) correlated with other low sublethal endpoints (Hecht et al. 2007).

More recently, McIntyre et al. (2012) conducted predation experiments that showed diminished predator avoidance behaviors of juvenile salmon in the presence of elevated copper. A short-term (30-minute) copper exposure made prey easier for predators to detect and capture. Predatory cutthroat trout captured and ate juvenile coho salmon that had been exposed to 4.5 µg/L copper in only about one-third of the time needed to capture and eat coho that had not been exposed to copper. The primary impact of copper on predator-prey dynamics in the McIntyre study (2012) was faster prey detection, manifested as faster time to attack and time to capture. This effect was similar when predators and prey were co-exposed to copper. Morris et al. (2019) examined rainbow trout olfactory inhabitation in low hardness waters and reported a 20 percent reduction in alarm cue response after being exposed to copper concentrations of 2.7 and 2.5 µg/L for 24 or 96 hours, respectively. Further, the fish did not recover (regain their ability to respond to an alarm cue) within 24 hours of exposure in clean water.

Salmonids are known to avoid elevated copper concentrations. Adult Atlantic salmon migrating upstream avoided areas contaminated with a mixture of zinc and copper. The threshold for copper avoidance was about 17 to 21 µg/L (Sprague et al. 1965; Saunders and Sprague 1967). Hansen et al. (1999) found that Chinook salmon avoided copper concentrations of about 0.8 µg /L, and 2.8 to 22.5 µg/L; however, avoidance was not observed in water containing 1.6 µg/L. Rainbow trout were found to avoid concentrations in the range of 1.6 to 88 µg/L. Fish may be more sensitive to (i.e., more readily avoid) lower concentrations of copper if the gradient from clean to contaminated water is sharp rather than gradual (Black and Birge 1980 *in* Atchison et al. 1987).

Many of the studies to date have examined waterborne copper exposures to fish, and less attention has been paid to toxic effects that may manifest through dietary exposures. A few authors (DeForest & Meyer 2015, Erickson et al. 2010, Mebane et al. 2015 and Saiki et al. 1995) have reported reduce growth in fish from dietary exposures to copper; however, fairly high levels of copper were necessary to elicit observable effects (Mebane 2023). Of the studies reviewed, DeForest and Meyer (2015) concluded fish were relatively insensitive to copper exposures through their diet, with the lowest LOEC being 760 ug/g dry weight.

Toxicity to Aquatic Invertebrates

Copper is highly toxic to many freshwater invertebrates (NMFS 2014). Benthic macroinvertebrate communities that form the food base of salmonids in freshwater streams appear particularly sensitive to copper in both the water column and stream sediments (NMFS 2014). NMFS (2014) concluded that while acute toxicity values (LC_{50}s) noted by EPA (1985b) were relatively high, compilations of short-term LC_{50}s derived from laboratory tests tend to do a poor job of reflecting the sensitivities of invertebrates to metals in field conditions.

Clements et al. (1988) observed a 24 to 36 percent reduction in the number of taxa and a 35 to 52 percent reduction in number of individuals when a stream was contaminated with low doses of copper (15 to 32 µg/L) for 96 hours compared to controls. Beltman et al. (1999) found that copper concentrations in Panther Creek as low as about 10 µg/L resulted in significant changes in community structure, with reductions in stonefly, mayfly, caddisfly and beetle taxa compared to uncontaminated sites. Mebane et al. (2015) found that recovery of *Rhithrogena* sp. in Big Dreek Creek was "apparently prevented" by about ≤ 5 ug/L copper, which is far less than the LC50 of 137 ug/L copper for *Rhithrogena hageni* in a 96-hour laboratory toxicity test (Brinkman and Johnston 2008).

Extensive field surveys have been conducted on Panther Creek, near the Blackbird Mine in central Idaho (Beltman et al. 1999, NMFS 2014, Mebane et al. 2015). Prior to the mid-1990s, measured copper concentrations in Panther Creek downstream of Blackbird Creek were always elevated (ranging from 12 to 140 ug/L), and have since declined by more than a factor of 10 as a result of restoration efforts. In 2013, copper concentrations ranged from <0.1 to 2.9 ug/L (Mebane et al. 2015) and were below the BLM-based copper criterion. Farther downstream, below Big Deer Creek, copper concentrations in Panther Creek ranged from 12-97 ug/L in the mid-1990s. By 2004, copper concentrations in Panther Creek at this location were generally below the BLM-based chronic criterion due to restoration actions. Mayflies and stoneflies were effectively eliminated from Panther Creek as a result of the water quality impacts; however, within a few years of restoration actions, stoneflies reappeared and by 2002 stonefly abundance was similar to upstream reference sites. Mayflies took longer to reestablish, becoming more abundant after in 2008.

Sediments with elevated copper that were collected from Chinook salmon and steelhead habitat in Panther Creek, Idaho, and tested in a laboratory setting with clean overlying water caused high mortality to *Hyalella azteca*, a freshwater benthic crustacean (Mebane 2002). The resident benthic invertebrates collected from the same locations as the copper-contaminated sediments had reduced diversity compared to reference collections. Unlike the sediment toxicity tests, adverse effects to the instream invertebrates could not be attributed solely to either copper in the sediments or in water, because copper was elevated in both (Mebane 2002). Elevated copper in sediments is also associated with elevated copper in benthic invertebrate tissues in field studies conducted in metals-contaminated streams (e.g., Ingersoll et al. 1994; Woodward et al. 1994; Beltman et al. 1999; Besser et al. 2001). Uptake and toxicity of copper by invertebrates is strongly influenced by the amount of acid-volatile sulfide in the sediments or by the amount of organic carbon in the sediments (Besser et al. 1995; Mebane 2002).

Elevated copper levels can reduce the availability of preferred invertebrate prey organisms for juvenile salmonids. These reductions have been observed even with relatively low copper concentrations. Reductions or changes in prey availability could translate to adverse effects on juvenile salmonid populations. In the Panther Creek field studies that NMFS (2014) reviewed in some detail, no obvious extinctions of macroinvertebrate effects to salmonids were observed. This suggests either or both that juvenile salmonids are able to switch prey when preferred prey are diminished, or that the food web effects were too subtle to tease out of the natural variability inherent in field monitoring studies using available information.

Summary

As described above, copper is highly toxic to aquatic life. Toxicity to fish includes, but is not limited to, direct mortality, reduced growth, and reduced olfaction function. The estimated 96-hour LC_{50} for Chinook salmon is 7.4 µg/L in test water at a pH of 7.7 and a hardness of 35 mg/L. Sandahl et al. (2007) reported reduced olfaction function after short-term (i.e., 3 hours) exposures to copper concentrations as low as increases in copper concentrations by as little as 0.18 µg/L over background (where background was identified as 3 µg/L). Reported EC_{10} values for reduced growth in Chinook salmon (Chapman 1982) and rainbow trout (Marr et al. 1996) chronically exposed (i.e., 120 days) to elevated levels of copper were 1.9 µg /L and 2.8 µg /L, respectively. Significant changes in aquatic macroinvertebrate community structure and abundance was observed when copper concentrations were as low as 10 µg /L.

CYANIDE

Cyanide occurs naturally in the environment via production by a variety of plant species. The most likely sources of cyanide in waters are probably forest fires, gold mining operations that use cyanide leaching, and perhaps road salting. Barber et al. (2003) examined releases of cyanides from biomass burning and their effect on surface runoff water. In laboratory test burns, available cyanide concentrations in leachate from residual ash were much higher than in leachate from partially burned and unburned fuel and were similar to or higher than a 96-hour median LC_{50} value of 45 µg/L for rainbow trout. Free cyanide concentrations in stormwater runoff collected after a wildfire in North Carolina averaged 49 µg/L, which is again similar to the rainbow trout LC_{50} and an order of magnitude higher than in samples from an adjacent unburned area (Barber et al. 2003). Eisler (1991) reported average background levels of cyanide in freshwater systems to be 0.9 µg/L.

Cyanide is toxic to most living organisms and primarily occurs in aquatic environments as free cyanide (i.e., hydrocyanide and cyanide ion), simple cyanide salts, metal-cyanide complexes, and in some organic compounds. The most bioavailable and toxic forms are the free cyanide (Gensemer et al. 2007). The Idaho criteria for cyanide are expressed as weak acid dissociable (WAD) cyanide, which includes free cyanide as well as metal-cyanide complexes that readily dissociate under weakly acidic conditions (pH 5–6). Analyzing samples for WAD cyanide produces a higher value than analyzing for free cyanide (NMFS 2014).

Toxicity to Fish

Free cyanide is extremely toxic and fast acting. The mechanism of cyanide toxicity involves inhibiting cytochrome oxidase, the terminal oxidative enzyme of the mitochondrial electron transport chain, thus blocking aerobic adenosine triphosphate synthesis. The result of this mechanism of toxicity is that cyanide is a rapid and potent asphyxiant (Eisler 1991). Its toxicity is strongly influenced by temperature in that toxicity increases with decreasing temperature. Kovacs and Leduc (1982a), reported 96-hour rainbow trout LC_{50} values of 27, 40, and 65 µg/L for exposures in waters with temperatures of 42.8, 53.6, and 64.4°F (6, 12, and 18°C), respectively. The authors Kovacs and Leduc (1982b) also examined sublethal effects associated with chronic exposure (i.e., 20-day exposure) to elevated cyanide concentrations at varying temperatures. The authors observed chronic toxicity effects on growth in terms of average fat gain and dry weight when juvenile rainbow trout were exposed to 5 µg/L around 6.1°C. At about 12.8°C, toxicity effects were evident at concentrations ≥10 µg/L. Significant growth reductions were observed when juvenile rainbow trout were exposed to 15 µg/L at all temperatures tested. No statistically significant difference between controls and test specimens were recorded at exposures to concentrations less than 4.8 µg/L in water temperatures of 6°C. The swimming abilities of juvenile rainbow trout were also found to be reduced at all cyanide concentrations tested in the range of 5 to 45 µg/L, with the effect increasing at lower temperatures.

Bioconcentration of cyanide is considered to be negligible in fish because the compound is easily metabolized. As reported by EPA (1985c) the existing literature does not provide evidence for cyanide biomagnification. This is likely due to the fact that vertebrate species, such as fish, may readily metabolize cyanide, thus removing the cyanide from the food chain at that level. Accumulation of metallocyanide complexes in sediment is not likely because dissociation occurs easily at pH values lower than 8.

Toxicity to Aquatic Macroinvertebrates

Available toxicity data for the types of aquatic insects and crustaceans that juvenile salmonids feed on indicate that they are similarly or less sensitive to cyanide compared with listed salmon and steelhead (EPA 1985c; Eisler 1991). As an example, Call and Brook (1982; as cited in ECOTOX) reported a 96-hour LC_{50} of 436 µg/L for the American salmonfly (*Pteronarcys dorsata*).

Summary

Short-term LC_{50} values for rainbow trout were reported as low as 27 µg/L for exposures in water temperatures of around 4.4°C. Sublethal effects (e.g., reduced growth and reduced swimming abilities) were documented when juvenile rainbow trout were exposed to cyanide concentrations as low as 5 µg/L for 20 days. Based on available information, aquatic invertebrates do not appear to be adversely affected by concentrations that are protective of fish.

MERCURY

Mercury is a naturally occurring heavy metal that is found in trace amounts in air, water, and soil. Mercury can enter the aquatic environment from aerial deposition, surface runoff and spills, and via contaminated groundwater. In surface water, mercury can be present in both inorganic and organic forms, with organic mercury (more commonly referred to as methylmercury) being the more highly toxic form. Mercury speciation is influenced by physical, chemical, and biological reactions. Elemental and inorganic mercury complexes are not bioavailable; however reactive forms of inorganic mercury and methylmercury are bioavailable.

Bioavailability

Mercury transformation in the environment influences how it moves through a watershed, and the biogeochemical cycling of mercury is complex and not fully understood (Bravo and Cosio 2020; Rodrigues et al. 2019). Inorganic mercury is often the dominant form in aquatic environments. In the water column, inorganic mercury can be reduced to elemental mercury and reemitted back into the atmosphere, methylated to the organic form of mercury, or bind to organic matter as well as inorganic particles and deposit to stream sediments. Mercury has a high affinity to sorb to sediments as well as suspended dissolved and particulate matter. Thus, hydraulic transport of mercury in streams is controlled by dissolved organic carbon and suspended particulate matter. Additionally, stream sediments may serve as a source and a sink for mercury, facilitating sequestration and reduction through burial in the aquatic ecosystem (Ullrich et al. 2001, Branfireun et al. 2020). The risk of bioaccumulation in an aquatic ecosystem depends on whether mercury transformation processes favor forms of mercury that are bioavailable for methylation (Bravo 2020).

Rates of bioaccumulation of methylmercury in the food web are thought to be affected by water temperature, pH, water hardness, organism age, organic carbon availability, dissolved oxygen, number of trophic levels, concentration of sulfates, and in the presence of zinc, cadmium, or selenium in solution (Porcella et al. 1995). Methylmercury levels in stream biota are determined by the supply of methylmercury to the base of the foodweb (Wentz 2014), which is determined by the amount of bioavailable inorganic mercury. While it was once believed that only sulfate reducing bacteria could methylate bioavailable inorganic mercury in anoxic conditions, it has been recently discovered that a variety of microorganisms carrying specific genes can methylate inorganic mercury. Furthermore, methylation of mercury can occur in oxygen poor aquatic environments such as lakes, ponds, wetlands, sediments, and flooded soils (Eckley et al. 2005, Jonsson et al. 2012; Windham-Myers et al. 2014, Bravo et al. 2020).

Methylation of bioavailable, inorganic mercury is primarily accomplished by bacteria (e.g., sulfate reducing bacteria, iron reducing bacteria, and methanogens), and methylation is greatest in environments with low pH, low dissolved oxygen, and high organic matter (Peterson et al. 2023; Eckley 2021a). Abundant sources of organic material as well as terminal electron accepting compounds such as sulfate or ferric iron can increase the activity of methylating bacteria. Contributing to the complexity of mercury cycling is the fact that methylmercury can break down in the environment through decomposition (demethylation) via abiotic processes involving chemical and photo-chemical reactions as well as microbial processes (Eckley et al.

2021b; Black et al. 2012; Kim and Zoh 2012). Demethylation yields methane and inorganic mercury species that will continue to cycle in the environment (EPA 2024).

Total mercury and methylmercury are not always strongly correlated and there can be substantial variation. For example, in Idaho waters, the percentage of methymercury ranged from 0.2 to 58 (Essig 2010; Poulin et al. 2020). In the project area, Holloway et al. (2017) reported methylmercury concentrations were up to two percent of mercury concentrations in samples from Sugar Creek and the EFSFSR. Eckley et al. (2021a) reported decreasing total mercury concentrations in Sugar Creek with increasing distance from the Cinnabar mine site, whereas methylmercury concentrations increased. The authors attributed the downstream increase in methylmercury to the more favorable lower gradient, forested ecosystem.
Both organic and inorganic mercury bioaccumulate; however, methylmercury accumulates at greater rates because it is more efficiently absorbed and preferentially retained (Scheuhammer 1987; Wiener 1995). Methylmercury is biomagnified between trophic levels in aquatic systems and in general proportion to its supply in water (Wattras and Bloom 1992). Accumulated mercury in fish tissue is almost entirely methylmercury (Bloom 1992; Hammerschmidt et al. 1999; Harris et al. 2003). As such, the toxicity of methylmercury is particularly important with respect to effects to higher trophic level fish (Sorensen 1991; Nichols et al. 1999).

Baseline concentrations of total inorganic mercury in Idaho waters ranged from <0.2 to 6.8 nanograms/liter (ng/L) (NMFS 2014). In April 2024, EPA proposed to promulgate revised mercury aquatic life criteria for Idaho. The proposed criteria include total mercury concentrations in fish tissue and the water column. More specifically, EPA has recommended a water column mercury criterion of 2.1 ng/L, expressed as a 30-day average concentration that is not to be exceeded more than once every three years.

Toxicity to Fish

Mercury is a potent neurotoxin that causes neurological damage, which in turn leads to behavioral effects (e.g., loss of coordination and reduced swimming activity) that can lead to reduced growth and reproduction (Berntssen et ak, 2003, Wiener et al. 2003, Weis 2009; Sandheinrich and Wiener 2010; Kidd and Batchelar 2011). Methylmercury readily penetrates the blood brain barrier, produces brain lesions, spinal cord degeneration, and central nervous system dysfunctions.

Most available data suggest that salmonid species are not susceptible to acute toxicity from direct exposure to mercury in water at concentrations approaching 2.1 µg/L (Kidd and Batchelor 2011). The EPA (1985d) reported LC_{50} values for salmonids exposed to inorganic mercury that ranged between 155 µg/L and 420 µg/L. For organic mercury, reported LC_{50}s ranged from 5 µg/L to 84 µg/L, depending on the chemical form, with a phenylmercuric compound being the most toxic (EPA 1985c). Buhl and Hamilton (1991) exposed coho salmon and rainbow trout alevins and parr to mercuric chloride, and determined average LC_{50}s ranging between 193 µg/L and 292 µg/L. Devlin and Mottet (1992) determined a methylmercury LC_{50} equal to 54 µg/L for coho salmon embryos exposed for 48 days. Niimi and Kissoon (1994) exposed rainbow trout sub-adults to 64 µg/L of mercuric chloride until the fish died. The average time to death was 58 days. All of these concentrations are orders of magnitude higher than a water column concentration that was previously deemed protective of anadromous salmonids (0.002 µg/L). In another experiment, the authors determined rainbow trout lived more than 100 days when exposed to 4 µg/L of methylmercury chloride. The lowest effect level noted from an "acute" type study was an LC_{10} of 0.9 µg/L following a 28-day exposure of rainbow trout embryos to mercury, with a no-effect (LC_1) estimate of 0.2 µg/L (Birge et al. 1980).

Effects due to chronic exposures to low concentrations of mercury in the water column are generally manifested through dietary exposures. Methylmercury both bioconcentrates and biomagnifies across trophic levels, and corresponding, field-measured BAFs can be in the millions for top trophic level fish (Nichols et al. 1999) and have been reported to be in the hundreds of thousands for rainbow trout (EPA 2024). Because methylmercury can readily bioaccumulate and biomagnify, food chain transfer is by far the most important mercury exposure pathway in aquatic ecosystems (Hall et al. 1997, Wiener et al. 2003, NMFS 2014, EPA 2024). To a lesser extent, fish obtain mercury from water passed over the gills, and fish also methylate inorganic mercury in their gut (Wiener and Spry 1996).

Methylmercury concentrations are generally greatest in higher trophic levels (e.g., piscivorous fish). However, exceptions to this general rule of thumb have been documented. MacRury et al. (2002) documented higher mercury burdens in fish that preyed on benthic invertebrates compared to fish that were strictly piscivorous. Juvenile Chinook salmon and steelhead in freshwater ecosystems feed predominantly on macroinvertebrates and would generally be at lesser risk of methylmercury accumulation, particularly if the recommended water quality criteria are adopted and implemented.

A number of researchers have attempted to quantify fish tissue burdens associated with lethal and sublethal effects (Table B-2). Fish tissue concentrations associated with acute mortality are quite high, ranging from 6 to 20 mg/kg ww in muscle (Sandheinrich and Wiener 2010; Wiener and Spry 1996). Devlin and Mottet (1992) exposed coho salmon eggs (after hardening) to methylmercury concentrations ranging from 6 to 139 µg/L for 50 days. Calculated prehatch LC_{50} values ranged from 54.1 to 70.8 µg/L. Some mortality was observed in the 13 µg/L treatment, and it is unclear whether any observed mortality occurred in the 6 µg/L treatment. The authors reported embryo mercury concentrations up to 20 times greater than water concentrations, illustrating that incubating embryos can rapidly uptake mercury from their environment. We did not find any studies examining embryo mortality from environmentally relevant exposures concentrations. (i.e., concentrations similar to those predicted to occur under the proposed action). Studies relating fish tissue concentrations to other apical endpoints such as reduced growth or reduced reproduction are limited. Available information suggests that sublethal effects are far more sensitive (Table F-2).

Table 68. Selected examples of adverse effects of mercury to salmonids or their prey (NMFS 2014; EPA 2024).

Species (life stage)	Exposure Duration	Dietary Conc. (mg/kg dw)	Tissue Conc. (mg/kg ww)	Tissue	Observed Effects	Source
Rainbow trout (fingerling)	84 days	23.9	10	Whole Body	Reduced growth; Survival not affected	Rodgers and Beamish 1982
Rainbow trout (fingerling)	84 days	46.9	20	Whole Body	Reduced growth; Survival not affected	Rodgers and Beamish 1982
Rainbow trout (fingerling)	84 days	94.8	30	Whole Body	Reduced growth; Survival not affected	Rodgers and Beamish 1982
Atlantic salmon (parr)	120 days	5	0.61 (0.4 – 0.8)	Muscle[1]	Increased antioxidant enzyme activity Severe vacuolation in brain tissue	Berntssen et al. 2003
Atlantic salmon (parr)	120 days	10			Decreased antioxidant enzyme activity Severe vacuolation in brain tissues; and diffuse necrosis Decreased neural enzyme activity Decreased feeding behavior	Berntssen et al. 2003
Fathead minnow (adult)	250 days	0.87	0.86 male 0.92 female	Whole body (minus gonads)	Decreased number of spawning fish; Decreased sex hormones Increased time to first spawn Decreased female gonadal somatic index Increased ovarian follicular apoptosis	Drevnick and Sandheinrich (2003); Drevnick et al. 2006
Fathead minnow	195 days	0.88	0.39 male[2] 0.52 female[2]	Whole body (minus gonads)	Decreased number of fish spawning Increased time required to first spawn Decreased egg production Decreased female gonadosomatic index	Hammerschmidt et al. 2002 [2]
Fathead minnow (adult)	>250 days	0.87	0.71	Whole body	Decreased reproductive behavior	Sandheinrich and Miller 2006
Walleye (1 year)	180 days	1 ww	2.37	Carcass (minus viscera)	Decreased growth Increased gonadal atrophy Decreased gonadal somatic index	Friedmann et al. 1996
Walleye (1 year)	180 days	0.1 ww	0.25	Carcass (minus viscera)	Decreased plasma cortisol (impaired immune function) Increased gonadal atrophy	Friedmann et al. 1996

Notes:
1 NMFS (2014) estimated muscle tissue concentrations from the reported brain tissue residues using organ tissue ratios derived from McKim et al. 1976
2. Dry weight converted to wet weight using 80% moisture.

Histological changes in the spleen, kidney, liver, and gonads have been reported for multiple species of freshwater fish at tissue concentrations of methylmercury well below 1.0 mg/kg ww (Sandheinrich and Wiener 2010). Sandheinrich and Wiener (2010) concluded that effects on biochemical processes, damage to cells and tissues, and reduced reproduction in fish have been documented at methylmercury concentrations of about 0.3 to 0.7 mg/kg ww (whole body) and 0.5 to 1.2 mg/kg ww (muscle tissue). In addition to organ tissue damage, exposure to sublethal concentrations of MeHg can cause neurotoxic effects resulting in impairment of the ability of fish to locate, capture, and ingest prey and to avoid predators (Wiener et al. 2003). In Atlantic salmon parr, brain tissue concentrations of 0.69 mg/kg ww were associated with brain lesions and behavior alterations (Berntssen et al. 2003). No reductions in growth or survival were noted. Using organ tissue ratios derived from McKim et al. 1976, NMFS (2014) extrapolated brain residues to muscle tissue concentrations of 0.61 mg/kg wet weight (range of 0.4 – 0.8 mg/kg ww).

Fjeld et al. (1998) showed that the feeding efficiency and competitive ability of grayling (*Thymallus thymallus*) exposed as eggs to waterborne methylmercury chloride at concentrations of $\geq$ 0.8 µg/L for 10 days and having yolk-fry with mercury concentrations of 0.27 mg/kg ww or greater, were impaired when fish were tested 3 years later. Based on studies by McKim et al. (1976), NMFS (2014) translated the NOEC (0.09 mg/kg ww in yolk-fry, associated with a 0.16 µg/L exposure) from Fjeld et al. (1998) to a maternal mother tissue concentration of 0.7 (range 0.15 to 1) mg/kg ww. Similar extrapolations of the 0.09 embryo NOEC by the U.S. Fish and Wildlife Service (2003) and Idaho Department of Environmental Quality (2005) using other data yielded muscle tissue concentrations ranging from 0.45 to 1.8 mg/kg ww. Bridges et al (2016) found that females fed diets of 5 mg/kg dw MeHg over a period of 30 days transferred MeHg to eggs. Survival of embryos was significantly reduced due to maternal transfer of MeHg, and a large number of the surviving offspring had spinal deformities and exhibited circular swimming patterns. The authors also noted earlier hatch times for embryos whose mothers were fed a 0.87 mg/kg dry weight MeHg diet, though there was no statistically significant reduction in survival.

NMFS (2014) found the most sensitive effects of long-term exposures of a variety of fish species to methylmercury to generally have been reproductive or behavioral effects, with concentrations greater than about 0.3 mg/kg ww in whole bodies or axial muscle tissues likely to be harmful to fish. However, NMFS noted that adverse effects (e.g., steroidogenesis, and changes in metabolic, endocrine, and immune-related genes) occurred at concentrations lower than this. Whether these sub-clinical effects would translate into harmful organism-level effects (e.g., reduced growth or reproduction) is unknown. Bevkar et al. (2005) recommended a 0.2 mg/kg ww (whole body) threshold as being protective of fish from sublethal effects. Most recently, EPA recommends a whole-body fish tissue concentration of 0.162 mg/kg ww whole body tissue, applied to adult trophic level 4 fish.

Evaluation of Water Column Threshold Concentrations. NMFS (2014) evaluated a variety of matched water and tissue mercury samples to assess concentrations in water that might result in mercury accumulation to harmful levels. Matched samples repeatedly show that mercury concentrations in fish commonly approach or exceed the lowest adverse effect threshold of about 0.2 to 0.3 mg/kg ww, even when mercury concentrations in the water were commonly an order of magnitude lower than 12 ng/L. NMFS then used two approaches to calculate potential water column concentrations of mercury that would present a low risk of bioaccumulation of mercury to harmful levels in fish. The first approach involved linear regression between paired water column and fish tissue data; the second approach used BAFs to estimate potential mercury tissue residues from mercury concentrations measured in the field. Using data reported by Essig (2010), a linear regression ($r^2 = 0.22$; $p < 0.00001$) suggested that a water concentration of 0.9 ng/L would, on the average, result in a fish tissue concentration of about 0.3 mg/kg. Using data from DeForest et al. (2007) and Essig (2010), the BAF approach suggested that if total mercury concentrations in the water were less than 2 ng/L, then fish tissue concentrations would be expected to be less than 0.3 mg/kg ww.

Evaluation of Dietary Concentrations. DePew et al. (2012) used data from twenty experimental studies to derive thresholds for dietary methylmercury concentrations. The authors concluded that adverse effects on behavior usually occurred when dietary concentrations exceeded 0.5 mg/kg ww (2 mg/kg dw, assuming a 75 percent water content), and adverse effects on reproduction occurred when dietary concentrations were at 0.2 mg/kg ww (0.8 mg/kg dw, assuming a 75 percent water content). Because these thresholds were derived from laboratory experiments where fish are held in ideal conditions (temperature, food availability, etc.), the thresholds may still underestimate adverse effects. This is because fish in the wild experience additional stressors related to foraging, predation, temperature fluctuation, and other contaminants that are not present in laboratory settings.

Bernssten et al 2003 fed Atlantic salmon parr diets with 4.35 mg/kg dw and 8.48 mg/kg dw MeHg and 10 mg/kg and 100 mg/kg inorganic mercury over a period of 4 months. No reduced growth or mortality was observed. While these levels did not result in outright mortality, the researchers observed increased brain lesions and behavior alterations (reduced swimming activity) at 8.48 mg/kg dw MeHg diets and increase oxidative stress at 4.35 mg/kg dw MeHg diets.

Toxicity to Aquatic Invertebrates

Nagpal (1989) summarized both acute and chronic toxicity data for macroinvertebrates. Acute toxicity for invertebrates was found to be dependent upon species, developmental stage, and overall environmental conditions. For inorganic mercury, *Daphnia sp*. were found to be the most sensitive invertebrate, with LC_{50}s of 1.4 to 4.4 µg/L for *D. magna* and 2.2 µg/L for *D. pulex*. In chronic toxicity tests of inorganic mercury and *D. magna,* adverse effects occurred at concentrations ranging from 0.72 to 1.82 µg/L. In chronic tests for methylmercury, adverse effects were observed in *D. magna* at concentrations less than 0.04 µg/L. In a field study, Kraus et al. (2022) documented reduced insect diversity in a stream with elevated levels of mercury from historic mining. The authors found that total mercury in the biota up to 4.7 miles downstream were up to 11 times greater than background levels and MeHg propagated through the downstream food web. Invertebrate communities sampled approximately 2.5 miles downstream of the mine site were substantially less diverse than reference conditions. The farthest downstream site did not have an apparent reduction in benthic invertebrate diversity; however, densities of mayfly and stonefly taxa were depressed.

Based on reviewed literature, toxicity of mercury to aquatic invertebrates and subsequent loss of abundance or taxonomic shifts is not the most important pathway of effect to ESA-listed species. Instead, bioaccumulation of mercury in invertebrate tissue is of greater concern due to the propensity of mercury to biomagnify.

Summary

Bioaccumulation of mercury through the food chain is the most important pathway of toxicity for fish. There is relatively little information from which to derive risk evaluation thresholds for anadromous species. Relying on previous work, the best available information suggests fish tissue concentrations of less than 0.2 mg/kg of total mercury should be adequately reduce the risk of sublethal effects in anadromous salmonids. While site specific factors will influence the extent to which mercury becomes bioavailable and subsequently bioaccumulates, in general, water column concentrations less than 2 ng/L are expected to have a low risk of contributing to sublethal effects in anadromous salmonids.

TOTAL DISSOLVED SOLIDS

Total dissolved solids (TDS) is an integrated measure of all the ions in water that can pass through a filter. Common freshwater ions include calcium, magnesium, bicarbonate, chlorides, nitrate, phosphorus, iron, and sulfate. The concentration of TDS affects the water balance in aquatic organism cells. In low TDS environments, water will move into the cell, causing it to swell. In high TDS environments, organisms may shrink as water moves out of their cells. The ionic composition of TDS affects its toxicity and is not predictable from TDS concentrations (Chapman et al. 2000; Weber-Scannell and Duffy 2007). Mining activities can increase major ion concentrations in streams by enhancing weathering of geological material (Brent et al. 2022; Pond et al. 2014).

TDS toxicity is exerted through changes in salinity, changes in the ionic composition of the water, and individual ions. In addition, TDS can influence the toxicity of other contaminants, such as metals. Because the toxicity of TDS depends on the specific ion composition comprising the measure, ecological thresholds to protect aquatic life are not readily available.

Toxicity to Fish

Toxicity of TDS to fish is dependent upon: (1) the ion composition; (2) concentrations of individual ions; and (3) species and life stage exposed (Weber-Scannell et al. 2007, Stekoll et al. 2003, Stekoll et al. 2009). As a result, it is not surprising that toxicity results vary in the literature. Chapman et al. (2000) did not observe any mortality or reduced growth of rainbow trout fry exposed to up to ~2,000 mg/L TDS for 7 days. Similarly, no adverse effects were observed for rainbow trout eggs fertilized and incubated in up to 2,000 mg/L TDS solutions.

When beginning exposure to elevated TDS during fertilization, Stekoll et al. (2009) found a dose-response relationship associated with continuous TDS exposure (fertilization through early development). Reported EC_{20} and LOEC values for steelhead were 1,100 and 750 mg/L, respectively. The reported EC_{20} and LOEC values for Chinook salmon were 85 and 250 mg/L, respectively (Stekoll et al. 2009). The LOECs were substantially higher when TDS exposure occurred after fertilization. The authors reported a LOEC of 1,875 mg/L for steelhead, and no LOEC was reported for Chinook since no mortality difference was observed between the test concentrations and controls. The authors also investigated which ion was likely responsible for the toxicity and concluded that calcium was the most likely culprit. In their specific ion tests, the fertilization process was most sensitive to calcium, and calcium was the most prevalent ion in the TDS mixture. The calcium ion has also been shown to be responsible for toxicity by a Ketola et al. 1988 and Brannock et al. 2002 (as cited in Weber-Scannell and Duffy 2007). Other authors (Mount et al. 1997 and Peterson et al. 1988) have found potassium as being the source of toxicity in their experiments, providing further evidence for the importance of site-specific considerations.

The majority of available toxicity studies show relatively high concentrations of TDS (>1,000 mg/L) are needed to elicit effects. However, few studies examined exposures at fertilization, which based on available information appears to be the most sensitive life stage (Stekoll et al. 2009).

Toxicity to Invertebrates

Similar to fish, invertebrate toxicity is dependent upon the concentration of TDS, ionic composition, and species being tested. A wide range of toxicity has been reported for aquatic invertebrates, with the vast majority of studies reviewed by Scannell et al. (2007) reporting LC_{50} or EC_{50} values greater than 1,000 mg/L (Weber-Scannell et al. 2007). Brent et al. 2022 reported LC_{50} values >3,000 mg/L for *C. dubia* and *H. azteca*. Chapman et al. (2000) documented reduced growth and survival of chironomid larvae exposed to 2,000 mg/L TDS. No observed effects were observed in test solutions of up to 1,200 mg/L TDS.

A number of authors have found macroinvertebrate assemblages to be influenced by TDS (Olson and Hawkins 2017, Pond et al. 2008, Pond et al. 2014, Lind 2018, and Cormier et al. 2018). These authors noted loss of macroinvertebrate genera with increasing TDS. Cormier et al. 2018 developed a specific conductance (which is closely correlated with TDS) chronic benchmark using a field-based methodology for the Central Appalachians ecoregion. They proposed a specific conductance benchmark $\leq$301 microseimens per centimeter as being protective of 95 percent of the macroinvertebrate assemblage documented in that ecoregion.

Mayfly genera appear to be among the most sensitive species to TDS. Kennedy et al. (2004) go so far as to suggest the standard test species, such as *D. magna* or *C. dubia* were not “ecologically relevant gauges” of toxicity TDS. They found the mayfly *Isonychia bicolor* was at least 2.5 times more sensitive to specific conductance than *C. dubia*. Similarly, Brent et al. (2022) suggest site-specific indigenous macroinvertebrate species be used in toxicity tests to more accurately evaluate toxicity risks from TDS exposures. NMFS did not find any studies of toxicity in low hardness and low TDS waters; however, once study, Cormier et al. (2018), suggested that macroinvertebrate assemblages are less vulnerable to low specific conductance (and by extension TDS).

Summary

Available science indicates that TDS toxicity is heavily dependent upon the ion composition and concentrations of ions. Furthermore, TDS tolerance varies widely among genera. The most sensitive fish life stage appears to be fertilization through early emergence, with the lowest EC_{20} value being 85 mg/L for Chinook salmon. Benthic community richness metrics decrease with increasing TDS concentrations, with mayflies being among the most sensitive genera. Given that juvenile salmonids are opportunistic feeders, as long as a diverse group of macroinvertebrates are protected, some loss of prey items would not be expected to reduce individual fitness.

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APPENDIX G

FLOW RELATED EFFECTS ON SNAKE RIVER SPRING/SUMMER CHINOOK SALMON AND SNAKE RIVER BASIN STEELHEAD

Calculation of The Flow Rate (cfs) Effects of the Proposed Action

The biological assessment (BA) (Stantec 2024) included estimates of the net effects of the proposed action on stream flow (flow effects). The effects are expressed as the percent change in flow compared to “baseline.” The flow effects for mine years (MYs) -2 through Post-Closure, for the three affected reaches of the East Fork South Fork Salmon River (EFSFSR) and for the affected reach of Meadow Creek, are in the BA Table 4.1-35 on pages 379-398. Table 4.1-35 included “baseline” flows, which enabled a mathematical conversion from percent change from baseline, to a flow rate (i.e., cubic feet per second [cfs]). For Sugar Creek, page 167 of the BA, flow effects are described as an approximate 3% reduction from baseline during the mine operation period and for approximately 50 years post-closure. However, the BA Table 3.5-33 describes flow effects in Sugar Creek as 1% for May and June, 2% for April, and 3% for all other months. We applied these estimated effects to average flows measured in Sugar Creek at U.S. Geological Survey (USGS) gage 13311450, and the result was 0.42 cfs. We also estimated the effects on flow in Sugar Creek by estimating the amount that flow would be reduced by removing 185 acres (i.e., the catchment area of the West End Pit Lake) from the drainage, and the result was 0.39 cfs. Because the mechanism for flow reduction in Sugar Creek will be the effective reduction in drainage area, we presumed that the proposed action would reduce flow in Sugar Creek by approximately 0.39 cfs from MY 1 through 50 years post closure. We also presumed that the effect of the proposed action on flow in downstream reaches (i.e., downstream from Sugar Creek) will be the sum of the effect on flow in Sugar Creek and the effect on flow in the EFSFSR reach upstream from Sugar Creek (i.e., between the Yellow Pine Pit [YPP] and Sugar Creek). The effects of the proposed action on flow expressed as cfs, calculated as described above, are in Table G-1.

These estimated effects are less than the maximum allowable diversion rates stipulated in the water rights, suggesting that flow effects could be greater. We assumed that the estimates in the BA are based on project water needs and discharge of treated water, and that the information in Table 4.1-35 accurately describes effects on mean monthly flow. Under this assumption, the effects could be greater on a temporary basis, but the effects on mean monthly flow would be as described in Table G-1. We therefore used the flow effects described in Table G-1 to estimate the flow related effects of the proposed action on Snake River (SR) spring/summer Chinook salmon and SR Basin steelhead.

Table G-11. Flow reduction (cfs) in the affected reaches of the EFSFSR, Meadow Creek, Sugar Creek, and the SFSR.

Mine Year	Net Flow Reduction (Cfs) Due to Water Diversion and Discharge				Flow Reduction (Cfs) Due to Drainage Area Reduction	Total Net Flow Reduction in the EFSFSR Downstream from Sugar Creek and the SFSR Downstream from the EFSFSR
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP And Sugar Creek	Sugar Creek	
-2	-0.20	0.00	-0.20	-0.21	0	-0.21
-1	0.20	0.00	0.20	0.82	0	0.82
1	0.42	0.00	0.44	1.50	0.39	1.90
2	0.77	0.00	0.76	3.42	0.39	3.82
3	0.84	0.00	0.86	2.40	0.39	2.80
4	1.40	0.00	1.35	2.61	0.39	3.01
5	-0.21	0.01	-0.15	0.97	0.39	1.37
6	1.12	0.02	1.34	2.48	0.39	2.88
7	2.23	0.02	2.38	3.69	0.39	4.09
8	1.75	0.01	1.70	3.54	0.39	3.94
9	0.55	0.00	0.56	2.10	0.39	2.50
10	0.55	0.00	0.54	2.20	0.39	2.60
11	0.54	0.00	0.56	2.40	0.39	2.80
12	0.62	0.00	0.63	1.97	0.39	2.37
13	0.67	0.08	0.75	2.14	0.39	2.54
14	0.47	0.14	0.61	1.45	0.39	1.85
15	0.53	0.10	0.48	1.02	0.39	1.42
16	0.20	0.05	0.13	0.45	0.39	0.85
17	0.21	0.14	0.30	0.54	0.39	0.94
18	0.26	0.11	0.34	0.57	0.39	0.97
19	0.18	0.08	0.22	0.34	0.39	0.74
20	0.11	0.07	0.15	0.33	0.39	0.73
20+	0.00	0.00	0.00	0.00	0.24	0.24

1.1 Flow Data for the Action Area

Flow in the affected stream reaches was characterized as described in the following bullets:

- EFSFSR above Meadow Creek – Data from the 13310800 EFSFSR above Meadow Creek gage.
- EFSFSR between Meadow Creek and the YPP – Data from the 13311000 EFSFSR at Stibnite, Idaho gage.
- Meadow Creek – We subtracted flows measured in the EFSFSR above Meadow Creek from those measured in the EFSFSR between Meadow Creek and the YPP.
- EFSFSR between the YPP and Sugar Creek – Data from the 13311250 EFSFSR above Sugar Creek hear Stibnite, Idaho gage.
- Sugar Creek – Data from the 13311450 Sugar Creek near Stibnite, Idaho gage.
- EFSFSR between Sugar Creek and Johnson Creek – We added flows measured in Sugar Creek and the EFSFSR above Sugar Creek (gages 13311450 and 13311250).
- EFSFSR between Johnson Creek and the South Fork Salmon River (SFSR) – We added flows measured in Sugar Creek, the EFSFSR above Sugar Creek, and Johnson Creek (gages 13311450, 13311250, and 13313000).
- SFSR between the EFSFSR and the Salmon River – We added flows measured in Sugar Creek, the EFSFSR above Sugar Creek, Johnson Creek, and the SFSR near the Krassel Ranger Station (gages 13311450, 13311250, 13313000, and 13310700).

We used average July-September flow for all analyses and we normalized flows by dividing the average July-September flow, for all years, by the average July-September flow during the period of record, and expressed the result as a percentage. We calculated the percent reduction in July-September flow, due to the proposed action, by dividing the estimated reduction in flow, expressed as cfs (Table G-1), by the average July-September flow for the period of record. The estimated percent reductions July-September flow for each affected stream reach, for each MY are in Table G-2.

Table G-2. Percent Reduction in Average July-September, Flow by Reach.

Mine Year	Percent Reduction in Average July – September Flow							
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP And Sugar Creek	Sugar Creek	EFSFSR Between Sugar Creek and Johnson Creek	EFSFSR Between Johnson Creek and the SFSR	SFSR Between EFSFSR and the Salmon River
-2	-2.2	0.0	-1.1	-1.0	0.0	-0.6	-0.1	-0.1
-1	2.2	0.0	1.1	3.9	0.0	2.3	0.5	0.2
1	4.6	0.0	2.4	7.2	2.7	5.3	1.0	0.5
2	8.4	0.0	4.1	16.3	2.7	10.6	2.1	1.0
3	9.2	0.0	4.6	11.4	2.7	7.8	1.5	0.7
4	15.4	0.0	7.3	12.4	2.7	8.4	1.7	0.8
5	-2.4	0.0	-0.8	4.6	2.7	3.8	0.8	0.4
6	12.3	0.0	7.2	11.8	2.7	8.0	1.6	0.7
7	24.5	0.0	12.8	17.6	2.7	11.4	2.3	1.1
8	19.2	0.0	9.1	16.9	2.7	11.0	2.2	1.0
9	6.0	0.0	3.0	10.0	2.7	7.0	1.4	0.6
10	6.1	0.0	2.9	10.5	2.7	7.2	1.4	0.7
11	5.9	0.0	3.0	11.4	2.7	7.8	1.5	0.7
12	6.8	0.0	3.4	9.4	2.7	6.6	1.3	0.6
13	7.4	0.1	4.0	10.2	2.7	7.1	1.4	0.7
14	5.2	0.1	3.3	6.9	2.7	5.1	1.0	0.5
15	5.9	0.1	2.6	4.8	2.7	3.9	0.8	0.4
16	2.1	0.1	0.7	2.2	2.7	2.4	0.5	0.2
17	2.3	0.1	1.6	2.6	2.7	2.6	0.5	0.2
18	2.9	0.1	1.8	2.7	2.7	2.7	0.5	0.3
19	1.9	0.1	1.2	1.6	2.7	2.1	0.4	0.2
20	1.3	0.1	0.8	1.6	2.7	2.0	0.4	0.2
20+	0.0	0.0	0.0	0.0	1.6	0.7	0.1	0.06

Effects of Flow Reduction SR spring/summer Chinook Salmon and SRB Steelhead Productivity

We compared population productivity to population density and flow during the rearing life stage to estimate the effects of the flow related effects of proposed action on SR spring/summer Chinook salmon and SR Basin steelhead.

Population Trend Data

We used redds counted in Johnson Creek from 1998 through 2022 as an index of EFSFSR Chinook salmon population size, redds counted in the SFSR from 2009 through 2022 as an index of the SFSR Chinook salmon population size (Idaho Department of Fish and Game reports), redds counted in the Secesh River system from 2009 through 2022 as in index for the Secesh River Chinook salmon population size (Kennedy et al. 2013; Stiefel et al. 2014; Stiefel et al. 2015; Stiefel et al. 2016; Belnap et al. 2017; Felts et al. 2018; Rabe et al. 2018; Felts et al. 2019; Felts et al. 2020; Nau et al. 2021; Poole et al., 2021; Ruthven et al., 2022) and estimated numbers of steelhead returning to the SFSR population as in index of the SFSR steelhead population size (Copeland et al. 2013; Copeland et al. 2014; Copeland et al. 2015; Stark et al. 2016; Stark et al. 2017; Stark et al. 2018; Stark et al. 2019a; Stark et al. 2019b; Stark et al. 2021; Steelhead Run Reconstruction Workgroup 2021; Baum et al. 2022).

2.2 Population Productivity

For the three Chinook salmon populations, we calculated whole life cycle productivity (productivity) by dividing the recruit redds by the stock redds, assuming that 75% of adult returns were four years old and 25% were five years old. For the SFSR steelhead population, we calculated productivity by dividing estimated number of returns by the estimated number of returns four year previous, under the assumption of a consistent four year generation time with no repeat spawning (i.e., all spawners are four years old).

2.3 Flow Data used in Productivity/Flow Comparisons

We used data from the Johnson Creek near Yellow Pine gage (USGS 13313000) (Johnson gage) for the EFSFSR Chinook salmon population and the SFSR steelhead population. Most of the EFSFSR Chinook salmon population, and a large portion of the SFSR steelhead population, spawns and rears in the Johnson Creek drainage. We used flow data from the SFSR measured at the Krassel Ranger Station gage (USGS 13310700) (SFSR gage) for the SFSR and Secesh River Chinook salmon populations. Most of the SFSR Chinook salmon population spawns and rears in the SFSR upstream form the EFSFSR and the SFSR gage is the only gage in that reach. There are no stream flow gages in the Secesh River drainage, but the SFSR gage is the closest gage outside of the Secesh River drainage.

2.4 Regression Equations and Reach Level Productivity Effects

For the three SR spring/summer Chinook salmon populations, we compared the natural log of population productivity to average July-September (see section 2.3) recorded during the year following the brood year. For the one SR Basin steelhead population, we compared the natural log of population productivity to average July-September flow recorded during the brood year. For all populations, we also included the natural log of brood year population size in the regression models. The results are in Figures G-1 through G-4.

We calculated the flow-related effects of the proposed action on fish population productivity, for each stream reach, by inputting the estimated percent reduction in average July – September flow (Table G-2), and the average population size for the period of record, into the regression equations. We used the regression equation for SFSR Chinook salmon (Figure G-2) to calculate flow effects on Chinook salmon in the SFSR downstream from the EFSFSR, and the equation for EFSFSR Chinook salmon (Figure G-1) to calculate flow effects on Chinook salmon in all other stream reaches. We used the regression equation for SFSR steelhead (Figure G-3) to calculate the flow effects on steelhead in all stream reaches. The percent reduction in Chinook salmon and steelhead productivity, by reach and MY, are in Tables G-3 and G-4.

We did not use the regression equation for Secesh River Chinook salmon (Figure G-4) in any of the effects analyses, but included the results here for informational purposes. The Secesh River Chinook salmon population is in the SFSR drainage, immediately adjacent to the EFSFSR and SFSR Chinook salmon population areas, and the population therefore experiences similar climatic and flow conditions as the SFSR and EFSFSR populations. Although not in the action area, the close proximity and similar conditions warrants inclusion of the Secesh River Chinook salmon population productivity versus flow relationship in this Appendix.

Table G-3. Percent Reduction in Chinook Salmon Productivity by Reach.

Mine Year	Percent Reduction in Chinook Salmon Productivity							
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP and Sugar Creek	Sugar Creek	EFSFSR Between Sugar Creek and Johnson Creek	EFSFSR Between Johnson Creek and the SFSR	SFSR Between EFSFSR and the Salmon River
-2	-2.3	0.0	-1.1	-1.0	0.0	-0.6	-0.1	0.0
-1	2.3	0.0	1.1	4.2	0.0	2.4	0.5	0.1
1	4.9	0.0	2.5	7.7	2.8	5.7	1.1	0.3
2	9.2	0.0	4.3	18.5	2.8	11.7	2.2	0.7
3	10.0	0.0	4.9	12.6	2.8	8.5	1.6	0.5
4	17.4	0.0	7.8	13.8	2.8	9.1	1.7	0.5
5	-2.4	0.1	-0.9	4.9	2.8	4.1	0.8	0.2
6	13.6	0.3	7.8	13.1	2.8	8.7	1.7	0.5
7	29.0	0.3	14.3	20.1	2.8	12.6	2.4	0.7
8	22.1	0.1	10.0	19.2	2.8	12.1	2.3	0.7
9	6.5	0.0	3.2	11.0	2.8	7.5	1.4	0.4
10	6.5	0.0	3.1	11.5	2.8	7.8	1.5	0.5
11	6.4	0.0	3.2	12.6	2.8	8.5	1.6	0.5
12	7.3	0.0	3.6	10.2	2.8	7.1	1.4	0.4
13	8.0	1.0	4.3	11.2	2.8	7.6	1.5	0.4
14	5.6	1.7	3.5	7.4	2.8	5.5	1.1	0.3
15	6.3	1.3	2.7	5.2	2.8	4.2	0.8	0.2
16	2.3	0.7	0.7	2.3	2.8	2.5	0.5	0.1
17	2.4	1.8	1.7	2.7	2.8	2.8	0.5	0.2
18	3.1	1.4	1.9	2.9	2.8	2.8	0.6	0.2
19	2.0	1.0	1.3	1.7	2.8	2.2	0.4	0.1
20	1.3	0.8	0.8	1.6	2.8	2.1	0.4	0.1
20+	0.0	0.0	0.0	0.0	1.7	0.7	0.1	0.04

Table G-4. Percent Reduction in Steelhead Productivity by Reach.

Mine Year	Percent Reduction in Average July – September Flow							
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP and Sugar Creek	Sugar Creek	EFSFSR Between Sugar Creek and Johnson Creek	EFSFSR Between Johnson Creek and the SFSR	SFSR Between EFSFSR and the Salmon River
-2	-4.3	0.0	-2.1	-2.0	0.0	-1.2	-0.2	-0.1
-1	4.4	0.0	2.2	8.1	0.0	4.6	0.9	0.4
1	9.6	0.0	4.8	15.2	5.4	11.0	2.1	1.0
2	18.2	0.0	8.4	38.0	5.4	23.4	4.3	2.0
3	19.9	0.0	9.5	25.4	5.4	16.7	3.1	1.4
4	35.5	0.0	15.4	27.9	5.4	18.0	3.3	1.5
5	-4.5	0.2	-1.6	9.6	5.4	7.8	1.5	0.7
6	27.5	0.5	15.3	26.4	5.4	17.2	3.2	1.5
7	62.3	0.5	28.8	41.6	5.4	25.3	4.6	2.1
8	46.2	0.2	19.8	39.6	5.4	24.3	4.4	2.0
9	12.7	0.0	6.1	21.9	5.4	14.8	2.8	1.3
10	12.8	0.0	5.9	23.0	5.4	15.4	2.9	1.3
11	12.5	0.0	6.1	25.4	5.4	16.7	3.1	1.4
12	14.3	0.0	6.9	20.4	5.4	13.9	2.6	1.2
13	15.7	1.7	8.3	22.3	5.4	15.0	2.8	1.3
14	10.8	3.0	6.7	14.6	5.4	10.7	2.0	0.9
15	12.3	2.2	5.3	10.0	5.4	8.1	1.6	0.7
16	4.3	1.2	1.4	4.3	5.4	4.8	0.9	0.4
17	4.6	3.1	3.2	5.2	5.4	5.3	1.0	0.5
18	5.9	2.4	3.6	5.5	5.4	5.5	1.1	0.5
19	3.9	1.8	2.4	3.2	5.4	4.2	0.8	0.4
20	2.5	1.4	1.6	3.1	5.4	4.1	0.8	0.4
20+	0.0	0.0	0.0	0.0	3.2	1.3	0.3	0.1

2.5 Population Level Productivity Effects

We used the amount of habitat in each affected stream reach, expressed as weighted intrinsic potential (Cooney and Holzer 2006), to scale the stream reach specific reductions in productivity to the population level. The amount of Chinook salmon and steelhead weighted intrinsic potential, in each of the analyzed stream reaches, is in Table G-5. We calculated the population level effects by multiplying the stream reach specific reductions in productivity (Tables G-3 and G-4) by the percent of habitat in the affected stream reach (Table G-5). The results for Chinook salmon and steelhead are in Tables G-6 and G-7, respectively.

Table G-5. The amount of Chinook salmon and steelhead habitat, measured as weighted intrinsic potential, and expressed as m^2 and as a percentage of the population, for each analyzed stream reach.

Stream Reach	Weighted Intrinsic Potential			
	Chinook Salmon		Steelhead	
	m^2	Percent	m^2	Percent
Meadow Creek	0	0	4,786	0.12
EFSFSR above Meadow Creek	0	0	15,844	0.41
EFSFSR between Meadow Creek and the YPP	0	0	15,224	0.39
EFSFSR between the YPP and Sugar Creek	2,402	0.55	3,913	0.10
Sugar Creek, between West End Creek and mouth	1,126	0.26	7,407	0.19
EFSFSR Between Sugar Creek and Johnson Creek	63,593	14.66	124,533	3.18
EFSFSR between Johnson Creek and the SFSR	55,315	12.76	203,938	5.21
SFSR between EFSFSR and the Salmon River	13,779	2.06	615,905	15.75

Note: The percentages are for the SFSR steelhead population (all stream reaches), the EFSFSR Chinook salmon population (all stream reaches except the SFSR), and the SFSR Chinook salmon population (SFSR between the EFSFSR and the Salmon River).

Table G-6. Chinook Salmon Population Level Reduction in Productivity, By Reach, And Total for the EFSFSR And SFSR Chinook Salmon Populations.

Mine Year	Percent Reduction in Productivity (Percent)								
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Between Meadow Creek and the YPP	EFSFSR Between the YPP and Sugar Creek	Sugar Creek	EFSFSR Between Sugar Creek and Johnson Creek	EFSFSR Between Johnson Creek and the SFSR	Total for the EFSFSR Chinook Salmon Population	SFSR Between EFSFSR and the Salmon River, Total for the SFSR Chinook Salmon Population
-2	0	0	0	-0.001	0.000	-0.090	-0.016	-0.112	-0.001
-1	0	0	0	0.003	0.000	0.355	0.061	0.439	0.003
1	0	0	0	0.005	0.007	0.831	0.140	1.021	0.007
2	0	0	0	0.011	0.007	1.717	0.283	2.109	0.014
3	0	0	0	0.008	0.007	1.240	0.207	1.524	0.010
4	0	0	0	0.008	0.007	1.337	0.222	1.643	0.011
5	0	0	0	0.003	0.007	0.595	0.101	0.730	0.005
6	0	0	0	0.008	0.007	1.279	0.213	1.572	0.010
7	0	0	0	0.012	0.007	1.849	0.303	2.271	0.015
8	0	0	0	0.012	0.007	1.776	0.292	2.182	0.014
9	0	0	0	0.007	0.007	1.103	0.185	1.356	0.009
10	0	0	0	0.007	0.007	1.147	0.192	1.410	0.009
11	0	0	0	0.008	0.007	1.240	0.207	1.524	0.010
12	0	0	0	0.006	0.007	1.042	0.174	1.280	0.008
13	0	0	0	0.007	0.007	1.120	0.187	1.377	0.009
14	0	0	0	0.004	0.007	0.807	0.136	0.991	0.007
15	0	0	0	0.003	0.007	0.615	0.104	0.755	0.005
16	0	0	0	0.001	0.007	0.367	0.063	0.449	0.003
17	0	0	0	0.002	0.007	0.405	0.069	0.496	0.003
18	0	0	0	0.002	0.007	0.418	0.071	0.512	0.003
19	0	0	0	0.001	0.007	0.318	0.054	0.389	0.003
20	0	0	0	0.001	0.007	0.312	0.053	0.382	0.003
20+	0.0	0.0	0.0	0.0	0.004	0.103	0.018	0.126	0.0009

Table G-7. SFSR Steelhead Population Level Reduction in Productivity, By Reach and Total.

Mine Year	Percent Reduction in Productivity (Percent)								
	Meadow Creek	EFSFSR Above Meadow Creek	EFSFSR Betwee n Meadow Creek and the YPP	EFSFSR Between the YPP and Sugar Creek	Sugar Creek	EFSFSR Between Sugar Creek and Johnson Creek	EFSFSR Between Johnson Creek and the SFSR	SFSR Between EFSFSR And the Salmon River	Total for the SFSR Steelhead Population
-2	-0.005	0.000	-0.008	-0.002	0.000	0.000	-0.012	-0.017	-0.045
-1	0.005	0.000	0.008	0.008	0.000	0.000	0.047	0.066	0.135
1	0.012	0.000	0.019	0.015	0.010	0.000	0.109	0.153	0.319
2	0.022	0.000	0.033	0.038	0.010	0.000	0.222	0.310	0.635
3	0.024	0.000	0.037	0.025	0.010	0.000	0.162	0.227	0.485
4	0.044	0.000	0.060	0.028	0.010	0.000	0.174	0.244	0.559
5	-0.006	0.001	-0.006	0.010	0.010	0.000	0.079	0.111	0.198
6	0.034	0.002	0.060	0.026	0.010	0.000	0.167	0.233	0.532
7	0.076	0.002	0.112	0.042	0.010	0.000	0.238	0.332	0.813
8	0.057	0.001	0.077	0.040	0.010	0.000	0.229	0.320	0.734
9	0.016	0.000	0.024	0.022	0.010	0.000	0.144	0.202	0.418
10	0.016	0.000	0.023	0.023	0.010	0.000	0.150	0.210	0.432
11	0.015	0.000	0.024	0.025	0.010	0.000	0.162	0.227	0.463
12	0.018	0.000	0.027	0.020	0.010	0.000	0.136	0.191	0.403
13	0.019	0.007	0.032	0.022	0.010	0.000	0.147	0.205	0.443
14	0.013	0.012	0.026	0.015	0.010	0.000	0.106	0.149	0.332
15	0.015	0.009	0.020	0.010	0.010	0.000	0.081	0.114	0.260
16	0.005	0.005	0.005	0.004	0.010	0.000	0.049	0.069	0.147
17	0.006	0.013	0.012	0.005	0.010	0.000	0.054	0.076	0.176
18	0.007	0.010	0.014	0.006	0.010	0.000	0.055	0.078	0.180
19	0.005	0.007	0.009	0.003	0.010	0.000	0.042	0.060	0.137
20	0.003	0.006	0.006	0.003	0.010	0.000	0.042	0.059	0.128
20+	0.0	0.0	0.0	0.0	0.006	0.043	0.014	0.019	0.082

2.6 Population Level effects on Fish

We converted the effect on population productivity into the effect, expressed as the number of returning adults, but multiplying the percent reduction in population productivity by the average population size. The before action population productivity was assumed to be the productivity at average population density and average flow for the period of record (Table G-8).

Table G-8. Estimated effects expressed as number of returning adults.

Mine Year	EFSFSR Chinook Salmon	SFSR Chinook Salmon	SFSR Steelhead
-2	-0.4	0.00	-0.4
-1	1.5	0.02	1.3
1	3.5	0.04	3.0
2	7.2	0.09	6.0
3	5.2	0.07	4.6
4	5.6	0.07	5.3
5	2.5	0.03	1.9
6	5.4	0.07	5.0
7	7.8	0.10	7.7
8	7.4	0.09	6.9
9	4.6	0.06	3.9
10	4.8	0.06	4.1
11	5.2	0.07	4.4
12	4.4	0.05	3.8
13	4.7	0.06	4.2
14	3.4	0.04	3.1
15	2.6	0.03	2.5
16	1.5	0.02	1.4
17	1.7	0.02	1.7
18	1.7	0.02	1.7
19	1.3	0.02	1.3
20	1.3	0.02	1.2
20+	0.4	0.01	0.8

Note: Negative numbers are positive effects.

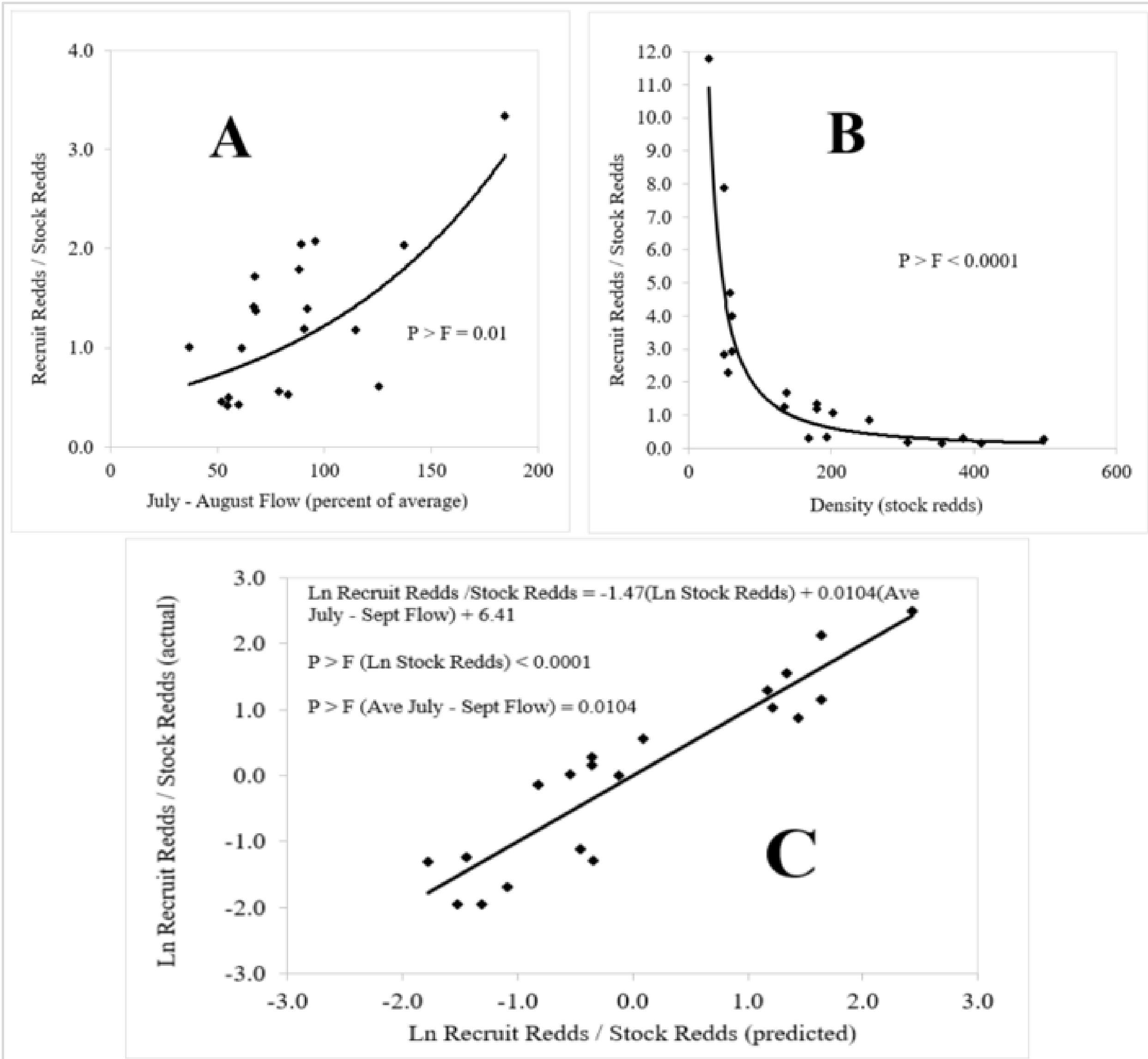

Figure G-1. Results of Multivariate Regression of EFSFSR Chinook Salmon Population Productivity Against Flow and Population Density.

Note: The leverage plots for flow and density are in panels A and B, respectively, and the whole model plot is in panel C.

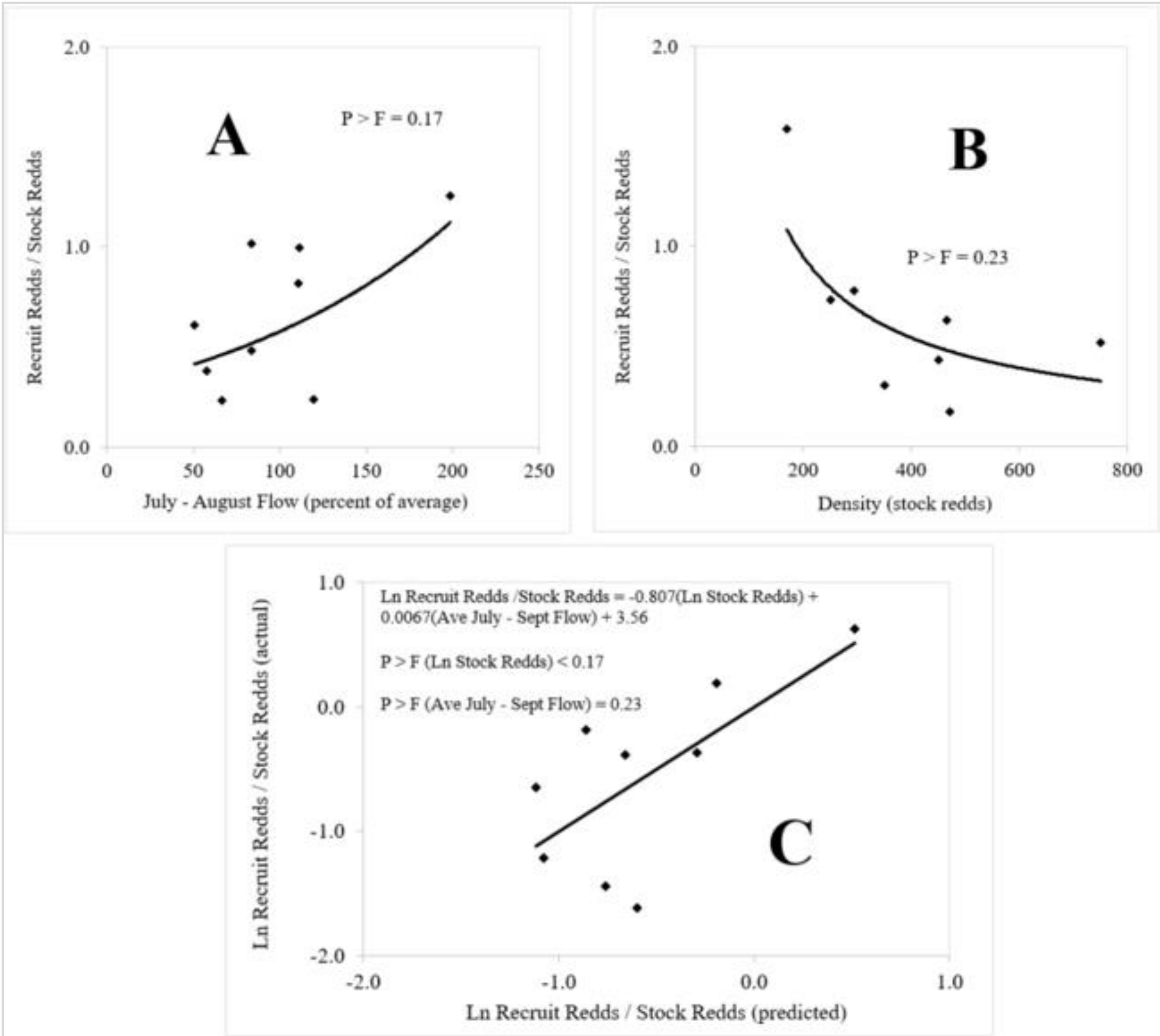

Figure G-2. Results of Multivariate Regression of SFSR Chinook Salmon Population Productivity Against Flow and Population Density.

Note: The leverage plots for flow and density are in panels A and B, respectively, and the whole model plot is in panel C.

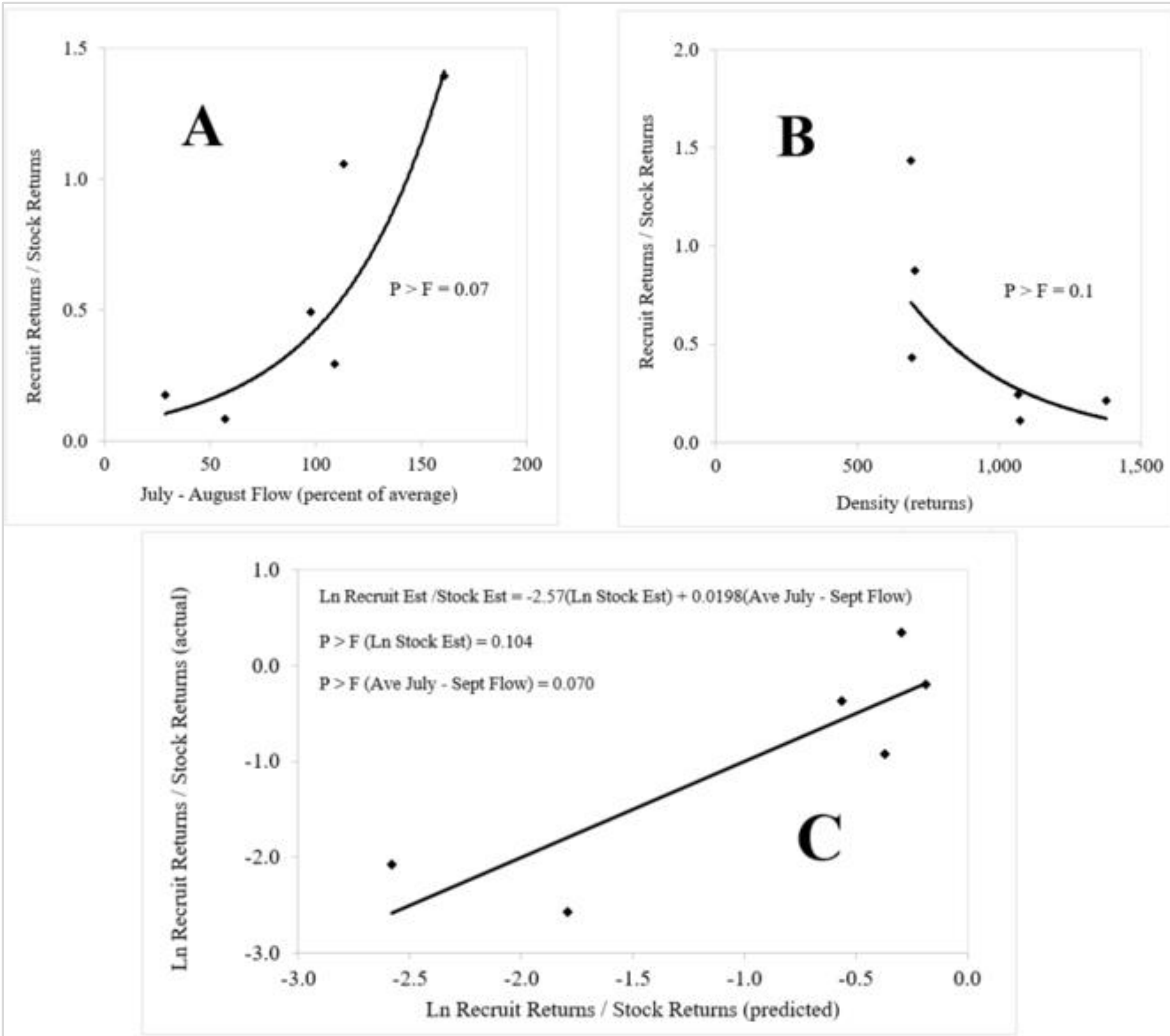

Figure G-3. Results of Multivariate Regression of SFSR Steelhead Population Productivity Against Flow and Population Density.

Note: The leverage plots for flow and density are in panels A and B, respectively, and the whole model plot is in panel C.

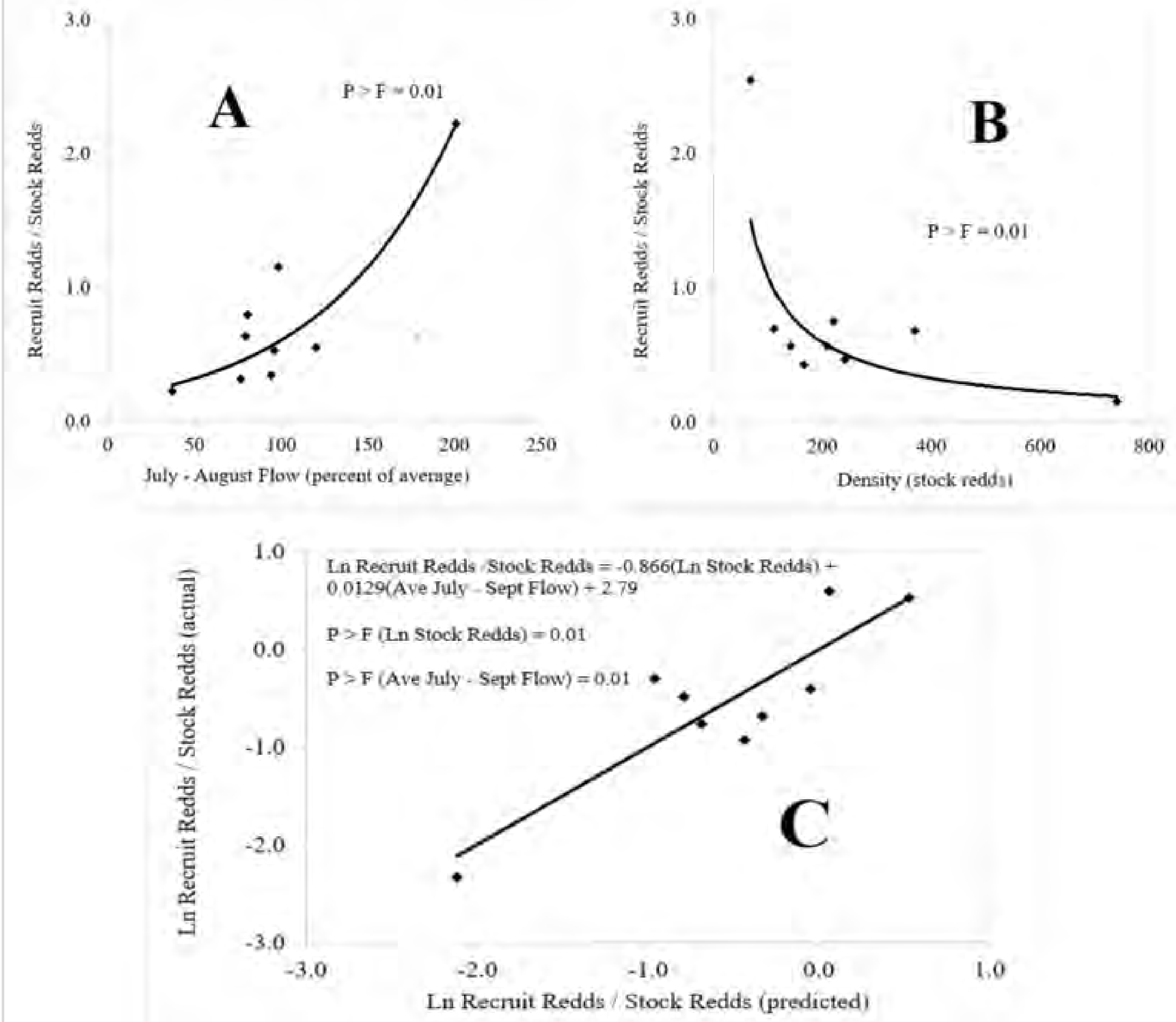

Figure G-4. Secesh River Chinook Salmon.

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Observed and Projected Changes in Idaho's Climate

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Current climatic setting of Idaho

Idaho's climate varies substantially from the dry rangelands of southern Idaho to the temperate wet forests of the panhandle. The mid-latitude setting of Idaho and topographic patterns both upwind and within the state dictate much of the seasonal and geographic variability in climate. Mid-latitude storms from the Pacific Ocean deliver semi-frequent widespread precipitation during the cool season (November-May), while the poleward retraction of the jet stream in summer leads to generally drier conditions. Large mountain barriers both west (Cascades) and east (Rockies) of Idaho limit both the intrusion of maritime airmasses that moderate temperatures and the intrusion of cold continental airmasses that promote extreme cold air outbreaks.

Substantial geographic variability in temperature and precipitation is evident across the state. The warmest average annual temperatures are found at lower elevations, including near Lewiston (*ca.* 745 ft above sea level) and the broader Treasure Valley near Boise (Figure 1a). Locations in the Treasure Valley experience several days per year of temperatures exceeding 100˚F, with Swan Falls averaging upwards of 20 such days per year during the period 1981-2010. The length of the freeze-free season (the period between the last day in spring with sub-freezing temperatures and the first day in autumn with sub-freezing temperatures) tops more than 200 days in Lewiston. By contrast, the high-elevation mountain peaks and valleys in central Idaho are home to the state's coldest temperatures. The weather station in Stanley, Idaho is frequently the coldest reporting station in the contiguous U.S. during summer and averages nearly 300 days per year of below-freezing temperatures.

Precipitation differences are very pronounced across the state (Figure 1b). Portions of southwestern Idaho near Bruneau received an average of 7 inches of precipitation a year during 1981-2010, while the higher-elevation western slopes of the Bitterroot Range in north-central Idaho averaged more than 70 inches of precipitation a year. Nearly the entire extent of the Snake River Plain, which comprises almost all of the state's agricultural lands and a vast majority of the population, receives less than 14 inches of precipitation a year on average. Thus, much of the water used for irrigation is dependent on water that falls in mountain headwaters and is delivered downstream. Approximately three-quarters of Idaho's annual precipitation is received from November-May as a result of Pacific storms. Precipitation and cloud cover are more plentiful in the northern half of the state than in southern Idaho as moisture-laden airmasses from the Pacific pass through the Cascade Range via the Columbia River Gorge. Summers (June-August) are generally dry. However, thunderstorm activity tied with the strong surface heating and moisture pulses, including from the North American monsoon, can produce local intense precipitation in parts of the state. This is most evident in eastern Idaho, which experiences a more continental climate receiving less precipitation directly from Pacific storms in winter and relatively more precipitation in the spring and summer, with convective activity.

Much of the winter precipitation that falls as snow in Idaho's mountains is stored seasonally as snowpack. The amount of water stored in mountain snowpack (called snow water equivalent; SWE) on April 1 (Figure 1c), a date that often serves as a bellwether for seasonal water availability, averaged approximately 36 million acre-feet over the late 20th century (data from hydrologic simulations, Figure 1c). Idaho's dry, warm summers necessitate water storage to sustain water for multiple needs. Snow delays the release of mountain moisture and serves as a natural reservoir, with snowmelt in the spring and early summer providing a buffer to compensate for the seasonal mismatch in water demands (Li et al., 2017).

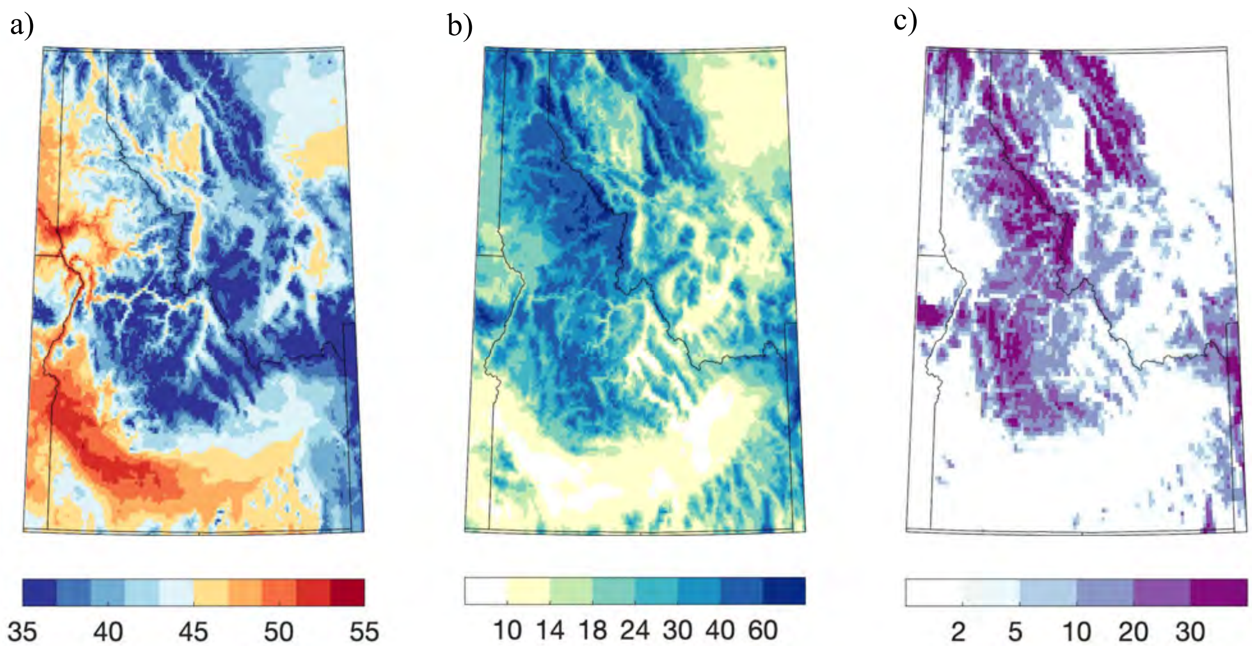


Figure 1: Maps show (a) mean annual daily temperature (degrees F), (b) annual total precipitation (inches), (c) April 1 snow water equivalent (SWE) (inches) averaged for the period 1971-2000. Data source: PRISM gridded data from Oregon State University and VIC hydrologic simulations from the University of Washington.

The diverse climate across the state shapes many of the natural resources that, in turn, shape Idaho's economic sectors and culture. Abundant water from mountain snowmelt flows into the tributaries of the Snake River and supports the vast agricultural lands that require irrigation. These same cool waters provide habitat for trophy fisheries, recreation for whitewater enthusiasts, and the region with abundant, low-carbon hydropower energy. Mountain snowpack yields opportunities for winter recreation, like skiing, snowboarding, and snowmobiling, as well as associated businesses. Idaho is shaped by the vast tracts of forests, waterways, agricultural potential, and recreational opportunities, such as hiking, fishing, hunting, and skiing.

Observed changes in Idaho's climate

Global air temperatures have warmed by 1.8˚F over the past 200 years, a vast majority of which occurred during the past 50 years (Hawkins et al., 2017). Twenty of the warmest 21 years in the instrumental record from 1880 to 2020 have occurred since 2000 (NOAA, 2021). Warming is evident in documented increases in global mean sea level and declines in glacier mass balance and Arctic sea ice extent. The northwestern U.S. and western U.S. have experienced warming trends similar to those seen globally over the past 125 years (1895-2020) (Abatzoglou et al., 2014; Melillo et al., 2014; U.S. Global Change Research Program (USGCRP), 2018). From 1895 to 2020, the northwestern U.S., including Idaho, Washington, and Oregon, experienced an increase in temperature of approximately 2˚F (NOAA, 2021).

Statewide warming trends in Idaho mirror those of the northwestern U.S., featuring a long-term warming of 1.8˚F since 1895 (Figure 2a). While the warmest year in Idaho was 1934 during the Dust Bowl, 7 of the 10 warmest years during 1895-2020 have occurred since 1990, whereas only 1 of the coldest 10 years has occurred since 1990. Moreover, warming trends are evident in all seasons over the past five decades. In addition, observations show approximately a two-week lengthening in the freeze-free season for lower elevation weather stations across in Idaho during the period 1918-2010 (Klos et al., 2015).

Observed statewide precipitation in Idaho has varied, with no significant trends over the 1895-2020 period (Figure 2b; USGCRP, 2018). Rather, statewide precipitation records reflect substantial interannual to decadal variability, including the chronic Dust Bowl (1920s to early 1940s) and a persistent wet epoch (1960s to early 1980s). Records of precipitation across Idaho's mountainous regions are sparse and short in duration. However, declines in westerly wind speed at 10,000 feet in elevation during the winter months across the northwestern U.S., including Idaho, since 1950 are hypothesized to have reduced orographic uplift and mountain precipitation over the past 70 years (Luce et al., 2013). Precipitation intensity has increased across the Northwest, with a 22% increase in the amount of precipitation falling in the wettest 1% of wet days for the 1986-2016 period versus the 1901-1960 period (USGCRP, 2018). Similarly, Klos et al. (2015) showed an increase in maximum daily precipitation accumulation in spring (March-May) in Idaho from 1919 to 2011.

a)

b)

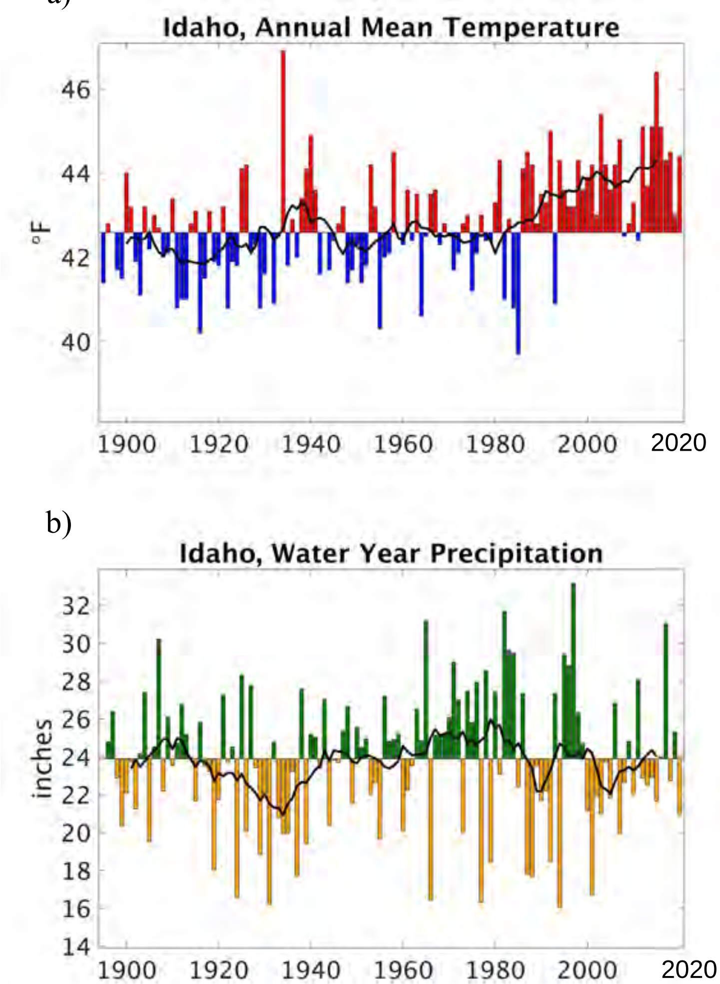
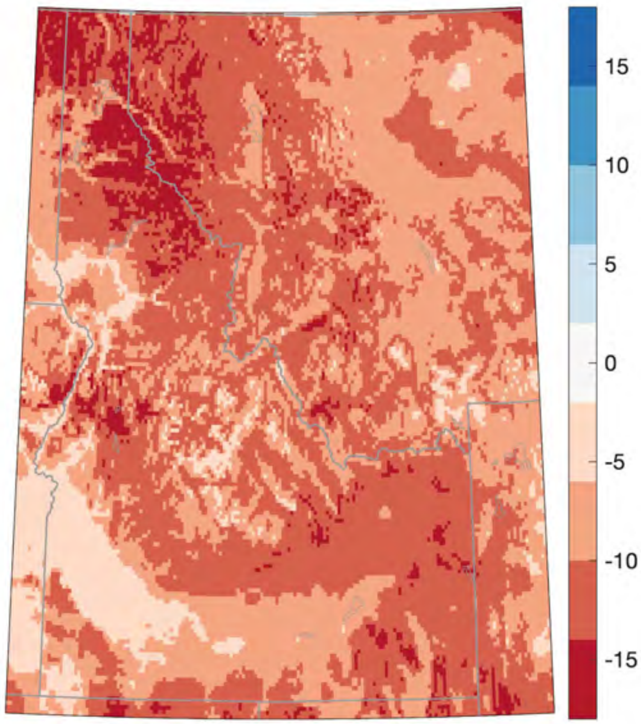


Figure 2: Multipanel time series showing (a) mean annual temperature, (b) total water year precipitation (Oct. 1-Sept. 30). The black line shows an 11-year centered moving mean. For reference, data are plotted relative to the 1901-2000 average. Data source: NOAA National Centers for Environmental Information Climate at a Glance: https://www.ncdc.noaa.gov/cag/statewide/time-series/10/

Observed warming has contributed to declines in April 1 snowpack in Idaho and the western U.S. as a whole since the 1950s, particularly in areas that lie close to the rain-snow transition (Mote et al., 2018). The elevation of the freezing level in Idaho and the broader Northwest has increased over 500 feet during November-April since 1950, commensurate with warming trends, leading to a reduction in the fraction of cool season precipitation falling as snow (e.g., Nayak et al., 2010; Abatzoglou, 2011). As a result, widespread reductions in snowfall are evident across the state, with reductions of up to 15% in snowfall in the Bitterroot Mountains during the period 1950-2020 (Figure 3; Lynn et al., 2020).

a)



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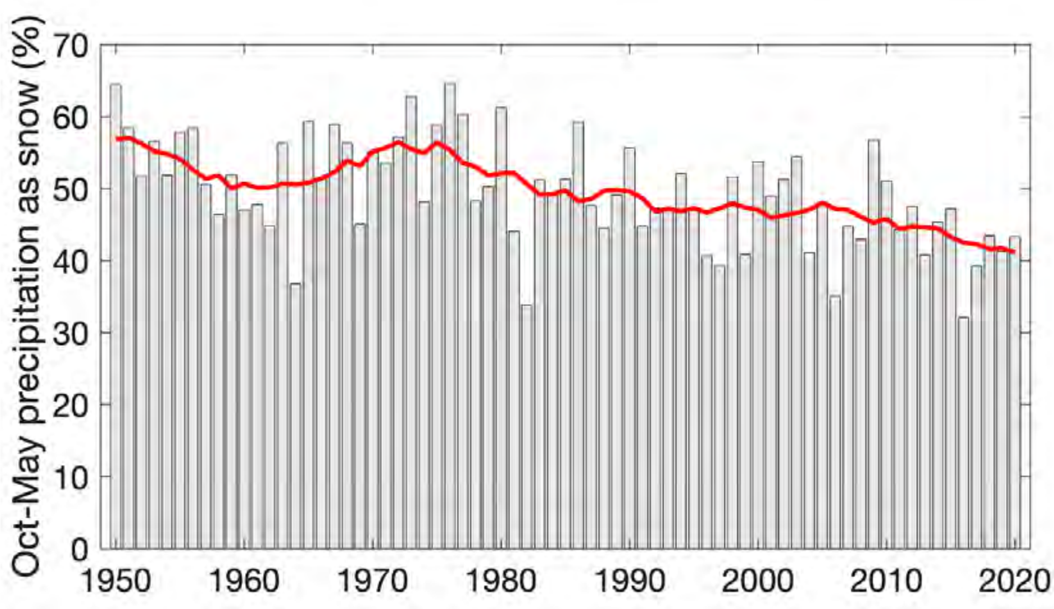

Figure 3: (a) Trends in the modeled percent of October-May precipitation falling as snow during the period 1950-2020 across the state from Lynn et al. (2020). (b) Time series of annual percent of October-May precipitation falling as snow for Idaho. Data source: Lynn et al. (2020)

Changes in streamflow in unregulated basins in Idaho, as measured by U.S. Geological Survey streamgage data, reflect four changes that are related to climate. First, observations show a reduction in total annual streamflow, particularly in the driest quarter of years since 1950 (Luce and Holden, 2009; Clark 2010; Luce et al., 2013). Second, in snowmelt-dominated regions, peak streamflow has occurred 1-2 weeks earlier in the year, tracking the reduction in spring snowpack and a greater portion of runoff occurring in the cool season since 1950 (Stewart et al., 2005; Clark, 2010; Klos et al. 2015). Third, streamgage measurements show decreases in minimum annual streamflow (Kormos et al., 2016). Finally, summer stream temperatures have warmed by an average of 1.5˚F during 1975-2015 (Isaak et al., 2018).

Conceptually, drought is defined as water demand exceeding water supply (Redmond, 2002). This definition thus yields numerous ways to monitor drought and track its impacts, given the variety of users and uses of water and different timescales that dictate imbalances in supply and demand. Drought trends in Idaho are nuanced. Although streamflow records suggest a trend toward more low flow conditions that comprise drought, observations using other measures suggest a different view of changes in drought. The most pronounced multidecadal drought characterized by chronically low cool season precipitation in Idaho's observational record occurred during the Dust Bowl period during the 1920s and 1930s (e.g., Wise 2010). In contrast, there has been a notable trend toward warmer and drier summers over the past five decades that have increased atmospheric water demand and dryness (Abatzoglou et al., 2014). Such changes have contributed to a substantial decrease in fuel moisture (Abatzoglou and Williams, 2016), contributing to escalating fire potential, as well as reduced water availability for many species that have limited post-fire tree establishment at low elevations (Stevens-Rumann et al., 2018).

Box 1: ***Why is the climate changing?***

Long-term records of climate, including those developed from ice cores, ocean records, fossil records, and pollen studies around the globe provide evidence that climate change has occurred throughout Earth's history. The processes governing changes in climate globally over the past several thousand to several hundreds of millions of years are generally well-known. Ongoing cyclical changes in Earth's orbit and axial tilt have largely been responsible for oscillations in global temperature between cold glacial periods (last one ending 18,000 years ago) and warm interglacial periods (like the last 11,700 years). These glacial-interglacial cycles have occurred nearly every 100,000 years during the last 800,000 years. What is known about orbital parameters and their effect on Earth's climate suggest that the present interglacial period is coming to an end. Indeed, long-term records show that most of the North Hemisphere has steadily cooled over the past 3000 years prior to the Industrial Revolution, starting in the late 19th century (Masson-Delmotte et al., 2013). On longer timescales of millions of years, paleoclimate data show that the planet has been substantially warmer than present-day throughout much of Earth's history, corresponding with much higher concentrations of greenhouse gases (Masson-Delmotte et al., 2013).

What is responsible for the changes in global climate that we've seen over the past century? Through the study of past climates and our understanding of the climate system today, the answer comes down to three possible factors: i) the amount of shortwave radiation received from the Sun, ii) the amount of shortwave radiation reflected back from the Earth's atmosphere and surface, and iii) the amount of longwave radiation emitted from the Earth's surface that is trapped by greenhouse gases in Earth's atmosphere.

Regarding the first possible factor, the amount of shortwave radiation that the Sun emits varies on 11-year and longer cycles and there is some evidence to suggest a slight increase in the amount of solar radiation the Earth has received over the past three centuries. However, there has not been significant change in incoming solar radiation for the past 70 years, during which the Earth's climate has changed most rapidly (Myhre et al., 2013).

As for the second possible factor, changes in the amount of cloud cover and the reflectivity of the planet's surface can also contribute to changes in global temperature. There is limited information about long-term changes in global cloud cover. However, increases in fine particles suspended in air or liquid droplets, called aerosols, have been observed since the 1950s as a byproduct of air pollution, which has the effect of cooling the planet by reducing the amount of sunlight reaching the Earth's surface (Myhre et al., 2013). Finally, competing effects with land-cover change have occurred: increased urbanization has darkened the planet, increasing the amount of solar radiation absorbed, while widespread deforestation has brightened the planet – albeit also contributing to carbon emissions.

The third possible factor is important. While water vapor is the dominant greenhouse gas in terms of trapping heat, the addition of carbon dioxide, methane, and other human-caused greenhouse gases to the atmosphere has strengthened the greenhouse effect and allows the Earth-atmosphere system to better retain heat. Globally, carbon dioxide concentrations in the atmosphere over last 800,000 years have fluctuated between 180 parts per million during glacial periods and 280 parts per million during interglacial periods. In the spring of 2021, global carbon dioxide concentrations reached 420 parts per million, 50% higher than recent 'warm' interglacial periods on Earth. These levels of atmospheric carbon dioxide are higher than levels seen in at least the last two million years of the Earth's history. The story is similar for methane, another important greenhouse gas.

The amount of shortwave radiation absorbed by the Earth and its atmosphere versus the energy radiated back to space is termed *radiative forcing*. Recent estimates suggest that collective addition of greenhouse gases and aerosols in the atmosphere has contributed to an additional 2.3 Watts per square meter (W/m^2) of energy trapped in the Earth-atmosphere system during the period 2005-2015 relative to the late 1800s (Andrews and Forester, 2020).

To better understand how natural and anthropogenic factors have contributed to observed changes in global climate, scientists use numerical models based in physics that describe the climate system. Different research groups around the world use climate models (Box 2) to examine the influence of known natural changes in solar activity and volcanic eruptions, as well as experiments that additionally include changes in aerosols, land-use, and greenhouse gases due to human activity on Earth's climate. Model experiments that consider changes in solar activity and volcanic eruptions show a small amount of warming globally from 1850 to 1950 (0.2°F), but with no change in global temperature over the most recent 70 years (Bindoff et al., 2013). By contrast, experiments that include anthropogenic increases in greenhouse gases largely capture the observed increase in global temperature (Bindoff et al., 2013). These experiments, along with other lines of scientific evidence allowed the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) to conclude that effectively all of the observed warming of global-mean surface air temperature since the late 19th century can be accounted for by human influences on the climate system (IPCC, 2021).

Understanding the causes of regional climate change is more nuanced. Regional changes in climate are influenced by changes in atmospheric circulation that occur in the absence of humans. Several modes of atmosphere-ocean variability influence temperature and precipitation patterns across much of the western U.S., including Idaho, namely the Pacific Decadal Oscillation, the El Niño-Southern Oscillation, and the Pacific North American Pattern (e.g., Redmond and Koch, 1991). Some regional attribution efforts have been undertaken to understand the fractional contribution of changes to a variety of factors. While natural factors, including modes of climate variability, solar activity, and volcanic activity, can help resolve year-to-year fluctuations in regional climate, they alone are inadequate for explaining observed warming across the northwestern U.S. (Abatzoglou et al., 2014). In contrast, regional warming trends in the northwestern U.S. are well-explained when anthropogenic factors were included (Abatzoglou et al., 2014). Barnett et al. (2008) showed that a majority of observed changes in snowpack, winter temperature, and streamflow across the western U.S. are likely influenced by human-induced changes in climate.

A longer view of Idaho's climate

One of the ways to assess long-term trends in climate, including the period before formal weather monitoring records were kept, is by using natural archives of environmental change. Tree rings are a widely used natural archive. Most trees produce a growth ring; the width of each year's ring is controlled by the temperature and precipitation conditions during that year (Fritts, 1976). The science of dendrochronology (tree ring science) allows researchers to use tree rings to view climate conditions that existed before the instrumental record (e.g., late 19th century), which facilitated recording temperature and precipitation with thermometers and rain gauges.

Idaho's large expanse of forests make the state an excellent place to use old trees to better understand past climate conditions of the region. Using tree rings as a predictor of drought, Cook et al. (1999) produced a multi-millennial length dataset of reconstructed summertime (June, July, August) Palmer Drought Severity Index (PDSI) for North America to assess the historical variability of drought conditions (Figure 4). Over the past *ca.* 1000 years, the Idaho region experienced droughts that were more prolonged and severe than those in the instrumental period. A prolonged and severe drought that occurred during the 12th century (*ca.* 1130-1200) appears to be the longest and most severe drought over the past *ca.* 1000 years and exceeds the most noteworthy droughts of the 20th century, such as the Dust Bowl of the 1920s-1940s. The 12th century drought highlights the magnitude and duration of drought potential in Idaho, the likes of which would create major problems for water resource managers should it recur in the contemporary world.

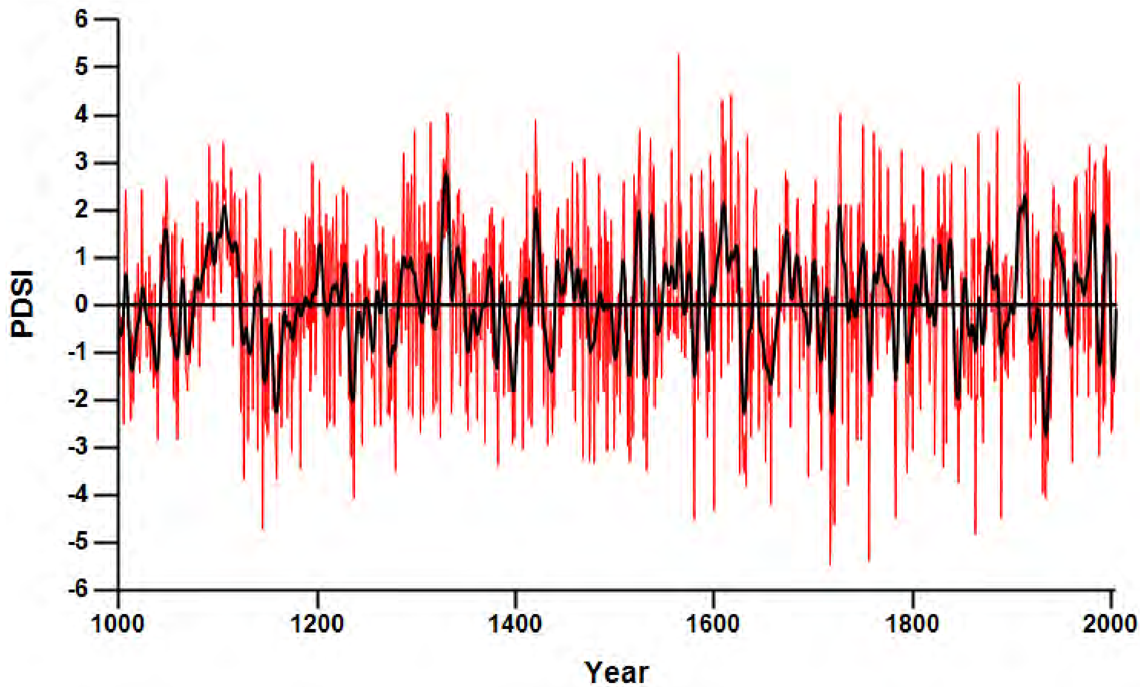

Figure 4: Tree ring-reconstructed June-August drought (Palmer Drought Severity Index; PDSI) for the Idaho region (42-49°N, 111-118°W) during the period 1000-2005. Data source: Cook et al. 1999 (figure adapted from drought.memphis.edu).

While tree rings provide important information about drought, temperature reconstructions for the Idaho region are scarce (e.g., Biondi et al., 1999). However, data from temperature-sensitive trees growing at Big Fisher Lake and Moscow Mountain were used to develop a model for reconstructing April-September maximum temperature (T_{max}) for Idaho. The regression model explains 42% of the annual variability during the period 1905-2019 (Figure 5A-B). The Idaho temperature reconstruction shows that temperature conditions recorded during the instrumental period (*ca.* 1905-2019) are unprecedented within the context of the past *ca.* 200 years (Figure 5C). Temperatures during the Dust Bowl were some of the hottest in the past 200 years, although most of the warmest summers on record have occurred since the year 2000.

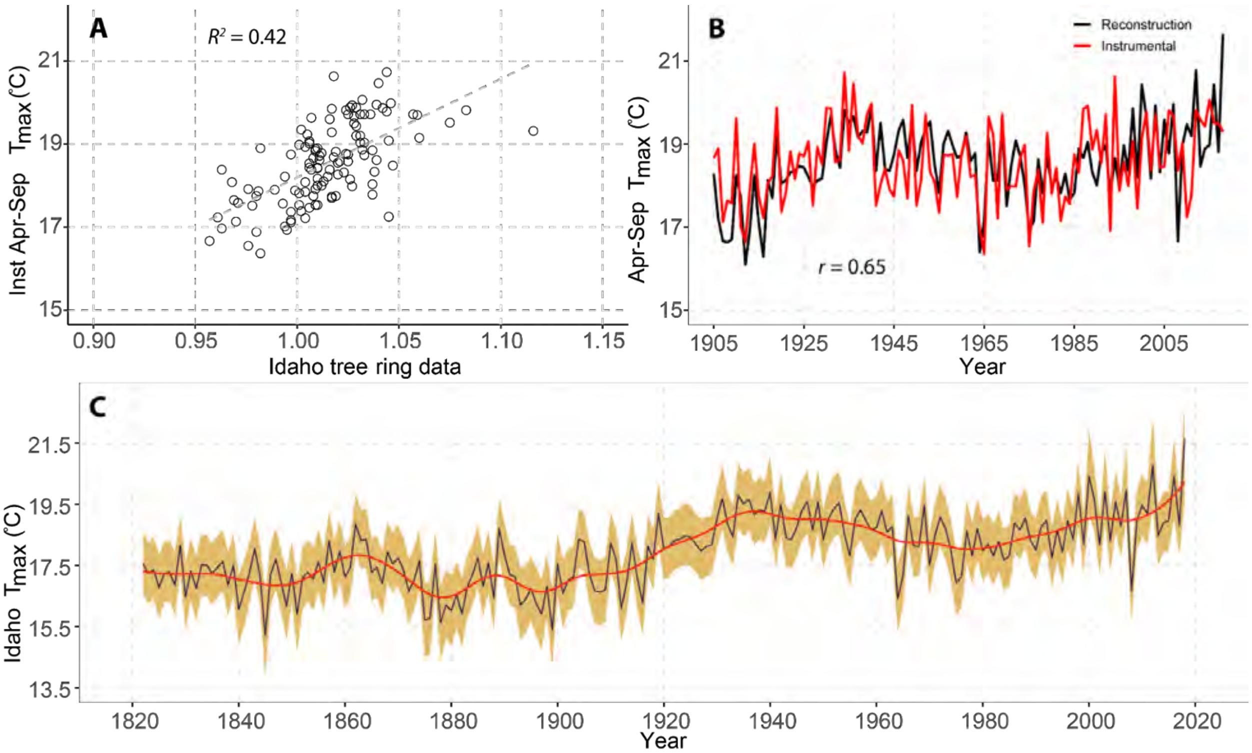

Figure 5: Tree ring-reconstructed April-September maximum temperature (T_{max}) for the Idaho region (42-49°N, 111-118°W) during the period 1822-2019.

Box 2: ***Modeling the future***

Models are physical, mathematical, or conceptual representations of a system used both to better understand how a complex system works and to provide prognostic information to help guide decisions. Models are used in many facets of day-to-day life, are continuously used in the business world, and have become increasingly integrated in our world. Perhaps the most common recognized model outputs we hear about come in the form of weather forecasts. These forecasts use observations and numerical models based on the laws of physics to resolve the evolution of weather over the next several days. Actionable information provided through weather forecasts has been valued at $20 billion dollars net value annually in the U.S. – including efforts to mitigate weather-related hazards and improve overall decision making (Katz et al., 2010).

Climate models are mathematical models that have been used by researchers for decades to better understand the climate system and how it responds to everything from El Niño events, to volcanic eruptions, to changes in greenhouse gas concentrations. Climate models are continuously improving through advances in scientific understanding about the physics and feedbacks of the climate system and increased computational capability. Despite these improvements, state-of-the-art climate models depict a very similar global temperature response to changes in human-caused emissions as some of the original climate models from a half-century ago, suggesting high consistency in our fundamental understanding of the climate system. This report primarily focuses on climate model experiments run for the 21st century that are based on different scenarios of anthropogenic greenhouse gas emissions, based on economic, social, technological, and environmental conditions (Box 3).

Climate models are developed by numerous international research groups. This allows the scientific community to evaluate the results and underlying model assumptions results across models, rather than to rely on the results of a single model. There have been several organized model comparison projects in which all modeling groups run the same experiments and share their results with the broader scientific community. These model comparisons provide an opportunity to improve knowledge on climate system processes, as well as information on future climate that informs climate impacts, adaptation, and mitigation efforts. The Fifth Coupled Model Intercomparison Project (CMIP5) brought together output from over 40 climate models and has provided a rich set of information for scientific studies, including those highlighted in the Fifth Assessment Report of the IPCC (IPCC, 2014). A new suite of modeling efforts is now being compared in Coupled Model Intercomparison Project Phase 6 (CMIP6), although the general projections for climate change globally and in Idaho are largely unchanged from the previous generations of models.

While climate models have improved, they are still unable to resolve fine spatial features and processes that characterize the climate of mountainous regions like Idaho. Additional efforts have been developed to downscale the coarse spatial output of climate models to scales more appropriate for informing state-level climate impacts. This includes statistical approaches based on observed relationships between variables (e.g., precipitation) at local scales that climate models may not directly resolve and larger-scale predictors that climate models can resolve. Several statistical downscaling approaches have been used, including the Multivariate Adaptive Constructed Analogs (MACA; Abatzoglou and Brown, 2012) method that is used in some examples within this report. A more sophisticated, but computationally intensive, approach for downscaling climate models is called dynamical downscaling. Dynamical downscaling runs higher-resolution physics-based climate models at regional scales using the coarse resolution output from climate models.

Uncertainty in the climate experiments is evaluated based on the range of model outcomes. First, most climate models are run multiple times using slightly different initial conditions (e.g., realistic, but random differences in ocean surface temperature patterns when the model commences its experiment). This bit of randomness can lead to slightly different trajectories that arise through modes of climate variability internal to the model. Likewise, the community effort of running the same experiments across different climate models provides another way to evaluate uncertainty, as some models are more sensitive to increased concentrations of greenhouse gases than others. Rather than focus on a deterministic future, which offers a single answer, these models can provide a probabilistic view of the future, which may be more useful in planning and adaptation.

Box 3: *Future scenarios*

Projected changes in climate in the 21st century are a response to changes in greenhouse gas concentrations in the atmosphere. Increased concentrations of greenhouse gases enhance the amount of longwave radiation the Earth's atmosphere retains. Net changes in energy, termed *radiative forcing*, provide one approach for contextualizing socioeconomic pathways that are used to drive climate modeling experiments.

In this report, we adopt the Representative Concentration Pathways (RCP) convention used by the Fifth Assessment Report of the IPCC (IPCC, 2014). RCPs are meant to capture potential scenarios that may play out under a variety of changes in population, energy choices, and policies. In brief, we focus primarily on two pathways: (i) RCP4.5, which results in 4.5 W/m^2 of energy trapped (above pre-industrial levels, mid-1800s) through changes in greenhouse gases and aerosols by 2100 and (ii) RCP8.5, which results in 8.5 W/m^2 of energy trapped through changes in greenhouse gases and aerosols by 2100. For reference, an additional 2.3 W/m^2 of energy trapped has been trapped in the Earth-atmosphere system during the period 2005-2015 relative to the late 1800s (Andrews and Forster, 2020). Herein, we refer to RCP4.5 as a moderate-warming scenario and RCP8.5 as a high-warming scenario. Mid-century projections are less sensitive to choice of RCP; differences between RCP4.5 and RCP8.5 are most important for late century projections.

There are several plausible ways to achieve any of these scenarios through changes in global population, global economic development, energy sources, and mitigation efforts. Briefly, RCP8.5 is a high-warming scenario, with limited efforts to mitigate greenhouse gas emission, use of fossil fuel reserves (namely coal), and continued growth in global population. Climate models forced by RCP8.5 inputs typically show global warming 8°F or more above pre-industrial levels by 2100. Recent studies have suggested that RCP8.5 may be less likely, given that global coal use peaked in 2013 and slow divergence from continued rapid increases in emissions from the energy sector (Hausfather and Peters, 2020). However, increases in greenhouse gas concentrations may still occur through carbon cycle feedbacks (e.g., carbon uptake by global oceans, permafrost melt) that may not be adequately modeled by current climate models. By contrast, RCP4.5 requires mitigation efforts, including increased use of non-carbon-based energy sources, reduced land-use emissions, and increased carbon capture and storage efforts. Climate models forced by RCP4.5 yield global temperatures that are 4°F above pre-industrial by 2100, with limited additional warming beyond 2060.

The most recent IPCC report uses a slightly different convention for describing these scenarios. The report uses so-called Shared Socioeconomic Pathways (SSP), which prescribe different narratives to the socioeconomic trends that shape future society – and resultant emission trajectories (IPCC, 2021). Notably, SSP2 describes a trajectory of socioeconomic development following historical patterns, including the adoption of moderate mitigation efforts, yielding an emission scenario following RCP4.5. This scenario assumes limited growth in human-caused carbon dioxide emissions through 2050, with emissions falling and reaching net zero by 2100 through the adoption of carbon sequestration and other negative carbon emission technologies. By contrast, SSP5 describes rapid global economic growth driven by carbon-intensive energy sources, yielding an emission scenario following RCP8.5. This scenario assumes carbon dioxide emissions triple by the end of the 21st century. We note that scenario SSP1 (SSP1-2.6) emphasizes sustainability and decarbonization of the economy, yielding limited additional change in radiative forcing beyond current levels. This scenario assumes emissions decline immediately, investment in carbon sequestration solutions, and net-zero carbon emissions for the latter half of the 21st century. Climate models forced by this scenario limit increase in global mean temperature to not less than 2°C (3.8°F) above pre-industrial levels.

Idaho's future climate

Temperature and precipitation

Climate projections from climate models participating in CMIP5 show continued and substantial warming through the 21st century. The magnitude of change in climate through 2050 is largely independent of climate action due to committed warming and inertia in the climate system. In contrast, the trajectories of change for the latter half of the 21st century are strongly influenced by the choice of current emission trajectories (see Box 3). Projected changes in temperature in Idaho largely mirror projected changes for the northwestern U.S. (Rupp et al., 2017; USGCRP, 2018). The annual mean temperature averaged for Idaho is projected to warm 11˚F on average above 1950-1999 values by 2100 under a high-warming scenario (RCP8.5), compared with a warming of 6˚F on average under a moderate-warming scenario (RCP4.5) (Figure 6a). Climate models have also been run using aggressive climate mitigation pathways (RCP2.6), with rapid reductions in emissions and implementation of negative carbon dioxide emission technologies that yield low-warming scenarios. We do not examine these projections here, but note that they tend to show slightly less warming by mid-century compared with a moderate-warming scenario, with nominal additional warming after mid-century. Individual models show varying rates of warming, but all models show faster rates of warming over the 21st century than in the 20th century.

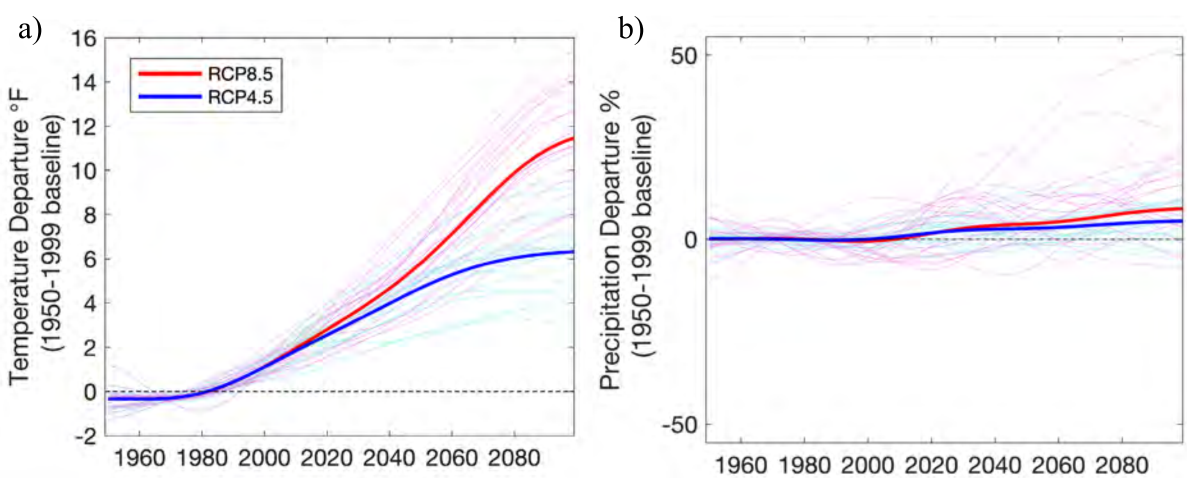

Figure 6: Smoothed traces of (a) annual mean annual temperature anomalies and (b) annual total precipitation departures for the Idaho region averaged over 42-49°N, 110-117°W relative to 1950-1999 averages for two future climate scenarios: moderate-warming scenario (RCP4.5, blue) and high-warming scenario (RCP8.5, red). Individual light traces show results for 20 CMIP5 models, while the thick line (blue and red) shows the CMIP5 multi-model ensemble mean. Data are smoothed using a 50-year low-pass filter to highlight long-term changes. Data source: Direct output from 20 climate models participating in CMIP5.

Accompanying changes in mean annual temperature are changes in seasonal temperatures that have a direct bearing on water resources, agriculture, and human health. The length of the freeze-free season is projected to increase substantially across Idaho (Figure 7a-b). For example, in Nampa, the length of the freeze-free season extends from around 160 days for the late 20th century to 210 days by the mid-21st century under a high-warming scenario. Climate projections also show more acute warming of the coldest temperatures of the year, which limit the severity of extreme cold (Parker and Abatzoglou, 2016), due to the amplified warming of continental Arctic air masses that are host regions for Idaho's cold air outbreaks.

Warming is projected throughout the year, with slightly greater warming in the summer months (Rupp et al., 2016). In addition, summer precipitation and cloud cover are projected to decrease slightly. Despite small decreases in relative humidity, increased temperatures and increased overall atmospheric moisture are projected to dramatically increase the occurrence of days with elevated heat index values across Idaho. The heat index – which incorporates a combination of air temperature and relative humidity – is used by the National Weather Service and health information services across the country to assess heat-related impacts. While Idaho has rarely seen heat indices exceeding 100˚F despite daytime highs topping the century mark, the Snake River Valley could see more frequent days where the heat index exceeds 100˚F by the mid-21st century (Dahl et al., 2019). For example, Boise has seen an average of less than 1 day per year with heat indices over 100˚F during the late 20th century (1971-2000). Model projections suggest the region could see upwards of two weeks of such conditions by the mid-21st century under a high-warming scenario (Figure 7c-d).

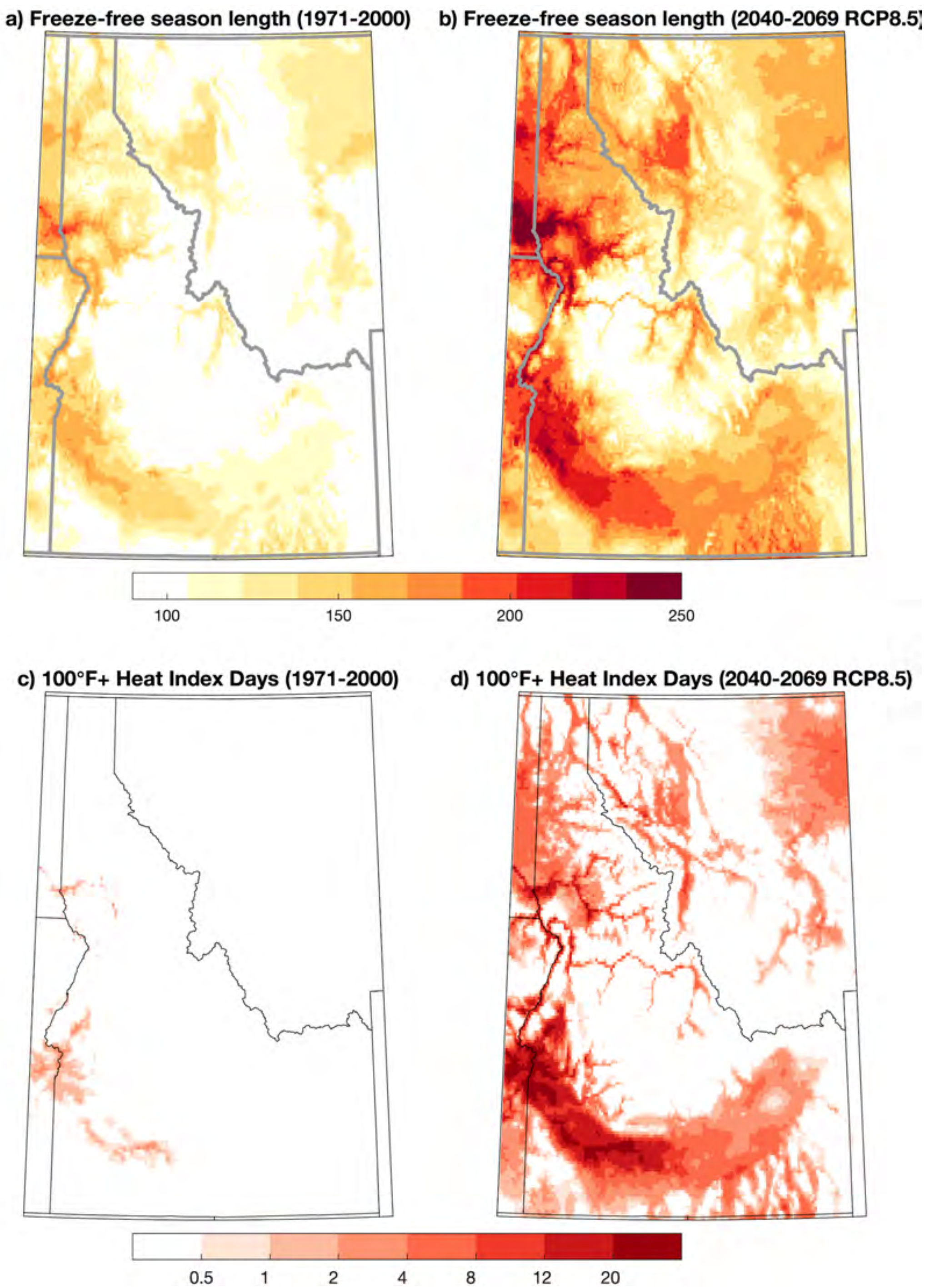

Figure 7: Maps of (a, b) length of the freeze-free season in days and (c, d) number of days with heat index above 100°F for the (a, c) late 20th century and (b, d) mid-21st century under a high-warming scenario (RCP8.5). Data source: MACAv2-gridMET downscaled data.

Projected changes include a slight increase (5-10%) in total annual precipitation by 2100, but there is substantial variability among the climate model projections (Figure 6b). Note that this increase in precipitation is far less than historical interdecadal variability (Figure 2b). This is in contrast to projected changes in temperature that greatly outpace historical interdecadal variability. The projected increase in mean annual precipitation is dominated by increases in winter and spring precipitation, whereas precipitation in summer is projected to slightly decline (Rupp et al., 2017; USGCRP, 2018).

While climate models simulate overall increases in mean annual precipitation across the state, the output from dynamically downscaled climate model output provides additional nuance that may further inform downstream impacts. Climate models suggest a slight decrease in westerly flow near mountain top level across the northwestern U.S. that would weaken upslope flow and orographic precipitation leading to reduced mountain precipitation (and weaker rainshadow-effect) in the cool season across the region (Luce et al., 2013). Similarly, studies have pointed to increases in cool season atmospheric stability that would reduce mountain precipitation relative to lower elevations (Shi and Durran, 2014; Rupp et al., 2017; Grose et al., 2019). As nearly all runoff in Idaho originates from mountain precipitation, mountain precipitation is critically important for many water-dependent sectors of the state.

In addition to changes in cumulative precipitation, models suggest changes in the character of precipitation. Climate models generally project increases in extreme precipitation magnitudes in mid-latitudes, with short-duration precipitation magnitudes increasing approximately 7% for every degree Celsius increase in temperature, substantially more than changes in average precipitation (O'Gorman et al., 2016; Prein et al, 2017). Likewise, the frequency of extremely heavy hourly precipitation during December-February is projected to increase 3-5 fold across Idaho by the end of the 21st century using a high-warming scenario (Prein et al., 2017). Compensatory changes in the frequency of precipitation are also projected for the region, with a few additional days per year without notable precipitation (Polade et al., 2015).

Snowpack

Despite uncertain projected changes in the total amount of precipitation, warming results in decreased snowpack as precipitation falls more as rain and less as snow (Peacock et al., 2011; Ashfaq et al., 2013; Mankin et al., 2015; Fyfe et al., 2017). April 1 volumetric snowpack storage across Idaho is projected to decrease by one-third by the mid-21st century under a high-warming scenario relative to the late 20th century (Gergel et al., 2017) – equivalent to the current potential reservoir storage in Idaho (Figure 8). Substantial reductions in the land area that is snow-dominated (i.e., areas where most precipitation falls as snow in the winter) are anticipated with warming (Klos et al., 2014). In addition, multiple consecutive years of snow drought—years with very low snow or snow that melts very early—are projected to become much more common, particularly in the northern part of the state (Marshall et al., 2019). Across parts of Idaho that averaged of 4 inches or more of annual maximum SWE during the late 20th century, multi-year snow droughts occurred in approximately 7% of these years; multi-year snow droughts are projected to occur 45% of the time by the period 2050-2079 in a high-warming scenario (Marshall et al., 2019).

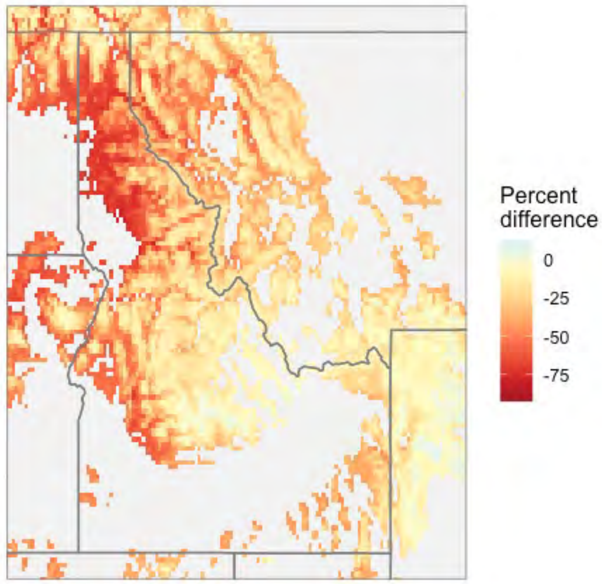

Figure 8. Percent difference in annual maximum snow water equivalent (SWE) from the historic (1970-1999) to future (RCP8.5, 2050-2079) case. Data source: Hydrologic simulations from the VIC model forced by downscaled climate projections from 10 different climate models – MACAv2-Livneh.

In addition to a reduction in total snowpack, several other projected changes to snow accumulation and melt dynamics affect snow-dependent social and ecological systems. A larger fraction of the annual snowpack is projected to come from large storm events (Lute et al., 2015) and snowmelt is projected to occur earlier in the year (Musselman et al., 2017; Marshall et al., 2019). In northern Idaho, rain-on-snow (ROS) events are projected to become less common due to the shorter duration of the snow season, while in the higher elevation regions of southern Idaho where snowpack is expected to persist, ROS events are projected to become more common as a consequence of increased spring rain with warming temperatures (Musselman et al., 2018). Despite more ambiguous changes in snowmelt contributions to flooding, hydrologic simulations suggest increases in annual maximum flows across the region as a result of increased rainfall magnitudes (Chegwidden et al., 2020; Queen et al., 2021). Finally, earlier snowmelt runoff (Parida and Buermann, 2014; Harpold and Molotch, 2015) and increased evapotranspiration in spring and early summer lead to decreased streamflow and heightened stress for water resources (e.g., Hamlet et al., 2010; Xin and Sridhar, 2012; Vano et al., 2015).

Drought

The likelihood, duration, magnitude, and character of drought are also likely to change across the state in the coming decades. As mentioned previously, definitions of drought can vary depending on impacts, but generally refer to water demands exceeding available supplies (Redmond, 2002).

The earlier timing of snowmelt and subsequent earlier drawdown of soil moisture result in decreased soil moisture and increased climatic water deficit (potential evapotranspiration minus actual evapotranspiration). Increased moisture deficits during summer are also expected to increase drought stress and associated disturbances in Idaho forests. For example, fuel moisture – a measure of the water content in vegetation – in Idaho forests is projected to decline substantially by the mid-21st century (Gergel et al., 2017), contributing to the escalating potential for large fires across the region (e.g., Barbero et al., 2015). Paradoxically, increased winter rainfall (rather than snow) in lower elevations of Idaho during periods of low water demand and unfrozen soil allows water to percolate to deeper soil moisture pools, leading to increased soil moisture in winter and spring for deeper soils while surface soil moisture declines (Berg et al., 2017). Meanwhile, increased temperature and evaporative demand increase water demand for irrigated agricultural systems in Idaho.

Warming, associated increased evaporative demand (i.e., evapotranspiration without surface water limitations), and reduced mountain snowpack all favor a future of increased summer drought, particularly in mountainous parts of the state where snowmelt is projected to occur earlier in the year. At larger scales, drought, as quantified through summer soil moisture and related metrics, is projected to increase substantially across much of the western U.S., including Idaho (Cook et al., 2015). However, drought, as viewed through the lens of solely precipitation accumulation, may not exhibit substantial changes, given the weak tendency for increased precipitation. Some studies have suggested that changes in climate will increase the likelihood of multidecadal drought across the west through the 21st century (Ault et al., 2016). The combination of warmer temperatures and changes in seasonal precipitation, superposed with naturally occurring megadrought conditions similar to those seen in the 12th century, would substantially impact water resources in Idaho (Overpeck and Udall, 2010).

An example of changing drought occurrence based on four different indicators averaged over the Upper Snake River Basin is shown in Figure 9. Drought conditions are nominally defined statistically as conditions that occur for 20% of years historically. Model projections for the period 2021-2050 indicate an uptick in drought occurrence based on low summer runoff, low summer soil moisture, and low spring snowpack. For example, models project that low April 1 snowpack that occurred one out of every five years in the late 20th century is projected to occur, on average, in one of every three years during the period 2021-2050. On the other hand, the frequency of low precipitation years is not projected to change significantly.

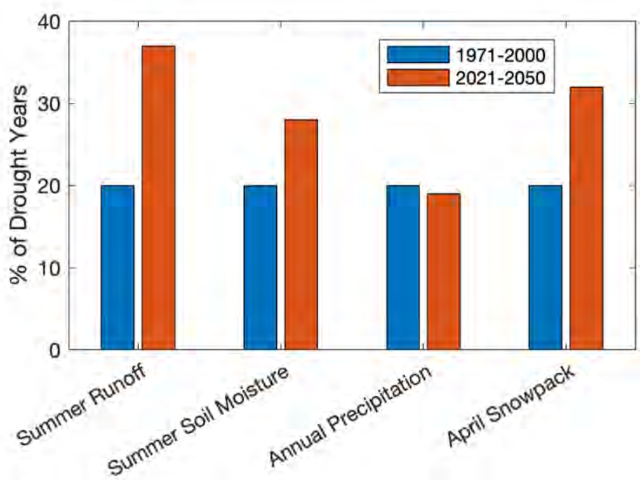

Figure 9: Modeled percent of years in drought for the period 1971-2000 (blue) and 2021-2050 (orange, scenario RCP4.5) in the Upper Snake River Basin averaged from 10 downscaled climate models. Drought conditions were defined as occurring for 20% of the driest years (e.g., driest 20% of years for summer runoff) for the period 1971-2000. Data source: MACAv2-gridMET and MACAv2-Livneh simulations.

Conclusion

Projected changes to Idaho's climate suggest very high confidence in warming trends, limited changes in total annual precipitation albeit a significant reduction in the proportion of precipitation falling as snow, and high potential for increased frequency of certain types of droughts. The magnitude of future changes is a function of global greenhouse gas emissions and sequestration pathways, with global pathways in conjoined climate and energy policies having measurable impact on changes in climate over the latter half of the 21st century. Natural climate variability, such as the El Niño-Southern Oscillation, is projected to continue to exert influence on Idaho's climate through the 21st century. The fusion of natural climate variability with shifting baselines imposed by climate change is likely to yield significant changes in certain climate and meteorological extremes. These changes pose serious challenges for the state's economic and cultural dependence on snow, water resources, forests, agriculture, and outdoor recreation.

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NOAA Fisheries WCR Anadromous Salmonid Design Manual - NMFS 2022

NOAA FISHERIES

NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual

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Table of Contents

Table of Appendices

Table of Figures

List of Tables

Acknowledgments

These engineering guidelines were developed through decades of work conducted by past and present NMFS fish passage engineers and biologists who laid much of the foundation for this document. We are grateful for their hard work and dedication. We also thank the numerous tribal, agency, and utility researchers; biologists; and engineers who contributed to an improved understanding of how juvenile and adult salmonids behave when approaching and passing structures. The state of knowledge on fish passage engineering has improved substantially over the course of developing these guidelines and will continue to do so over time as new engineering designs, evaluation techniques, and methods are developed and tested. We are also grateful to our reviewers who took the time to provide thoughtful and constructive comments to assist in updating these guidelines.

Acronyms and Abbreviations

Symbol or Acronym	Term or Title
°C	degrees Celsius
°F	degrees Fahrenheit
ASP	Alaska steeppass
AWS	auxiliary water system or auxiliary water supply system
BOR	U.S. Bureau of Reclamation
ft^3/s	cubic feet per second
EDF	energy dissipation factor
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FERL	Fisheries-Engineering Research Laboratory
FPA	Federal Power Act
ft^2	square foot
ft^3	cubic foot
ft/s	foot per second
$ft\text{-}lb/ft^3/s$	foot pounds per cubic foot of flow per second
GCF	grade control fishway
gpm	gallon per minute
HDM	Hydraulic Design Method
HGMP	Hatchery and Genetic Management Plan
lb	pound
LSSS	Low Slope Stream Simulation
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mm	millimeter
NMFS	National Marine Fisheries Service

Symbol or Acronym	Term or Title
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
PIT	passive integrated transponder
R/D	ratio of radius of curvature to pipe diameter
SSD	Stream Simulation Design
USACE	U.S. Army Corps of Engineers
VFD	variable frequency drive
WCR	West Coast Region

1 Introduction

The Environmental Service Branches provide technical and engineering assistance to National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) West Coast Region (WCR) fisheries biologists. NMFS also plays a supportive and advisory role in the management of living marine resources in the areas under state jurisdiction. This document is intended to assist with improving conditions for salmonids that must migrate past barriers to complete their life cycle. Effective Fish passage requires the integration of numerous scientific and engineering disciplines including, but not limited to, fish behavior, ichthyomechanics, hydraulics, hydrology, fluvial geomorphology and engineering. Installing a fish passage structure does not constitute providing satisfactory fish passage unless all of the above components are adequately factored into the design.

This document is intended to: provide internal assistance to NMFS biologists in designing effective fish passage; encourage consistency across the WCR region; while supporting the implementation of NMFS's statutory authorities related to the conservation and protection of marine resources; and provide technical assistance to project proponents.

The efficacy of any fish passage structure, device, facility, operation, or measure is highly dependent on local hydrology, target species and life stage, obstacle orientation relative to the stream, facility operation, and many other site-specific considerations. While the information provided herein will apply to many structures, it should be regarded as general guidance for the design, operation, and maintenance of fishways throughout the WCR. The criteria described in this document are not universally applicable and should not replace site-specific recommendations.

This document provides general guidance and is not intended as an alternative to active consultation with NMFS biologists and engineers. Application of these criteria in the absence of consultation does not imply approval by NMFS. This document provides criteria and additional guidelines for the design and operation of facilities at barriers to fish migration and water intakes in California, Washington, Oregon, and Idaho. The facilities are designed to create safe passage routes for adult and juvenile salmonids in rivers and streams and through reservoirs, restore habitat connectivity within watersheds, and enhance salmonid population productivity. NMFS's manual for fish passage facility design is meant to help NMFS staff advise project applicants on the engineering design of future fish passage projects and modifications to existing projects. The criteria are based on decades of experience developing, testing, operating fish passage systems and relies on the best available scientific information.

The WCR has developed a flow chart for how to use their various fish passage guidance documents (Figure 1). Prior to designing a fish passage facility, NMFS recommends the project proponent familiarize themselves with the "NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change" (Improving Resilience) guidance document. The Improving Resilience document outlines how to incorporate projected future flows the facility may experience over the life of the project and should be the starting point for the design process.

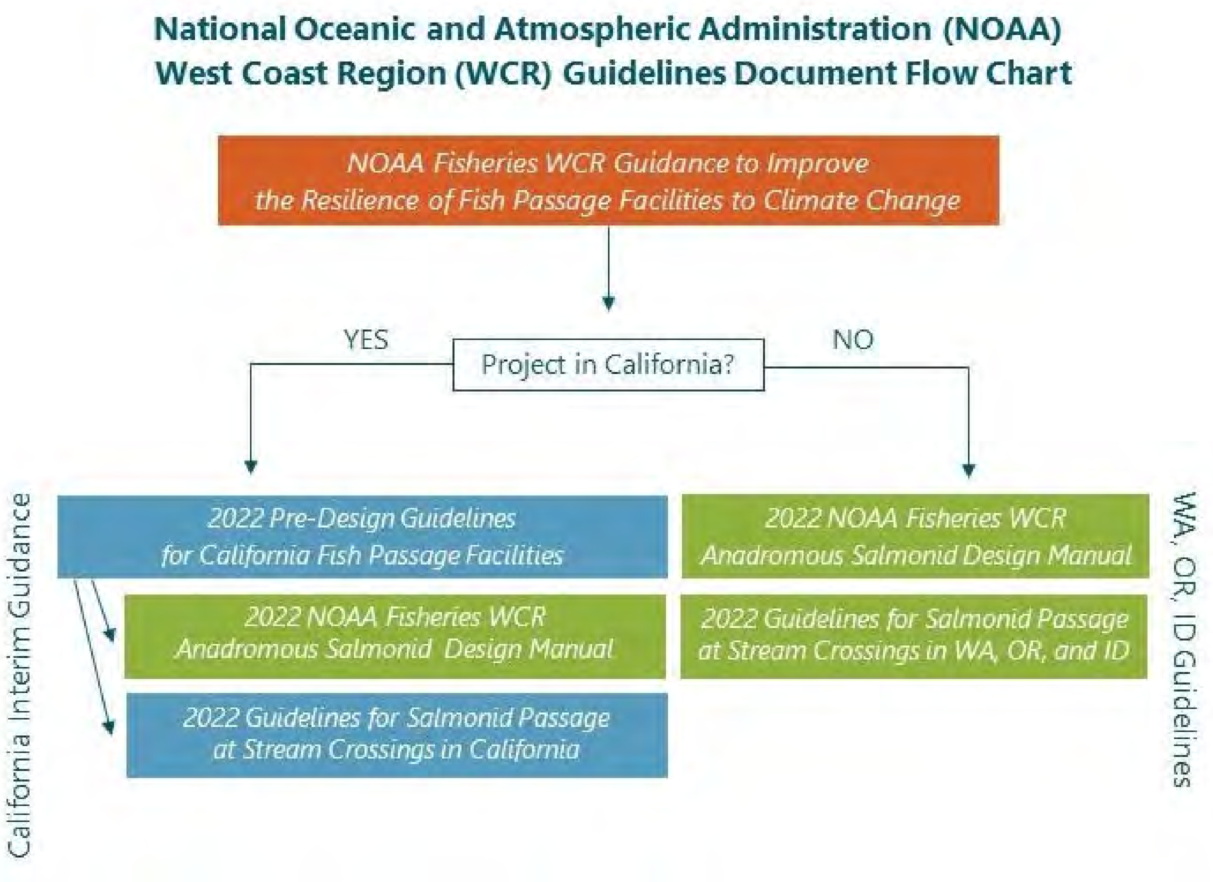

Figure 1-1. West Coast Region Fish Passage Guideline Flow Chart

In 2013, the Northwest and Southwest regions of the National Oceanic and Atmospheric Administration's (NOAA) NMFS were merged to form the WCR. This document is the first step in integrating fish passage design criteria and guidelines of the two former regions. This document, *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Guidelines* supersedes the following documents:

- Northwest Region's *Anadromous Salmonid Passage Facility Design*, dated July 2011
- Southwest Region's *Fish Screening Criteria for Anadromous Salmonids*, dated January 1997
- Southwest Region's Experimental Fish Guidance Position Statement, dated January 1994
- Southwest Region's Water Drafting Specifications, dated August 2001

This document provides criteria and guidance for passage of anadromous salmonids only. For additional passage guidance concerning non-salmonids, refer to applicable state and federal entities.

This document contains introductory chapters, technical chapters, and appendices. The introductory chapters (Chapters 1 and 2) provide the statutory and biological background for the requirement to provide safe, timely, and effective passage of salmonids around barriers and definitions of key terms. The technical chapters (Chapters 3 through 10) present design criteria and guidelines that result in hydraulic conditions salmonid fish require to successfully pass barriers and minimize effects to salmonid populations, along with the scientific basis for criteria for which applicable references are available. The appendices provide information on aspects of fish passage facility design that are under development and may change over time after additional testing. Additionally, the appendices contain background information that was removed from the technical chapters to make the chapters more streamlined, but still needs to be available to the reader because the information is informative and relevant.

Throughout the chapters all criteria are italicized to be easily identifiable. In addition, chapter and appendix sections are cross-referenced where applicable. For example, the chapter on screens may direct the reader to the chapter on design flows so a reader interested in screens will understand that additional information is available in another chapter.

NMFS has separated these fish passage engineering guidelines into two volumes. This first volume entitled *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual* provides design guidance for structural fish passage, protection, and exclusion projects not associated with river or stream crossings. This first volume represents guidelines that are based on decades of research, monitoring, and NMFS' experience with these types of passage systems. NMFS considers material in this volume to be in a mature state and does not anticipate it will change significantly over time.

The guidance in Chapter 4 of this volume applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat in those states. Due to significantly different hydrologic conditions in California and those conditions impact on life history of NMFS trust species, project proponents should work with NMFS engineering staff to determine the appropriate design flows following the 2022 Pre-Design Guidelines for California Fish Passage Facilities.

The second volume, entitled *Guidelines for Salmonid Passage at Stream Crossings in Oregon, Washington, and Idaho* (NMFS 2022b) represents a growing body of work relating to fish passage at stream crossings that NMFS expects will expand significantly in the future. Separating these guidelines into two volumes will allow NMFS to refine and expand this additional volume in the near future as new information becomes available, without having to reopen and modify the entire guidelines document. NMFS 2022b includes introduction matter as well as two technical chapters relating to stream crossings and grade control fishways.

The guidance in Chapters 3 and 4 of NMFS 2022b applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Given significantly different hydrologic conditions, stream crossing projects in California should refer to: *Guidelines for Salmonid Passage at Stream Crossings in California* (NMFS 2019, addendum).

These criteria and guidelines were developed based on 60 years of agency experience in creating successful fish facility designs and have been further refined through a collaborative process with regional fish facility design experts. The criteria and guidelines in Volume 2 address more emerging fields of fish passage engineering and stream restoration. The criteria and rationale provided will be revised as needed if new information suggests that updated criteria would further improve passage conditions for fish.

1.1 Statutory Background

NMFS is mandated by U.S. Congress to manage, conserve, and protect living marine resources within the U.S. Exclusive Economic Zone. NMFS is authorized to conduct these actions under the Federal Power Act (FPA; administered by the Federal Energy Regulatory Commission [FERC]), the Fish and Wildlife Coordination Act (administered by the U.S. Fish and Wildlife Service), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSA). This document provides criteria and technical assistance to project proponents on the design of fish passage facilities in order to provide safe, timely, and effective fish passage, consistent with NMFS responsibilities under the ESA, FPA, and MSA.

The requirement of safe, timely and effective passage derives from the unofficial but reliable definition of a fishway presented by Congress in a report related to the Energy Policy Act of 1992. The definition of "safe and timely passage" was expanded to include both passage structures and operations "necessary to ensure the effectiveness" of such structures. None of the terms "safe," "timely," or "effective" are further defined. However, in practice NMFS typically includes provisions which give these terms meaning. Regarding "safe" passage, NMFS requires licensees to design and operate their fishways so that they minimize the occurrence of injury or mortality experienced by fish while attempting to utilize the fishway. Regarding "timely" passage, a fishway prescription may include provisions for reducing the time in which a fish utilizing the fishway is subjected to stressful interactions, such as time spent in a trap or in transit, or a requirement for flows which will attract fish to a passage facility. Regarding "effective" passage, NMFS typically includes provisions requiring the operator to ensure that its facility succeeds in passing as close to 100% of the fish attempting to migrate through the system as possible.

Following these criteria will likely streamline processes, improve certainty, and improve the likelihood of success. NMFS also provides support and advice to states regarding the management of living marine resources in areas under state jurisdiction. This includes salmon (*Oncorhynchus spp.*) and steelhead (*O. mykiss*) due to their economic, cultural, recreational, and symbolic importance to society (NRC 1996).

NMFS pursues fish passage to contribute to its fishery management and ESA recovery goals. In reviewing, planning, designing, and implementing fish passage facilities, NMFS engineers will coordinate with NMFS biologists to make sure the particular target species, population numbers, migration timing and recovery goals are met.

1.2 Biological Background

Fish species within the family Salmonidae spawn in fresh water. Some species spend their entire lives in fresh water. Others spend a portion of their lives in marine waters where they grow and become sexually mature before returning to fresh water to spawn (Quinn 2005). The life history pattern that involves marine residence is known as anadromy, and salmonid species that display this pattern are referred to as anadromous salmonids.

NMFS has identified several key parameters that are used to judge the overall status and viability of salmon and steelhead populations. These include abundance, genetic diversity and life history diversity, productivity, and spatial structure (McElhany et al. 2000). NMFS considers a population to be viable if over a 100-year timeframe it can withstand threats and the risk of extinction from demographic variation, local environmental variation, and genetic diversity changes (McElhany et al. 2000). For examples of how these population parameters are used in viability assessments and recovery planning, see Lindley et al. (2007) and NMFS (2014). NMFS assesses any effects of barriers to migration and water intake structures on anadromous salmonids in the context of these parameters and overall population viability. The viability parameters are briefly described as follows:

Abundance. This is a commonly used species conservation and management parameter that refers to the number of organisms in a population.

Genetic diversity and life history diversity. Diversity refers to the distribution of traits within and among populations, which range in scale from DNA sequence variation at single genes to complex life history traits (McElhany et al. 2000). Genetic diversity and life history diversity are interrelated; thus, this parameter is not as straightforward as abundance. For example, a unique characteristic of anadromous salmonids is their high degree of fidelity to natal streams or rivers (Quinn 2005), which is a genotypic trait. This trait in turn facilitates local adaptations that result in phenotypic expressions of highly variable life history patterns (Taylor 1991; Waples 1991).

Life history diversity is often cited as a crucial component of salmonid population resiliency. This is based on evidence that maintaining multiple and diverse salmon stocks that fluctuate independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003). Schindler et al. (2010) describe this as the portfolio effect, where risk is spread across multiple stocks. Preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). In addition, it is increasingly recognized that strengthening a population's resilience to environmental variability, including climate change, will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

Productivity. Productivity represents the ability of a population to grow when conditions are suitable, which is essential to conservation success. In the absence of density-dependent factors, productivity is a measure of a population's ability to survive to reproduce and its reproductive success (McElhany et al. 2000). Populations that are below cohort replacement rate or have limited ability to respond to favorable environmental conditions are less viable and at higher risk of extinction.

Spatial structure. This parameter refers to the geographic distribution of individuals in a population or populations. A population's spatial structure comprises the geographic distribution of individuals and the processes that generate that distribution (McElhany et al. 2000). The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population among the available habitats (McElhany et al. 2000).

The viability of salmonid populations can change over time, and NMFS considers the potential for this to occur when reviewing fish passage designs. Changes in population viability could occur from multiple factors, including the following:

- Terminating or adding new hatchery supplementation programs
- Recolonization of historical habitats after removal of a migration barrier
- Increased partitioning of the spatial structure of a population due to new barriers being installed and loss of access to habitat
- Habitat degradation and restoration
- Shifts in river hydrology and water temperature due to climate change
- Disasters (fires, landslides, etc.)
- Changes in water management

1.3 Migration Barriers

Anthropogenic barriers include, but are not limited to, hydroelectric dams, water storage projects, irrigation diversions, water withdrawals, and tide gates. Dams can have significant effects on the structure and function of river ecosystems (Ward and Stanford 1979), and change in flow regulation is considered one of the most pervasive changes to rivers worldwide (Stanford et al. 1996). The effects of restricted access to migrating fish caused by dams and weirs have been broadly implicated in population declines of freshwater species around the world (Northcote 1998).

Dams can block access to habitat, eliminate habitat in the footprint of a dam and reservoir, affect the amount and timing of water flow, and result in mortality during passage (Ruckelshaus et al. 2002). Columbia River dams have blocked access to nearly 40% of the habitat historically available to salmon (NRC 1996). Construction of Hells Canyon Dam resulted in the loss of 90% of the historical spawning habitat of fall-run Chinook salmon (*O. tshawytscha*) in the Snake River, Idaho (McClure et al. 2001). In California, approximately 95% of Chinook salmon spawning habitat has been lost or is no longer accessible (Yoshiyama et al. 1996). Smaller water diversions can block access to habitats as well as cause mortality from entrainment at unscreened (or improperly screened) diversions and predation above or below the diversion. Another example, is the substantial amount of historical spawning and rearing steelhead habitat rendered unavailable in the Santa Clara River (due to the construction of dams). Santa Felicia Dam blocks 95% of the steelhead habitat within the Piru Creek watershed; more than 30 miles of stream lies between Santa Felicia Dam and Pyramid Dam (NMFS 2006 and references therein).

Dams blocking passage of steelhead to upstream habitats constitute an obstruction within a freshwater migration corridor for the species and, therefore, an impact to steelhead habitat.

In summary, some anadromous salmonid populations migrate hundreds of miles in fresh water, and barriers in their migration corridors can affect population viability (Ruckelshaus et al. 2002). This includes barriers that are complete blockages as well as barriers that are partial blockages due to localized hydraulic conditions or poorly functioning passage facilities. NMFS is responsible for evaluating the degree to which barriers affect anadromous salmonid populations and providing guidance on how to resolve any migration effects.

1.4 Design Process

Resolving effects on salmonid migrations from barriers involves the integration of information on fish behavior and physiology, biomechanics, hydraulic and hydrologic conditions, and civil engineering. Simply installing a fish passage structure does not constitute providing satisfactory fish passage. A successful design requires that information on each of these components be factored into the design.

Instances can also occur where a fish passage facility may not be a feasible solution for correcting a passage impediment due to biological, societal, or economic constraints. In these situations, removal of the impediment or altering project operations may be a suitable surrogate in lieu of constructing fish passage facilities (Clay 1995).

When determining whether NMFS will promote or prescribe solutions to fish passage issues, NMFS will rely on a collaborative approach that considers the views of other fisheries resource agencies, Native American tribes, non-governmental organizations, citizen groups, and other governmental agencies. The approach strives to consider fish passage objectives developed by other parties (e.g., well-placed stakeholder groups) to support fisheries restoration and habitat enhancement actions identified in conservation plans.

This document addresses design features that may provide for to the safe, timely, and effective passage of fish. It is the responsibility of the design engineer to ensure that other design requirements are met such as the structural integrity of the facility and public safety.

This document provides specific fish passage facility design criteria and technical assistance for actions within the WCR pertaining to the various authorities of NMFS. When reviewing fish passage proposals by project proponents, NMFS will apply the criteria to major upgrades to existing facilities and the design of new fish passage facilities to the extent practicable. Existing facilities that are not compliant with this document may have to be modified using the criteria identified herein if fish passage problems are observed at these facilities. If the project is unable to meet the criteria, then the project proponent should continue to work with NOAA staff in developing a recommended solution that would best attain fish passage goals for the project.

1.5 Experimental Technologies

Experimental technologies include devices or systems that have demonstrated some potential for protecting or passing fish, but for which adequate scientific evidence has not been collected to verify effectiveness and gain agency acceptance or to be considered for general application (AFS 2000). Experimental technologies are new, innovative and unproven technologies that could be broadly applied, rather than deviations from criteria applying to a single site.

NMFS considers experimental technologies to include designs with major departures from conventional fish passage technologies as covered in this document. Experimental technologies may also include application of proven techniques to unusual environmental conditions or facility operations. Site specific deviations from criteria may not rise to the level of experimental designs, but rather warrant a conversation between the applicant and appropriate NMFS staff.

Proponents of experimental fish passage designs should provide NMFS with a sound biological or scientific basis to support the proposed design. This may include the following proof-of-concept steps as appropriate:

- A demonstrated, favorable fish behavioral response in a laboratory setting
- An acceptable plan for evaluating the prototype installation
- An acceptable alternate fish passage design developed concurrently with the unproven fish passage design that satisfies the criteria listed herein, should the prototype not perform as anticipated nor adequately protect fish

Appendix C (Experimental Technologies) provides additional information on the NMFS approval process for unproven fish passage technologies.

1.6 Temporary and Interim Passage

Where construction and/or modifications to artificial impediments (e.g., dams), natural impediments (rockslides, other natural issues) or upstream passage facilities are planned, upstream and downstream passage may be adversely impacted or interrupted. If possible, these activities should be scheduled for periods when migrating fish are not present, as specified in the in-water work period allowable for construction of facilities in streams. However, this may not always be possible or advisable. In these cases, an interim fish passage plan should be prepared and submitted to NMFS for review, in advance of work in the field.

In the interim plan, upstream and downstream fish passage should be provided for any adult or juvenile fish likely to be present in the action area during construction, unless passage did not exist before construction or where the stream reach is naturally dry at the time of construction. Methods for work area isolation and dewatering, as necessary, should be determined in consultation with NMFS.

Design criteria listed elsewhere in this document also apply to the interim passage plan. Where this is not possible, project owners should seek NMFS review of alternate interim fish passage design criteria, and a final interim passage plan. Coordination with NMFS ahead of time is advised to determine appropriate work windows and other recommended alternatives or both.

1.7 Section 7 Consultation under the Endangered Species Act

This fish passage manual can be useful during ESA Section 7(a)(2) and Essential Fish Habitat (EFH) consultations. Incorporating the criteria within this document will help project proponents design projects that provide fish passage in a variety of situations. During the design process project developers can incorporate criteria within this document and work with NMFS engineers and biologists to ensure their projects meet these fish passage criteria. While this document provides substantial criteria related to fish passage, there are aspects of project design that are beyond the scope of this document. For instance, this manual does not identify or endorse specific construction best management practices. Project developers should coordinate with NMFS on project elements that fall outside the scope of this document.

This manual can also be used to achieve regulatory streamlining by aiding in the development of programmatic ESA and EFH consultations on activities involving fish passage. By incorporating these criteria into programmatic actions, action agencies and other stakeholders can help ensure their actions provide fish passage and appropriate conservation for protected resources, while streamlining the regulatory process.

1.8 Additional Information

Additional information on fish passage is available at the WCR website: http://www.westcoast.fisheries.noaa.gov/. Questions regarding this document and requests for assistance from NMFS fish passage specialists can be directed to the following offices:

For Washington, Oregon, and Idaho:

NOAA Fisheries West Coast Region
Environmental Services Branch
1201 Northeast Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

503-230-5400

For California:

NOAA Fisheries West Coast Region
Environmental Services Branch
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2 Definition of Terms

Anadromous – pertaining to a fish species that displays the life history pattern known as anadromy in which adults spawn in fresh water and juveniles migrate to sea to grow to their final size and then return to fresh water to spawn (Quinn 2005).

Active screens – juvenile fish screens equipped with efficient mechanical cleaning capability that are automatically cleaned as frequently as necessary to keep the screens free of any debris that may restrict flow through the screen area. NMFS requires active screen designs in most cases.

Applicant – a person or entity that proposes to design, modify, or construct a fish passage facility at an existing or new barrier, water diversion, or water conveyance that NMFS will review under its authorities identified in Chapter 1.

Approach velocity – the vector component of canal velocity that is normal (perpendicular) to, and immediately upstream of, the screen surface. Approach velocity is calculated based upon the submerged area of the screen for conical screens, all cylindrical screens (torpedo, T-screen, and end-of-pipe or hose screens) where submergence and clearance criteria are met, and inclined screens where angle and submergence requirements are met. For rotary drum screens, approach velocity is the vector component of canal flow velocity that is normal to, and immediately upstream of, the vertical projection of the screen surface.

Approach velocity is a design parameter that is used to calculate the minimum amount of effective screen area required to protect fish. The amount of effective screen area required to meet screen performance criteria is calculated by dividing the maximum diversion flow by the approach velocity. Approach velocity can be measured in the field with precise flow measurement equipment, and average operating approach velocity can be calculated by dividing the measured screen flow by the effective screen area. Approach velocity should be measured as close to the boundary layer of turbulence generated by the screen face as is physically possible. Chapter 8 provides a more detailed discussion of approach velocity.

Apron – a flat or slightly inclined slab of concrete below a flow control structure that provides erosion protection and produces hydraulic characteristics suitable for energy dissipation or, in some cases, fish exclusion.

Attraction flow – flow that emanates from a fishway entrance with sufficient velocity and quantity, and in the proper location and direction, to attract upstream migrants into the fishway entrance. Attraction flow consists of gravity flow from the fish ladder and any auxiliary water system (AWS) flow added at points within the lower fish ladder.

Auxiliary water system or auxiliary water supply system (AWS) – a hydraulic system that augments fish ladder flow at various points in a passage facility for upstream migrating fish. Large amounts of auxiliary water flow are typically added near the fishway entrance pool to increase the amount of attraction flow emanating from the fishway entrance and the attractiveness of the entrance to fish.

Backwash – a system that removes debris from dewatering screens by using pressurized flow against the screen surface in the opposite direction of the approach flow.

Backwater – a condition whereby a hydraulic drop is influenced or controlled by a water surface control feature located downstream of the hydraulic drop.

Baffles – physical structures placed in the water flow path designed to dissipate energy or redirect flow to achieve more uniform flow conditions.

Bankfull flow– the bank height when a stream or river channel is inundated under a flow that occurs at the 1.2-year to 1.5-year average flood recurrence interval. Bankfull height may be estimated by morphological features in the channel such as: 1) a topographic break from a vertical bank to a flat floodplain or from a steep to a gentle slope; 2) a change in vegetation from bare ground to grass, moss to grass, grass to sage, grass to trees, or no trees to trees; 3) a textural change of depositional sediment; 4) the elevation below which no fine debris (e.g., needles, leaves, cones, seeds) occurs; and 5) a textural change of fine sediment deposits (matrix material) between cobbles or rocks.

Bedload – sand, silt, gravel, soil, and rock debris transported by moving water on or near the streambed.

Bifurcation (trifurcation) pools – pools in a fish ladder below which the fish ladder (and flow) is divided into two or three separate routes.

Brail – a device that is moved upward (vertically) through a water column to crowd fish into an area for collection.

Bypass flow – in the context of dewatering screen design, the portion of diverted flow that is specifically used to return fish to the river.

Bypass reach – the portion of the river between the point of flow diversion and where bypassed flow and fish are returned to the river.

Bypass entrance – an unscreened opening in a facility that fish can enter, and after which are conveyed in flow to a sampling facility or back to the stream or river. The number and locations of entrances at a facility can range from one to several and are discussed in Chapter 8.

Bypass system – the component of a downstream fish passage facility that conveys (transports) fish from the diverted flow back into the body of water from which they originated. Bypass systems typically consist of entrance, conveyance (flume or pipe), and outfall structures.

Canal velocity – the water particle speed (feet per second) in a canal flowing parallel to the streambank.

Channel bed width – the width of the streambed under bankfull channel conditions.

Conceptual design – an initial design concept based on the site conditions and biological needs of the species intended for passage, also sometimes referred to as preliminary design or functional design. This is the first phase in the design process of a fish passage facility and is discussed in Chapter 3.

Crowder – a combination of static or mobile panels installed in a fishway, raceway, or holding pool for the purpose of moving fish into a specific area for sampling, counting, broodstock collection, or other purposes. Crowder panels are usually porous and constructed of perforated plate or picket bars. The panels can also be fabricated using solid, non-porous materials. Also, see the definition for picket leads in this chapter.

Diffuser – a system of hydraulic components arranged to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy, uniform flow. A diffuser also includes one or more panels of narrowly spaced horizontal or vertical bars to prevent fish from passing through the bars and entering the area upstream of the panels.

Distribution flume – a channel used to route fish to various points in a fish trapping system.

Effective screen area – the total wetted screen area minus the area occluded by major structural elements.

End of pipe screen – juvenile fish screening devices attached directly to the intake of a diversion pipe.

Entrainment – the diversion of fish into an unsafe area or passage route.

Exclusion barriers – facilities that prevent upstream migrants from continuing to migrate upstream. These are typically used to prevent fish from entering areas that have no egress route or may result in fish being injured.

Exit control section – the upper portion of an upstream passage facility that provides suitable passage conditions to accommodate varying forebay water levels. Water level fluctuation is accommodated by adjusting the pool geometry and weir design, and by adding or removing flow at specific locations.

False weir – a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to move into a specific area. The device usually creates a strong upwelling flow that cascades over a weir. Fish are attracted to the cascading flow and swim through the upwelling into a distribution flume.

Fish ladder – the structural component of an upstream fish passage facility (or fishway) that allows fish to move over a barrier by dissipating the potential energy caused by the head differential that results from a barrier being placed in a waterway. The ladder dissipates energy using a series of discrete pools, a series of baffled chutes and resting pools, or uniformly with a single baffled chute placed between an entrance pool and an exit pool.

Fish lift – a mechanical component of an upstream passage system that provides fish passage by lifting fish in a water-filled hopper or other lifting device into a conveyance structure that delivers upstream migrants past the impediment.

Fish lock – a mechanical and hydraulic component of an upstream passage facility that raises fish over a dam by attracting or crowding fish into a chamber, closing access to the chamber, and filling the chamber until the water surface in the lock chamber reaches (or comes sufficiently close to) the reservoir forebay level. Once at this water surface elevation, a gate to the chamber is opened, allowing fish to swim into the reservoir above the dam (Clay 1995). Fish locks can also be used as part of a trap and haul system to lift fish from the river level to a higher elevation for sorting, or transportation, or both.

Fish passage season – the range of dates that characterize when juvenile or adult life stages of a species will arrive at a specific location during their downstream or upstream migration. The locations could include, for example, a dam or an existing or proposed fishway.

Fish weir (also called picket weir, picket lead, or fish fence) – a device with closely spaced pickets or bars that allows water flow to pass, but precludes fish from migrating farther upstream. This term is normally applied to the device used to guide adult fish into a trap or counting window. This device is not a weir in the hydraulic sense.

Fishway – the suite of facilities, structures, devices, measures, and project operations that constitute and are essential to the success of an upstream or downstream fish passage system. The suite provides a water passage route around or through an obstruction that is designed to dissipate the energy in such a manner that enables fish to ascend the obstruction without undue stress (Clay 1995).

Fishway entrance – the component of an upstream passage facility that discharges attraction flow into the tailrace of a barrier and that upstream migrating fish use to enter the facility.

Fishway entrance pool – the pool immediately upstream of the fishway entrance(s) where fish ladder flow combines with AWS flow to form the attraction flow.

Fishway exit – the component of an upstream fish passage facility where flow from the forebay of the dam or barrier enters the fishway, and where fish exit the ladder and enter the forebay upstream of the dam.

Fishway weir – the partition that divides two pools in a fishway and passes flow between adjacent pools.

Flood frequency – the probable frequency that a streamflow will recur based on historical flow records. For example, a 100-year flood event refers to a flood flow magnitude that is likely to occur on average once every 100 years or has a 1% chance of being exceeded in any given year. Although calculating possible flood recurrence is often based on historical records, there is no guarantee that a 100-year flood will occur within the 100-year period, or not occur several times within that period.

Floodplain – the area adjacent to a stream that is inundated during periods of flow that exceed the channel capacity the stream has established over time.

Flow control structure – a structure in a water conveyance designed to maintain flow in a predictable fashion.

Flow duration exceedance curve – the plot of the relationship between the magnitude of daily flow and the percentage of time during a specific period that flow is likely to be equaled or exceeded. Flow exceedance curves may use flow data from an entire year or part of a year. For example, the 1% annual exceedance flow is the flow level exceeded 1% of the time within the entire year (i.e., 3.6 days on average), whereas the 1% exceedance flow for the fish migration window is the flow level exceeded 1% of the time during the fish passage season for a particular species and location. Exceedance values are usually derived using daily average flow data.

Forebay – the waterbody located immediately upstream of a dam that results from the dam impounding river flow behind the structure.

Freeboard – the height of a structure that extends above the maximum water surface elevation.

Fry – a juvenile salmonid with an absorbed egg sac that is less than 60 millimeters in total length (as defined for the purposes of this document). An embryo develops within an egg until it hatches. The hatchling (alevins) feeds off the large external yoke sac for nourishment, grows, and emerges from the spawning gravel as a fry when it can feed on its own (Quinn 2005).

Functional design – an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as preliminary design or conceptual design. Also, see the definition for conceptual design in this chapter. The functional design commonly includes the general layout, interior dimensions, and specifications covering the hydraulic features of the fishway (Clay 1995).

Hatchery supplementation – hatchery programs designed for hatchery-origin fish to spawn in the wild and make a contribution to the conservation of a species or population (HSRG 2009).

Head loss – the irreversible reduction in total head (total energy per unit weight) of water as it flows through conduits, open channels, spillways, turbines, and other hydraulic structures. Total head is the sum of elevation head, pressure head, and velocity head. Head is described in units of length, usually in feet or meters.

Hopper – a device used to lift fish in water from a collection or holding area for release upstream of a barrier or into a transportation truck.

Hydraulic drop – the difference in total head between an upstream water surface and a downstream water surface. It includes the sums of the elevation head, pressure head, and velocity head at the upstream and downstream water surface locations. Also, see the definition for head loss in this chapter.

For fishway entrances and fishway weirs, the differences in velocity head and pressure head are usually negligible, and only water surface elevation differences are considered when estimating hydraulic drop across the structure.

Impingement – the condition where a fish comes in contact with the surface of a dewatering screen and remains on the screen. This occurs when the approach flow velocity immediately upstream of the screen exceeds the swimming capability of a fish given its size and condition. Impingement can injure a fish, and prolonged contact with a screen surface or bar rack can result in mortality. One objective of NMFS' approach velocity criterion is to eliminate the possibility for healthy salmonid fry or larger fish to become impinged on a screen surface or bar rack.

Infiltration gallery – a facility used to withdraw surface water from beneath the streambed.

Intermediate bypass entrance – a bypass entrance installed upstream of the main bypass entrance. Also, see the definition of bypass entrance in this chapter. Chapter 8 provides guidelines on the number of bypass entrances needed in a bypass facility and their location.

Invert – the lowest inside surface of a culvert or flume.

Kelts – an adult steelhead that survived spawning and is migrating downstream (Quinn 2005).

Off-ladder trap – a facility or system for capturing fish located adjacent to a fish ladder in a flow route that is separate from the normal fish ladder route. This system allows fish to pass a barrier via the ladder or be routed into the trap, depending on the management objectives for the species or population at the facility.

Minimum effective screen area – the maximum screen flow divided by the allowable approach velocity.

Passive screens – juvenile fish screens that do not have an automated mechanical cleaning system.

Picket leads or pickets – a set of narrowly spaced vertical or inclined flat bars or slender circular cylinders designed to exclude fish from a specific route of passage. Picket leads are similar to diffusers, but picket leads generally lack the ability to control the flow rate or significantly alter the flow distribution. Also, see the definitions of a fish weir and crowder in this chapter.

PIT-tag detector – a device used to scan fish for the presence of a passive integrated transponder (PIT) tag implanted in the fish. While passing through the detector, PIT tags transmit a unique identifying number that can be read at a short distance, depending on the tag size, type, and antenna design. These passive tags operate in the radio frequency range and are inductively charged and read by the detector. They do not have a battery and can remain operational for decades.

Plunging flow – flow over a weir that falls into a receiving pool where the water surface elevation of the receiving pool is lower than that of the weir crest elevation. Surface flow in the receiving pool is typically in the upstream direction, downstream from the point of entry into the receiving pool. Also, see the definition for streaming flow in this chapter.

Porosity – the percent open area of a mesh, screen, rack, or other flow area relative to the entire gross area.

Positive exclusion – a means of excluding fish by providing a barrier the fish cannot physically pass through.

Preliminary design – an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as a functional design or conceptual design. Also, see the definition for conceptual design in this chapter.

Ramping rates – the rate at which the water surface level at a specific point in a river is artificially altered (either increased or decreased) over a specific time period as a result of changes in the regulation of flow upstream. The rate is typically measured and stated as the change in vertical inches per hour.

Rating curve – graphed data depicting the relationship between water surface elevation and streamflow.

Redd – the nest a female salmonid excavates, deposits embryos into, and immediately buries with gravel substrate. Redds can be located in streams, rivers, or lake beaches. The locations selected vary with populations and species (Quinn 2005).

Rotary drum fish screen – a horizontally oriented cylinder (drum) constructed of fish screen material. Rotary drum screens include an active cleaning method and at least one fish bypass route. The drum rotates on its horizontal axis during each cleaning cycle. Debris deposited on the upstream surface of the drum is lifted by the rotating drum and washed off the downstream surface of the drum by the flow passing through the drum. Fish are guided to a bypass entrance upstream of one end of the screen array.

Screen material – the material that provides physical exclusion to reduce the probability of entraining fish into diverted flow. Examples of screen material include perforated plate, bar screen, and woven wire mesh.

Scour – erosion of streambed material resulting in the temporary or permanent lowering of the streambed profile.

Soffit – the inside top of culvert or underside of a bridge.

Smolt – a juvenile salmonid that has completed its freshwater rearing cycle and initiated a downstream migration to reach a marine environment. To prepare for seawater, the freshwater life stage (parr) undergoes a physiological and osmoregulatory transition and begins its downstream migration. Fish in this transitional stage between fresh water and marine rearing that are actively migrating downstream are termed smolts (Quinn 2005).

Streaming flow – flow over a weir that falls into a receiving pool and where the water surface elevation of the receiving pool is above the weir crest elevation. In these situations, surface flow in the receiving pool is typically in the downstream direction and away from the point where flow enters the receiving pool.

Sweeping velocity – the vector component of water particle speed that is measured parallel to, and immediately upstream of, the screen surface.

Tailrace – the portion of the water channel below a dam that conveys turbine and spillway discharge downstream from the dam.

Tailwater – the body of water immediately downstream of a dam or other in-stream structure.

Total project head – the difference in water surface elevation from upstream to downstream (or from the headwater to the tailwater) of a barrier such as a dam or weir. Normally, total project head encompasses a range of values based on streamflow and the operation of flow control devices.

Thalweg – the streamflow path following the deepest parts (i.e., the lowest elevation) of a stream channel.

Tide gate – a mechanical device that allows flow to pass in one direction but not in the opposite direction. Tide gates are often used as part of a levee or dike system to allow streamflow into a bay or estuary during ebb tides and prevent the flow of saltwater to pass in the opposite direction and enter the area upstream of the levee or dike during flood tides.

Training wall – a physical structure designed to direct flow to a specific location or in a specific direction.

Transport channel – a hydraulic conveyance designed to allow fish to swim between different sections of a fish passage facility.

Transport velocity – the velocity of the flow within a transport channel of a fishway.

Trap and haul – the collection, loading, and transportation of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or at another location, and juvenile fish from a collection site at or above a barrier to a release point located downstream from the barrier or at another location.

Trash rack – a rack of vertical bars with spacing designed to catch debris and preclude it from entering the fishway or other hydraulic structure but allows fish to pass through the openings between bars. Trash racks are also referred to as a grizzly.

Trash rack, coarse – a rack of widely spaced vertical bars designed to catch large debris and preclude it from entering a fishway, while providing sufficient openings between the bars to allow adult fish to exit the fishway.

Trash rack, fine – a rack of narrowly spaced vertical bars designed to catch both small and large debris and reduce or eliminate the entry of fish into the intake of an AWS.

Turbine intake screens – partial flow screens positioned within the upper portion of a turbine intake that guide fish entering the turbine into a collection system for transport or bypass back to the river. Turbine intake screens are installed at most mainstem Columbia and Snake River dams operated by the U.S. Army Corps of Engineers (USACE; Appendix G).

Upstream fish passage – fish passage relating to the upstream migration of adult and juvenile fish.

Upstream passage facility – a fishway system designed to pass fish upstream of a passage impediment, either by volitional passage (i.e., under their own swimming capability) or non-volitional passage (i.e., via a lift or transport vehicle).

Vee screens – a pair of vertically oriented juvenile fish screens installed in a vee configuration (i.e., positioned symmetrically about a centerline), and where the bypass entrance is located at the apex of the two screens. Vee screens are also referred to as chevron screens.

Velocity head, h_v – the kinetic energy per unit weight of fluid due to its velocity; h_v has the units of length (usually in feet or meters) and is calculated as shown in the following equation:

$$h_v = v^2/2g$$

where:

v = velocity of the fluid (feet per second, meters per second)
g = acceleration due to gravity (32.2 feet per second^2, 9.81 meters per second^2)

Vertical barrier screens – screens located between the bulkhead (upstream) and operating (downstream) gate slots at mainstem dams on the Columbia and Snake rivers operated by the USACE. The screens keep fish diverted into the bulkhead slot by turbine intake screens from passing back into the turbine through the operating slot. Fish retained in the bulkhead gate slot by the vertical barrier screen enter a specially designed juvenile fish bypass system through orifices. (Figure G-4 in Appendix G.)

Volitional passage – fish passage whereby fish transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish pass through the facility without the aid of any apparatus, structure, or device (i.e., they are not trapped, mechanically lifted or pumped, or transported).

Wasteway – a conveyance that returns excess water originally diverted from an upstream location back to the stream or channel from which it was diverted.

Weir – a low wall or dam built across the width of a river that pools water behind it while allowing water to flow steadily over the top of the structure.

3 Design Development

3.1 Introduction

Chapter 3 describes the general process NMFS follows and the types of information required during project design. Fish passage project designs subject to NMFS engineering review are typically developed in two major phases. The major phases are the preliminary design (Section 3.2.1), also referred to as the functional or conceptual design, and the final design (Section 3.2.2), which results in the development of detailed plans and specifications.

A review by NMFS of an applicant's fish passage facility designs will be conducted in the context of whether they meet the recommended criteria and technical assistance listed in this document.

Fish passage facilities refer to physical structures, facilities, or devices used to provide safe, timely, and effective passage for all life stages of fish as identified in Section 1.1 of this document. During its review, NMFS will consider site-specific information, including site limitations, biological information, and operations and maintenance (O&M) information provided by the applicant. Although the submittal of all information discussed in Chapter 3 may not be required in writing, the applicant should be prepared to describe how the biological and site information was included in the development of the project design.

3.2 Design Process

Both the preliminary and final designs should be developed in cooperation and interaction with WCR biological staff from effected Branch and engineering staff from the Environmental Services Branch.

To facilitate an iterative, interactive, and cooperative process, project applicants are encouraged to initiate coordination with NMFS early in the development of the preliminary design. Early and frequent interactions can aid in a smooth review process. NMFS' preference is to work with applicants in developing alternatives that comply with ESA. In general, NMFS cannot complete a project review of design plans that are submitted without the supporting information (listed in Section 3.3).

Project applicants should consult with NMFS on all phases of a design. Section 3.2.2 provides the minimum information needed for NMFS review. Large, complex projects will likely have multiple iterations within each of the two major design phases. As multiple design iterations are developed, each iteration should be made available to NMFS for review.

3.2.1 Preliminary Design

Depending on the size and complexity of the project, NMFS typically requests that it be allowed to review and provide comments on the 30%, 60%, and 90% design iterations of the preliminary design. Due to the nature of the review process, such as applications for a FERC license and ESA consultation, a preliminary design should be developed in cooperation and interaction with biological and engineering staff from the NMFS WCR. The preliminary design should be complete and to allow the application or engineering review to move forward.

The preliminary design establishes a preferred alternative based on comprehensive evaluations of the key elements of the design. This first phase in the design of a fish passage facility includes the following steps. Project proponents should:

1. Engage with project stakeholders and ascertain their operational requirements.
2. Identify and prioritize project objectives and the associated functional requirements.
3. Assemble the design criteria of the federal, state, and tribal fish resource agencies.
4. Collect pertinent biological, hydrological, and engineering information.
5. Develop appropriately scoped geomorphic assessments for the project.
6. Define project reliability and backup or contingency parameters.
7. Develop a process for evaluating and ranking alternative designs and operations.
8. Generate alternative designs and select the preferred alternative.
9. Develop initial layout drawings and models as needed to describe the facility.
10. Describe the operational requirements of the major facility sub-components

The preliminary design results in a facilities layout that includes section drawings and the identification of component sizes and water flow rates for the primary project features. Cost estimates are also included in the preliminary design. Completion of the preliminary design commonly results in a document that may be used for budgetary and planning purposes and for soliciting (and subsequently collating) design review comments provided by other reviewing entities. The preliminary design is usually considered to be at the 20% to 30% completion stage of the design process. The preliminary design may include the following sub-phases of design work:

- Reconnaissance study: Typically, this study investigates the optimal design and construction specific to each site. The study usually occurs early in the preliminary design process.
- Conceptual alternatives study: This study lists the types of facilities that may be appropriate for accomplishing the fish passage objectives at a selected site. It does not entail much on-site investigation. Its purpose is to develop a narrowed list of alternatives that merit additional assessment.
- Feasibility study: This study includes an incrementally greater amount of development of each design concept (including a preliminary cost estimate) than does the conceptual alternatives study. It enables the most-preferred alternative to be identified.

3.2.2 Detailed or Final Design

The final design should be based on the preliminary design that NMFS reviewed. Any significant deviation from the accepted preliminary design will trigger a new review. Once the detailed design process commences, NMFS should have the opportunity to review and provide *comments on the designs developed at the 30%, 60%, 90%, and 100% stages, or near each of these stages.*

The details of the final design phase uses the preliminary design as a springboard for beginning the final design and specifications in preparation for the bid solicitation (or negotiation) process. NMFS reviews usually provide refinements in the detailed design that will lead to O&M and fish safety benefits. Electronic drawings are the preferred review medium, though NMFS may request scaled 11-by-17-inch paper drawings in addition to electronic media.

3.2.3 Smaller Projects

For smaller projects where the review process may involve only one or two steps, each submittal to NMFS should include enough information about the project to ensure that the reviewing engineer is able to discern the goals of the project, any biological and physical constraints of the project, and how the proposed design intends to meet the goals of the project given constraints that were identified.

3.2.4 Review Timelines

NMFS should be allowed at least 30 days to review and comment on each stage of the design process (30%, 60%, 90%, and 100%).

Although NMFS may waive or voluntarily shorten a review period for a specific stage, project applicants should develop their design schedules using the standard 30-day review period for each stage of the design.

3.3 Information Requirements

The design of all fish passage facilities should be developed based on a synthesis of the required site and biological information listed below, with a clear understanding of how the facility will be operated and maintained. The following project information is needed for, and should be provided with, the preliminary design. In some cases, NMFS may need additional information not listed herein.

3.3.1 Functional Requirements

The project design should describe the functional requirements of the proposed fish passage facilities as related to all anticipated project operations and streamflows. The design should describe the expected median, maximum, and minimum monthly diverted flow rates and any special operations (e.g., the use of flash boards) that modify forebay or tailrace water surface elevations.

3.3.2 Site and Physical Information

The following physical information should be provided and used in developing the project design.

3.3.2.1 Plans

Design submittals should include visual representations of various project features. These plans may include any or all of the following:

- Site plan drawings: Showing the location and layout of the proposed fish passage facility relative to existing project facility features
- Surveys: Topographic and bathymetric surveys, particularly where they might influence locating fishway entrances and exits and personnel access to the site
- Additional drawings: Drawings of existing facilities illustrating longitudinal profile, elevations, and plan views, including details showing the intake configuration, location, and capacity of the project's hydraulic features
- Project Location Map including nearby town and north arrow along with Latitude and Longitude
- Temporary passage facility drawings: Drawings demonstrating plans for temporary or interim passage during construction of the primary facility. These temporary facilities should provide passage at a level no worse than existed prior to commencing construction on primary facility.

3.3.2.2 Hydrology

Design submittals should include information on the hydrology of the basin—including daily and monthly streamflow data and flow duration exceedance curves at the proposed site for a fish passage facility—based on the entire period of available records, which may be modified based upon site specific issues as approved by NMFS staff.

If stream gage data are unavailable for a proposed facility location (or if records exist for only a brief period of time), flow records may be generated using synthetic methods to develop the necessary basin hydrology information, which is used to develop the high and low fish passage design flows for the project (Chapter 4).

3.3.2.3 Project operations and basic information

Information on project operations that may affect fish migration should be provided.

Project information is key to understanding basic design parameters for fish passage (both for baseline conditions and for future fish passage changes). This could include information on powerhouse flow capacity, periods of powerhouse operation, turbine sequencing, debris management, flashboard or crest gate operation, flood or waster gate operation staffing levels, planned outages, pulse flows, project forebay and tailwater rating curves that encompass the entire operational range of the project, water temperature etc.

3.3.2.4 Morphology

Information on the stream or river channel at the site of the fish passage project should be provided, and includes but is not limited to the following:

- *Determine the potential for channel degradation, aggregation/subsidence, or channel migration, which may alter stream channel geometry and compromise fishway performance (if the fish passage facility is proposed at a new or modified diversion).*
- *Describe whether the stream channel is stable, conditionally stable, or unstable.*
- *Identify the overall geomorphology of the channel (e.g., straight, meandering, or braided).*
- *Provide the rate of lateral channel migration and change in stream gradient that has occurred during the last decade if migration is evident or likely to occur in the future using aerial photography, anecdotal information, or physical monitoring.*
- *Describe the effect the proposed fish passage facility may have on the existing stream alignment and gradient.*
- *Describe the potential for future channel modification to occur; this could be from construction of the facility or natural channel processes (i.e., instability).*
- *Describe the substrate of the channel and provide the D50.*

3.3.2.5 Sediment and debris

Any sediment and debris conditions that may influence the design of the fish passage facility or present potentially significant problems should be described.

3.3.3 Biological Information

Section 3.3.3 outlines miscellaneous information that should be provided and used in developing the project design. Contact the NMFS biologist in your area to determine which of the following is needed for the project.

3.3.3.1 Salmonid biological information

The following biological information should be provided for site specific conditions:

- Salmonid species present in the basin that are affected by the project, or are expected to be in the basin in the future
- Approximate abundance of each salmonid species and run (e.g., winter, spring, summer, fall, and late fall)
- Various life stages present, or expected to be present, in the future and their migration timing (fish passage season)
- Location and timing of spawning in the basin
- Location and timing of juvenile downstream migration

3.3.3.2 Non-salmonid passage

Information on any non-salmonid species (and life stages) present at the proposed fish passage site should be provided to address passage requirements for these species.

3.3.3.3 Predation risk

Information on predatory species that may be present at the proposed site should be provided along with information on conditions that favor or help to prevent their preying on salmonids. Information should include, but is not limited to, species type, life stage, spawning ground, and location of predator habitat.

3.3.3.4 Fish behavior characteristics

Any known fish behavioral traits of salmonid or non-salmonid passage that might affect the design of the facility should be provided.[1]

3.3.3.5 Additional research needs

Any uncertainty associated with how migrating fish approach the site where a new facility is being considered should be identified through directed studies, including routes fish may use when approaching the site. For more information related to large projects, see Appendix G.

3.3.3.6 Streamflow requirements

The minimum streamflow required to allow migration around the impediment during low water periods (See Design Flow Range in Chapter 4).

3.3.3.7 Poaching risk

The degree of poaching or illegal trespass activity in the immediate area of the proposed facility should be identified, along with any security measures needed to reduce or eliminate illegal activity.

3.3.3.8 Water quality

Water quality factors that may affect fish passage at the site should be described. For example, fish may not migrate if water temperature and quality are marginal and may instead seek coldwater refugia (e.g., deep pools fed by groundwater) or holding zones where dissolved oxygen levels are higher than surrounding reaches until water quality conditions improve. Water temperature issues are important considerations that can effect design. Therefore, it is also important to document other temperature issues (eg. reservoir stratification, or effluent releases in the project area, among other issues).

3.3.4 Operations and Maintenance Information

In order to provide a degree of certainty that necessary maintenance will be funded and performed, the following O&M information should be provided for in development of the preliminary design.

Historically, many fish passage facilities have been built and have subsequently fallen into disrepair due to improper operations or lack of maintenance or funding. New project designs

[1] For example, most salmonid species pass readily over a fishway weir with either plunging or streaming flow. However, pink and chum salmon have a strong preference for streaming flow conditions and may reject plunging flow. Therefore, if pink or chum salmon are in the basin, this needs to be identified. Similarly, American shad prefer streaming flow conditions and generally reject both plunging flow and orifice passage.

should consider the need for proper operations and long-term maintenance. Start up, daily, and yearly maintenance procedures, daily logs, and annual reports should be considered in the design development and included as part of the O&M plan.

3.3.4.1 Maintenance funding

The O&M plan should identify the party responsible for funding the O&M of the proposed facility.

3.3.4.2 Operating and maintaining entity

The O&M plan should identify the party responsible for operating the facility and carrying out maintenance actions.

3.3.4.3 Facility shutdown

The O&M plan should describe maintenance actions that will require the facility to be taken out of service and the timeline for these actions.

3.3.4.4 Schedule of operations

The O&M plan should identify the proposed schedule of operations for intermittently operated facilities, such as weirs or traps, and the accompanying plans for salvaging fish from these facilities after they are operational. This should include plans for how the facility will be dewatered and how salvaged fish will be returned to the stream or river.

4 Design Flow Range

Prior to determining the fish passage design flows, the steps in the 2022 NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change should be followed to determine what if any climate impacts should be considered and included in the design. The guidance in Chapter 4 applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Due to significantly different hydrologic conditions in California, project proponents should work with NMFS engineering staff to determine the appropriate design flows for site conditions.

4.1 Introduction

A fishway design and facility must allow for the safe, timely, and efficient passage of fish within a specific range of streamflow. The design streamflow range is bracketed by the designated fish passage design low flow and high flow described in Sections 4.2 and 4.3.

Within the design streamflow range, a fish passage facility should operate within its specific design criteria. Outside of the design streamflow range, fish should either not be present, not be actively migrating, or should be able to pass safely without need of a fish passage facility.

Site-specific information is critical to determining the design time period and river flows for the passage facility—local hydrology may require that the design streamflow range be modified for a particular site.

4.2 Design Low Flow for Fish Passage

Design low flow for fishways is the average daily streamflow that is exceeded 95% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records may be useable if they encompass a broad range of flow conditions. The fish passage design low flow is the lowest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.3 Design High Flow for Fish Passage

Design high flow for fishways is the average daily streamflow that is exceeded 5% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records may be used if they encompass a broad range of flow conditions. The fish passage design high flow is the highest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.4 Fish Passage Design for Flood Flows

The general fishway design should have sufficient river freeboard to minimize overtopping by 50-year flood flows.

Above a 50-year flow event, fishway operations may include shutdown of the facility to allow the facility to quickly return to proper operation when the river drops to within the range of fish passage design flows. Other mechanisms to protect fishway operations after floods will be considered on a case-by-case basis. A fishway should never be inoperable due to high river flows for a period greater than 7 days during the migration period for any anadromous salmonid species. In addition, the fish passage facility should be of sufficient structural integrity to withstand the maximum expected flow. It is beyond the scope of this document to specify structural criteria for this purpose. If the fish passage facility cannot be maintained, the diversion structure should not operate, and the impediment should be removed.

5 Upstream Adult Fish Passage Systems

5.1 Introduction

Chapter 5 provides criteria and guidelines for designing upstream adult fish passage facilities as well as selecting appropriate ladder types for specific site conditions. These criteria and guidelines apply to adult upstream fish passage facilities in moderately sized streams. Where applicable, supplementary criteria for facilities located in small streams will be noted. Chapter 5 does not address fish passage systems, such as fish locks and mechanical lifts, which may provide passage over barriers or be used as part of a trap and haul system. Fish lifting devices are covered in Section 7.6.

Chapter 5 also discusses upstream passage impediments, which are artificial or natural structural features or project operations that cause adult or juvenile fish to be injured, killed, blocked, or delayed in their upstream migration to a greater degree than in an unobstructed river setting. These impediments can present total or partial fish passage blockages. Artificial upstream passage impediments require approved structural and operational measures to mitigate, to the maximum extent practicable, for adverse impacts to upstream fish passage. These impediments require a fish passage design based on conservative criteria because the natural complexity of streams and rivers that usually provide passage opportunities has been substantially altered. The criteria in this chapter also apply to natural barriers, when passage over the barrier is desired and consistent with watershed, subbasin, or recovery plans.

Examples of passage impediments include, but are not limited to, the following:

- Permanent or intermittent dams
- Hydraulic drops over artificial instream structures[2] in excess of 1.5 feet
- Weirs, aprons, hydraulic jumps, or other hydraulic features that produce depths of less than 10 inches, or flow velocity greater than 12 feet per second (ft/s) for more than 90% of the stream channel cross section
- Conditions that create false attraction, including the following:
    - Project operations or features that lead upstream migrants into impassable routes
    - Discharges that may be detected and entered by fish with no certain means of continuing their migration (e.g., poorly designed spillways, cross-basin water transfers, canal wasteways, or unscreened diversions) or have the potential to result in mortality or injury (e.g., turbine draft tubes, shallow aprons, and flow discharges)
- Insufficient flow, which includes the following:
    - Diffused or braided flow that impedes approach to the impediment

[2] This is based on the *Fisheries Handbook of Engineering Requirements and Biological Criteria* (Bell 1991), which recommends using fishways for head differences as low as 2 feet.

- Insufficient flow in a bypass reach, such that fish cannot enter or are not stimulated to enter the reach and move upstream; bypass reaches are commonly located adjacent to a powerhouse or wasteway return
- Water diversions that reduce instream flow

- Poorly designed headcut control or bank stabilization measures that create poor upstream passage conditions such as those listed above
- Degraded water quality in a bypass reach, relative to the water quality downstream of the confluence of bypass reach and flow return discharges (e.g., at the confluence of a hydroelectric project tailrace and bypass reach)
- Ramping rates in streams or in bypass reaches that delay or strand fish
- Upstream passage facilities that do not satisfy the criteria and guidelines described in Chapter 5

The typical components of an upstream adult fish passage system are shown in Figure 5-1.

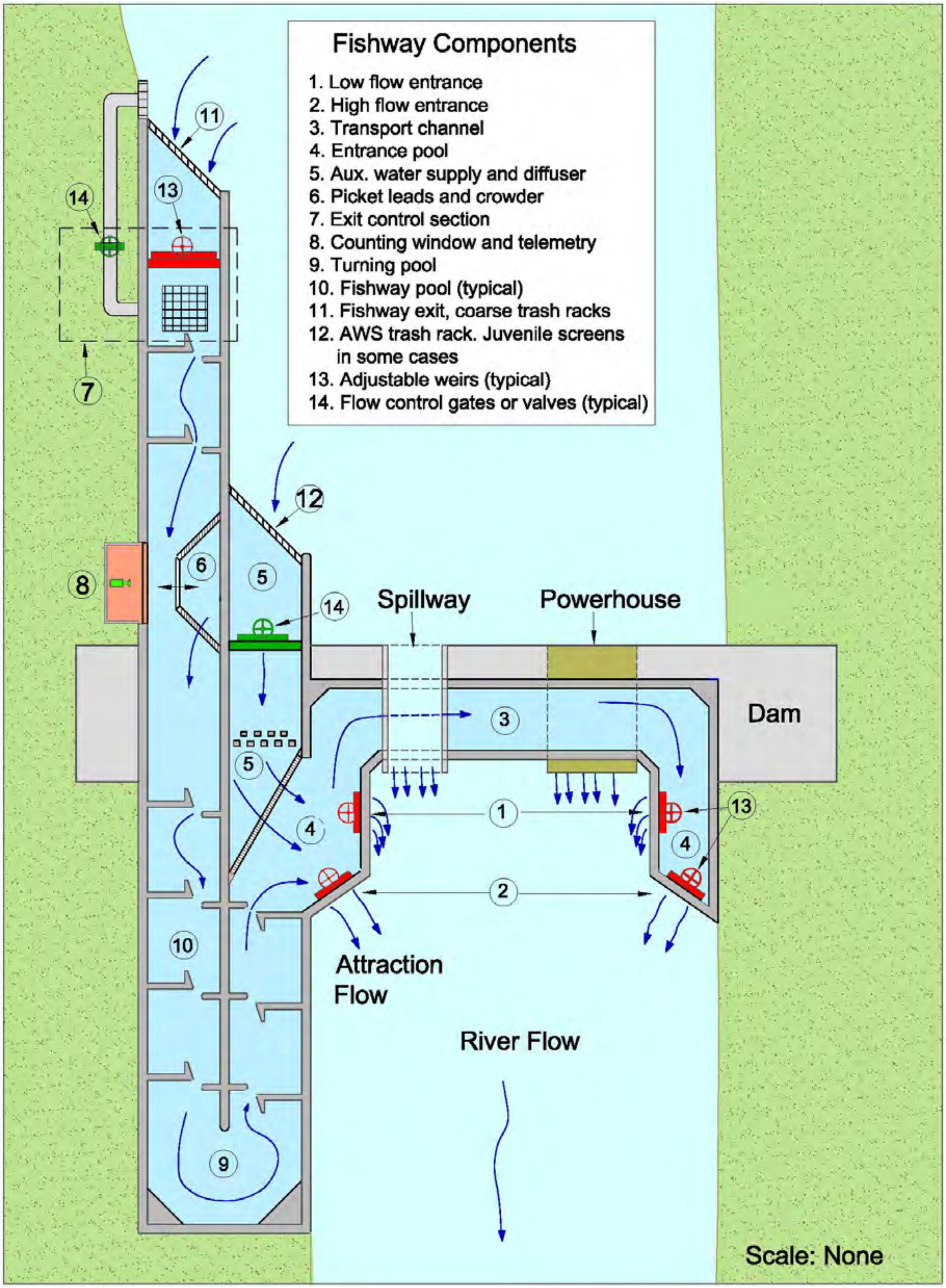


Figure 5-1. Components of vertical slot fishway for upstream passage

5.1.1 Passage Alternatives: Volitional and Non-volitional

Volitional passage is preferred for passage facilities over non-volitional passage. Non-volitional systems may be considered where volitional passage facilities are not feasible due to significant engineering constraints or biological limiting conditions.

NMFS typically prefers volitional fish passage as these systems afford passage opportunities for migrating fish at all times, and fish can transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish migrate through a volitional passage facility without the aid of any mechanical apparatus, structure, or device.

Volitional passage systems at dams usually consist of hydraulically engineered fish ladders that use one of the designs described in this manual. Under certain site conditions, a volitional passage system for a dam of low or moderate height may be designed as a nature-like channel; or it may be a hybrid design that incorporates features of both nature-like and traditional designs. Volitional systems for applications other than dams generally seek to emulate nature-like conditions with stream simulation techniques.

There are some situations where a volitional passage system is infeasible due to biological factors, engineering constraints, fish management objectives, or other project-specific limitations. In these instances, non-volitional systems may be appropriately considered to meet fisheries management goals and objectives, provided they are designed, constructed, and operated following the guidance in chapter 7 of this Manual.

Non-volitional systems, due to long term operations and maintenance requirements, can have higher total life-cycle costs when compared to fish ladders. Project proponents should carefully weigh the pros and cons of the different alternative modes of passage to select the most appropriate design that will consistently accomplish the project's fish passage goals. There may be instances where the inability of a project proponent to consistently and correctly operate and maintain a proposed collection and transport system represents an unacceptable risk to the managed fish species.

Although site specific challenges exist, non-volitional designs can be a viable management tool that provides Pacific salmonids access to some historic habitats, including cold-water sites that will be increasingly important given climate projections.

5.1.2 Passage of Other Species

Where appropriate, upstream adult fish passage systems should incorporate passage requirements for other species (e.g., shad, sturgeon, Pacific lamprey, and suckers) that may use the system, provided that the changes do not compromise the passage of target species (salmonids).

Failure to account for the passage requirements of other species may create a biological blockage in the ladder that could delay or compromise the passage of the target species. For example, if American shad (*Alosa sapidissima*) cannot pass a fishway, the numbers of shad in the fishway may build up to the point where other fish do not enter or move through the fishway.

5.1.3 Temperature Considerations

In certain cases, water temperature control may be a critical factor for fish ladder designs, particularly at high head dams. Some reservoirs or head ponds may become thermally-stratified at some point during the fish passage season, resulting in a potential temperature mismatch between the fish ladder's discharge and the dam's other tailwater or tailrace discharges. Also, during summer seasons, water temperature may increase as water passes through long fish ladders whose exterior concrete surfaces are exposed to solar energy for a considerable period of time. Such temperature mismatch situations may cause salmonids (or other species) to reject the fish passage route. To the degree these conditions exist, artificial temperature modulation at fishways and ladders may be necessary (Caudill et al. 2013).

5.2 Fishway Entrance

5.2.1 Description and Purpose

A fishway entrance is a gate or slot through which fishway attraction flow is discharged in a manner that encourages and allows adult fish to enter the upstream passage facility. The fishway entrance is often the most difficult (Bates 1992)—yet most critical—component to design for an upstream passage system, particularly at dams (Clay 1995). Fishway entrances should be placed to ensure that fish are attracted to and enter the best passage routes past the passage impediment throughout the entire design flow range. The most important aspects of fishway entrance design are as follows:

- Location of the entrance
- Pattern and amount of flow from the entrance
- Approach channel immediately downstream of the entrance
- Flexibility in adjusting entrance flow to accommodate variations in tailrace elevation, stream or river flow, and project operations

5.2.2 Specific Criteria and Guidelines – Fishway Entrance

5.2.2.1 Configuration and operation

Unless otherwise approved by NMFS, at sites where the entrances are located in deeper water, fishway entrances should be equipped with downward-opening slide gates or adjustable weir gates that rise and fall with the tailwater elevation. At locations where the tailwater is not deep, orifice entrances or downward-closing slide gates (which create an orifice entrance) may be used. The entrance gate should be able to completely close off the entrance when not in use. Gate stems or other adjustment mechanisms should not be placed in any fish migration pathway. Fishway entrance gates operating in an orifice configuration should not be closed to an opening height less than 12-inches except when fully closed.

The fishway entrance gate configuration and its operation may vary based on site-specific project operations and streamflow characteristics. Entrance gates are usually operated in either a fully open or fully closed position, with the operation of the entrance being dependent on tailrace flow characteristics. Sites with limited tailwater fluctuation may not require an entrance gate to regulate the entrance head, while other sites may maintain proper entrance head by regulating auxiliary water flow through a fixed-geometry entrance gate.

5.2.2.2 Location

Fishway entrances should be located at points where fish can easily locate the attraction flow and enter the fishway. When choosing an entrance location, high-velocity and turbulent zones in a powerhouse or spillway tailrace should be avoided in favor of relatively tranquil zones adjacent to these areas. A site-specific assessment must be conducted to determine entrance location and entrance jet orientation. A physical hydraulic model is often the best tool for determining this information (Bell 1991).

The fishway entrance should be located as far upstream as possible since fish will seek the farthest upstream point (Bell 1991). This is especially the case with low flow entrances. This guideline is subject to adjustment by NMFS based on site-specific constraints that include the configuration of the project, flow level, and flow patterns associated with powerhouse or facility operations and spill discharge in relation to site conditions.

Some fishway entrances at a project should be located on the shoreline (Bell 1991). This is because fish orient to shorelines when migrating upstream. Locating an entrance on the shoreline takes advantage of this behavior, where the shoreline serves to lead fish to the entrance.

One of the most significant design decisions for a fishway entrance is its location (WDFW 2000). Turbulence can be a barrier to fish passage because velocities, turbulence, upwells, reverse currents, and aeration can affect attraction and access to fishways (WDFW 2000). At locations where the tailrace is wide, shallow, and turbulent, excavation to create a deeper, less-turbulent holding zone adjacent to the fishway entrance(s) may be necessary. Therefore, it is important to fully characterize and understand flow patterns when locating a fishway entrance at a site.

5.2.2.3 Additional entrances

If the site has multiple zones where fish accumulate, each zone should have a minimum of one fishway entrance. For long powerhouses or dams, additional entrances may be required. Multiple entrances are usually required at sites where the high and low design flows create different tailwater conditions. All entrances should meet the requirements of Section 5.2.

Since tailrace hydraulic conditions usually change with project operations and hydrologic events, it is often necessary to provide two or more fishway entrances to accommodate the differences between high- and low-flow river conditions (often referred to as high- and low-flow entrances). When switching between high- and low-flow conditions, it is often necessary to close some entrances that are operating poorly or those the fish can no longer access, and open others where fish are congregating and holding. These features should be designed so that entrance changes can be performed simply, swiftly, and easily.

5.2.2.4 Attraction flow

Additional attraction flow from the fishway entrance is needed to extend the area of intensity of velocity of the outflow (from the entrance) to increase fish attraction into the entrance (Clay 1995). Attraction flow from the fishway entrance should be between 5% and 10% of the fish passage high design flow (Chapter 4). For smaller streams, NMFS may conclude that attraction flows up to 100% of streamflow may be required.

Larinier et al. (2002) conclude that a major cause of poor fishway performance is a lack of adequate attraction flow. At dams, the entrance flow for fish attraction should be sufficient to compete with spillway or powerhouse discharge flow (Bates 1992). Generally speaking, the higher the percentages of total river flow used for attraction into the fishway, the more effective the facility will be in providing upstream passage. The proportion of attraction flow needed is based on extensive research and results of laboratory studies.[3] The proportion selected should be sufficient to allow fish to both find and want to enter fishway entrances.

Under conditions where ladder entrances are optimally situated near the impediment and fish are naturally led to an entrance, an attraction flow of 5% of the fish passage design flow is used. However, some situations may require that more than 10% of the passage high design flow be used. For example, if a site features obscure approach routes to the passage facility or if entrances are located in a less than optimal location, a higher proportion of the design flow is needed as attraction flow. Additionally, facilities with multiple entrances may require more attraction flow (not to exceed a total of 10% of the fish passage design flow).

Powerhouse and spillway flows are not considered part of the proportion of project flow used for fishway attraction. Powerhouse and spillway flows should be shaped, and turbine unit and spill gate operation prioritized, to create tailrace conditions that naturally lead to and allow fish to rapidly locate the fishway entrances (Bell 1991).

5.2.2.5 Hydraulic drop

The fishway entrance hydraulic drop (also called entrance head) should be maintained between 1 and 1.5 feet, depending on the species present at the site, and designed to operate from 0.5 to 2 feet of hydraulic drop (USFWS 1960; Junge and Carnegie 1972).

A range of 1 to 1.5 feet is considered a normal operating range that helps establish streaming flow conditions (Bates 1992). Gauley et al. (1966) found in laboratory studies that Chinook salmon and steelhead made significantly faster ascents up an experimental ladder with orifice flow and flow over a weir when head on the weir was increased from 0.95 to 1.2 feet.

The hydraulic drop criterion is based in part on results of laboratory studies where an increasing number of Chinook and sockeye salmon and steelhead failed to enter all entrances tested when head was increased from 2 to 3 feet. Pink and chum salmon have more specific

[3] For example, Weaver (1963) conducted a study wherein he provided salmon and steelhead with a choice of entering adjacent channels of the same width but different velocities; a higher proportion chose to enter the channel with higher velocity.

requirements. Fish from these species can easily swim through an entrance with 1.5 feet or more of head differential, but they will not jump even a portion of that height (Bates 1992).

5.2.2.6 Dimensions

For larger streams, the minimum fishway entrance width should be 4 feet, and the entrance depth should be at least 6 feet, although the shape of the entrance is dependent on attraction flow requirements and should be shaped to accommodate site conditions.

For smaller streams, the ladder entrances should be as large as possible, consistent with available fishway entrance flow, to maximize fish attraction and minimize plugging by debris. The minimum size for an orifice-style entrance should be 1.5 feet by 1.5 feet. The minimum width for a vertical slot-style entrance should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise, and the depth (i.e., bottom of the slot to the tailwater level) should be at least 2 times the slot width.

In general, the dimensions of the fishway entrance should create a compact, strong attraction flow jet that projects out of the entrance a significant distance into the tailrace.

For identical water velocities, attraction jets created by entrances that are small, narrow, and deep, or are wide and shallow, do not project as far into the tailrace as does a compact entrance (Section 5.2.2.8; also, see requirements for mainstem Columbia and Snake rivers in Appendix G). The entrance width criterion is based partly on results of laboratory studies where Chinook salmon and steelhead preferred 3.9-foot-wide entrances over 1.5-foot-wide entrances under a constant velocity condition of 8 ft/s and lighted conditions. However, under dark conditions, all of these species preferred the wider opening, and coho salmon preferred the wider opening under both lighted and dark conditions (Weaver et al. 1976).

For ladder entrances at facilities located in small streams, orifice size is based on the minimum orifice size for an Ice Harbor-style ladder (Section 5.5.3.3). For a slot-style entrance at a facility in a small stream, the slot width is based on the minimum slot widths for vertical slot ladders (Section 5.5.2.1.1), and the minimum depth is based on the square area of a 1.5-foot by 1.5-foot orifice. For example, the criterion above states that slot depth (the depth from the bottom of the vertical slot-style entrance to the tailwater water surface elevation) should be double the slot width, and the minimum width should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise. Therefore, when sizing a 1-foot-wide slot, the design should submerge the slot 2 feet, which is close to the 2.25 square foot (ft^2) open area of a 1.5-feet by 1.5-feet orifice.

5.2.2.7 Types of entrances

Fishway entrances may be adjustable submerged weirs, vertical slots, orifices, or other shapes, provided that the requirements specified in Section 5.2.2 are achieved.

Care should be taken to select a fishway entrance that generates a good attraction jet and is passable by all species of interest (Junge and Carnegie 1972). For example, American shad typically refuse to pass through orifices. Therefore, at sites where American shad are present, orifice entrances should be avoided, and surface routes in fishways are required (Larinier et al. 2002). This is true of all species in the genus *Alosa*. Also, American shad orient to walls when migrating through fishways and can be trapped in corners if no surface-oriented route is available (Junge and Carnegie 1972; Bell 1991; WDFW 2000).

5.2.2.8 Flow conditions

The fishway entrance should create either streaming flow or hydraulic conditions similar to a submerged jet.

The desired flow condition for entrance weir and slot discharge jet hydraulics is streaming flow (WDFW 2000). A streaming flow is an intact plume of water moving almost horizontal near the water surface or at the elevation of an orifice entrance. In contrast, plunging flow drops vertically over an entrance sill or weir and then upwells downstream a few feet from an entrance. Plunging flow sets up a hydraulic roll where surface flow is moving in an upstream direction toward the entrance (Figure 5-2). This induces fish to jump at the flow, which may cause injuries, and it presents hydraulic conditions that some species may not be able to pass or may refuse to pass. This includes American shad and pink and chum salmon. Plunging flow also directs the attraction jet downward toward the stream bottom rather than across the tailrace. Streaming flow may be accomplished by placing the entrance weir (or invert of the slot) elevation such that flow over the weir falls into a receiving pool with a water surface elevation above the weir crest elevation (Katopodis 1992).

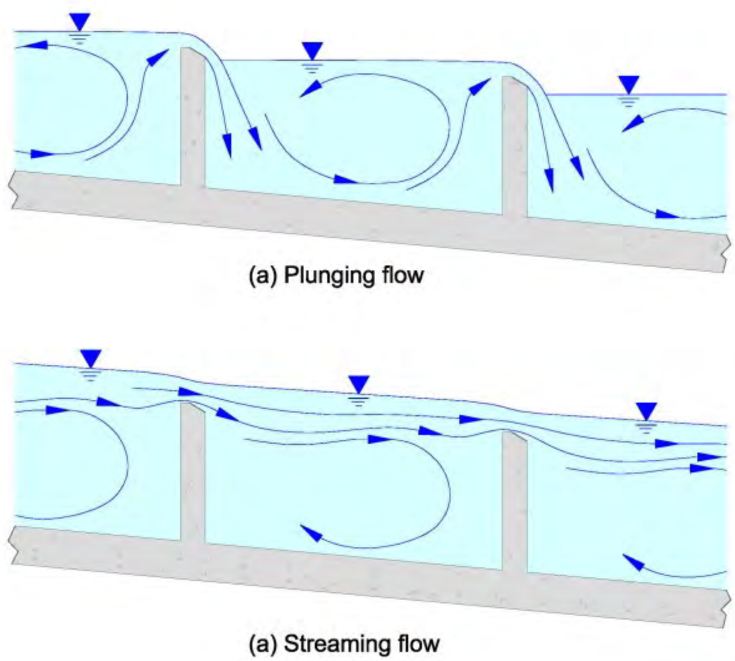


Figure 5-2. Plunging (a) and streaming (b) flows in pool and weir style of fishways

5.2.2.9 Orientation

Generally, low-flow entrances should be oriented nearly perpendicular to the streamflow (Figure 5-1; Bates 1992). High-flow entrances should be oriented to be more parallel to streamflow or at an angle away from the shoreline (Figure 5-1). A site-specific assessment should be conducted to determine entrance location and entrance jet orientation.

Low-flow entrances are designed to be used by fish during periods when flow conditions approach the low design flow. They are generally the entrances furthest upstream and closest to the passage barrier. High-flow entrances are designed for use during periods when flow conditions approach the high design flow. Bates (1992) suggests that high-flow entrances be placed at a 30-degree angle to the high-flow streamline, ideally along the edge of a high-flow hydraulic barrier. In general, high-flow entrances are located slightly downstream from the barrier at a point in the tailrace where the turbulence from the barrier under high flow conditions has just dissipated. A physical hydraulic model is often the best tool for determining this information; this model is used to test various design alternatives that favor fish passage (Bell 1991).

5.2.2.10 Staff gages

The fishway entrance design should include staff gages to allow for a simple determination of whether the entrance head criterion (Section 5.2.2.5) is met. Staff gages should be located in the entrance pool and in the tailwater just outside of the fishway entrance in an area visible from an easy point of access. Gages should be readily accessible to facilitate in-season cleaning.

Staff gages are important tools for determining whether a fish ladder entrance is meeting criteria. Care should be taken when locating staff gages to avoid placement in turbulent areas and locations where flow is accelerating toward a fishway entrance.

5.2.2.11 Entrance pools

The fishway entrance pool should be designed to combine ladder flow with auxiliary water system (AWS; also known as auxiliary water supply system) flow in a manner that encourages fish to move from the entrances in an upstream direction and optimizes the attraction of fish to lower fishway weirs.

The fishway entrance pool is at the lowest elevation of the upstream passage system. It discharges flow into the tailrace through the entrance gates to attract upstream migrants. In many fish ladder systems, the entrance pool is the largest and most important pool in terms of providing proper guidance of fish from the entrance to the ladder section of the upstream passage facility. Ladder flow and AWS flow through diffuser gratings are combined in the pool to form the entrance attraction flow (Section 5.3, Figure 5-1).

Attraction to the lower fishway weirs may be optimized by the following:

- Shaping the entrance pool to create a natural funnel leading fish to the ladder weirs
- Angling vertical AWS diffusers toward the ladder weirs
- Locating the jet from the ladder weir adjacent to the upstream terminus of the vertical AWS diffusers

The pool geometry will normally influence the location of attraction flow diffusers.

5.2.2.12 Transport velocity

Transport velocities between the fishway entrance and first fishway weir, fishway channels, and over-submerged fishway weirs should be consistent with the guidance found in section 5.4.2.1.

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

Note that as tailwater level rises and the lower fishway weirs become submerged, it becomes necessary to increase the flow in this area of the ladder to meet the transport velocity criterion (Bell 1991).

An AWS can be used to supply additional water through wall or floor diffusers. Care should be taken to design the fishway weirs that will be submerged to accommodate the additional flow in the ladder so that other fish passage (or hydraulic) criteria are not exceeded. The transport channel velocity guidelines do not apply to individual ladder pools since these are governed by design criteria specific to these pools.

5.3 Auxiliary Water Systems

5.3.1 Description and Purpose

An AWS should be used to supply additional water to the fishway when the required attraction flow (as specified in Section 5.2.2.4) is greater than ladder flow.

Auxiliary water is often required at fishways to provide additional attraction flow from the entrance pool to fishway entrances (Bell 1991). Adding AWS flow is based on the concept that fish migrating upstream are attracted by flow velocity of certain magnitudes, which the fish swim against to continue their migration upstream (Clay 1995). Auxiliary water can also be supplied through an AWS to areas between fishway weirs that are partially submerged by high tailwater elevations and fail to meet the flow velocity criterion, as discussed in Section 5.2.2.12. In addition, an AWS can be used to provide additional flows to various transition pools in the ladder such as bifurcation or trifurcation pools, multiple entrances, pools in fish trapping facilities, exit control sections, and counting station pools.

5.3.1.1 AWS supply source

The source of water for the AWS flow should be of the same quality (e.g., temperature, turbidity, and water chemistry) as the flow in the ladder (i.e., the receiving water).

The AWS flow is usually routed from the forebay to the ladder via gravity, but water quality may vary from the ladder flow depending on the location of the AWS intake. The AWS flow can also be pumped from the tailrace or delivered via a combination of gravity and pumped sources. Differences in the water sources could cause fish to reject the ladder.

5.3.2 Specific Criteria and Guidelines – AWS Fine Trash Racks

5.3.2.1 Bar spacing

A fine trash rack should be provided at the AWS intake with clear space between the vertical flat bars of 0.875 inch or less.

The purpose of an AWS fine trash rack is to stop debris from entering the AWS, which might plug the upstream side of the diffuser panel. Since the normal, clear opening between bars on the diffuser panels is 1 inch (Section 5.3.7), the AWS fine trash rack should be 0.875 inch or less. At sites where Pacific lamprey may be present and diffusers with 0.75-inch clear openings are used (Section 5.3.7), the AWS fine trash rack should have a maximum clear opening of 0.625 inch or less.

5.3.2.2 Velocity

Maximum velocity through the AWS fine trash rack should be less than 1 ft/s, as calculated by dividing the maximum flow by the submerged area of the fine trash rack.

5.3.2.3 Cleaning consideration

The support structure for the fine trash rack should not interfere with cleaning requirements and should provide access for debris raking and removal.

5.3.2.4 Slope

The fine trash rack should be installed at a 1H:5V (horizontal:vertical) or flatter slope for ease of cleaning. The fine trash rack design should accommodate maintenance requirements by considering access for personnel, travel clearances for manual or automated raking, and removal of debris.

5.3.2.5 Staff gages and head differential

Staff gages should be installed to indicate head differential across the AWS intake fine trash rack and should be located to facilitate observation and in-season cleaning. Head differential across the AWS intake fine trash rack should not exceed 0.3 foot in order to facilitate cleaning, minimize velocity hot spots, and maintain hydraulic efficiency in gravity and pumped systems.

Staff gages are used for determining whether the head across a trash rack is within criteria or not. Care should be taken when locating staff gages so that they can be easily read by personnel.

5.3.2.6 Structural integrity

AWS intake fine trash racks should be of sufficient structural integrity to avoid the permanent deformation associated with maximum occlusion.

5.3.3 Specific Criteria and Guidelines – AWS Screens

In instances where the AWS poses a risk to the passage of juvenile salmonids because of its design involving high head and convoluted flow paths, the AWS intake should be screened to the standards specified in Chapter 8 to prevent juvenile salmonids from entering the AWS.

Trip gates, pressure relief valves, or other alternate intakes to the AWS may be included in the design to ensure that AWS flow targets are achieved if screen reliability is uncertain under high river flow conditions. Debris and sediment issues may preclude the use of juvenile fish screen criteria for AWS intakes at certain sites. Passage risk through an AWS will be assessed by NMFS on a site-specific basis to determine whether screening of the AWS is warranted and how to provide the highest reliability possible.

5.3.4 Specific Criteria and Guidelines – AWS Flow Control

The AWS should have a flow control device located sufficiently far away from the AWS intake to ensure the flow at the AWS fine trash rack or screen is uniformly distributed. To facilitate cleaning, the flow control system should allow flow to be easily shut off for maintenance and then restarted (and reset) to proper operating conditions.

The flow control device may consist of a control gate, pump control, turbine intake flow control, or other flow control systems located sufficiently far away from the AWS intake to ensure uniform flow distribution at the AWS fine trash rack for all AWS flows. Flow control is necessary to ensure that the correct quantity of AWS flow is discharged at the appropriate location during a full range of forebay and tailwater levels.

5.3.5 Specific Criteria and Guidelines – AWS Excess Energy Dissipation

Excess energy should be dissipated from AWS flow prior to passage through diffusers.

Dissipation of excess energy is necessary to minimize surging and induce relatively uniform velocity distribution at the diffusers because surging and non-uniform velocities may cause adult fish jumping and associated injuries or excess migration delay. The introduction of highly turbulent or aerated water will discourage fish from entering or passing through a fishway and possibly result in fish delay or injury (Clay 1995). Examples of methods to dissipate excess AWS flow energy include the following:

- Routing flow into a fishway pool with adequate volume (Section 5.3.6.2)
- Passing AWS flow through a turbine
- Passing AWS flow through a series of valves, weirs, or orifices
- Passing AWS flow through a pipeline with concentric rings or other hydraulic transitions designed to induce head loss

All of these dissipation systems require that AWS flow passes through a baffle system that has a porosity of less than 40% to reduce surging through fishway entrance pool diffusers. Adjustable baffles may be required in some systems to properly balance flow across the diffuser.

Figure 5-3 provides a schematic of a fishway AWS diffuser system showing the components needed, and their shape and arrangement, to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy uniform flow.

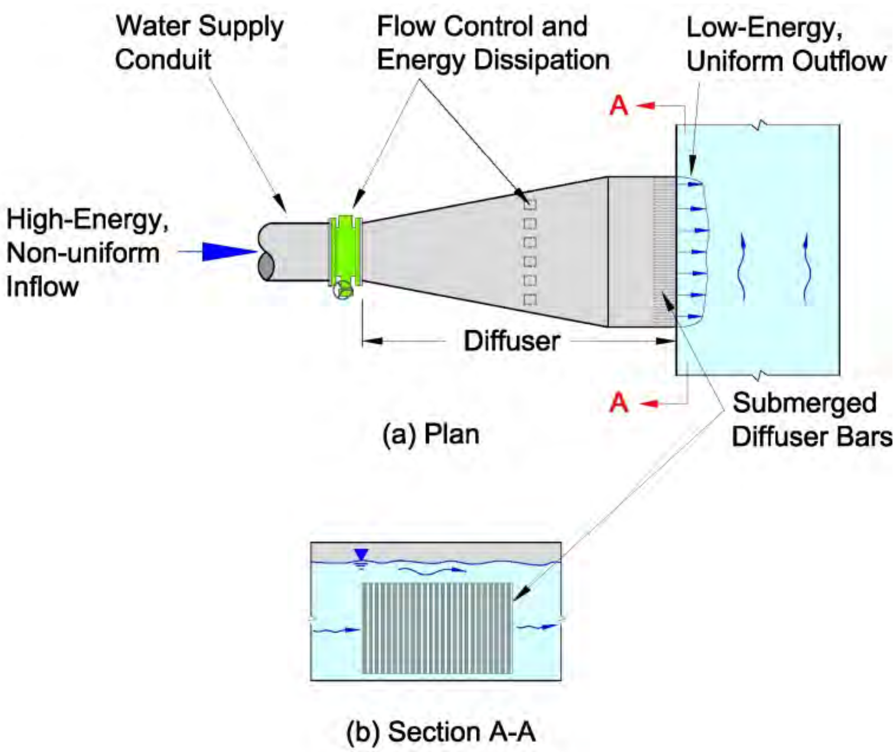


Figure 5-2. Schematic of a fishway AWS diffuser system in plan (a) and section (b) views

5.3.5.1 Energy dissipation pool volume

An energy dissipation pool in an AWS should have a minimum water volume established by the formula shown in Equation 5-1.

$$V = \frac{(\gamma)(Q)(H)}{16\ ft\text{−}lb\ /ft^3/s} \qquad (5\text{-}1)$$

where:

V = pool volume in cubic feet (ft^3)
γ = specific weight of water, 64.2 pounds (lb) per ft^3
Q = AWS flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet drop into the AWS pool

Note that the pool volumes required for AWS pools are smaller than those required for fishway pools. This is due to the need to provide resting areas in fishway pools and because AWS systems require additional elements (e.g., diffusers and valves) to dissipate energy and are not pathways for upstream fish passage.

5.3.6 Specific Criteria and Guidelines – AWS Diffusers

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bell 1991; Bates 1992). For adult salmonid passage, the maximum clear spacing between bars is 1 inch between diffusers bars. At sites where adult Pacific lamprey may be present, diffusers should have a maximum 0.75-inch clear spacing between bars.

Wall diffusers should consist of non-corrosive, vertically oriented diffuser panels of vertically oriented flat bar stock. Similarly, floor diffusers should consist of non-corrosive, horizontally oriented diffuser panels of horizontally oriented flat bar stock. Orientation of flat bar stock should maximize the open area of the diffuser panel. If a smaller species or life stage of fish is present, smaller clear spacing between bar stock may be required.

5.3.6.1 Material

The bars and picket panels used as part of AWS diffuser systems should be made of aluminum, stainless steel, or epoxy-coated carbon steel. The use of submerged galvanized steel should be minimized or eliminated, especially when used in close proximately to fish (i.e., fishways).

Galvanized steel is coated with zinc, a metal that can be toxic to fish.

5.3.6.2 Velocity and orientation

The maximum AWS diffuser velocity should be less than 1 ft/s for wall diffusers and 0.5 ft/s for floor diffusers based on the total submerged diffuser panel area (Bell 1991). Wall diffusers should only be used when the orientation can be designed to assist with guiding fish within the fishway. Diffuser velocities should be nearly uniform, which may require the use of porosity control panels (Section 5.3.6.3). The face of the diffuser panels (i.e., the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on *Design of Fishways and Other Fish Facilities* (Clay 1995), which states that 1 ft/s "has been adopted as the best compromise between practicality and efficiency," These criteria are also based on the results of laboratory studies where spring- and fall-run Chinook salmon and steelhead passage times increased when diffuser flows were added and were progressively longer as floor diffuser velocity increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

An example of wall diffusers being used to assist in guiding fish is when the diffusers in the entrance pool of a fishway are situated such that fish are naturally lead upstream to the first ladder pool.

When wall diffusers are used in conjunction with a half Ice Harbor-style ladder, the diffuser should be located on the same side as the overflow weir, and the diffuser bars should be oriented horizontally.

5.3.6.3 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure that average velocities at the face of the diffuser are uniform and can meet criteria (Section 5.3.6.2).

The purpose of the porosity control panels is to control the amount of flow through the diffuser pickets and create a uniform flow condition at the face of the pickets.

5.3.6.4 Debris removal

The AWS design should include access for personnel to remove debris from each diffuser unless the AWS intake is required per the criteria listed in Section 5.3.4 to be equipped with a juvenile fish screen (Chapter 8).

5.3.6.5 Edges

All flat bar diffuser edges and surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

5.3.6.6 Lamprey passage

At sites where Pacific lamprey are present, horizontal diffusers should not extend the complete width of the floor of the fishway or entrance pool. A solid surface, approximately 1.5 feet wide, should be located along the floor between the lateral sides of the diffuser panels and the base of either wall.

5.3.6.7 Elevation

Wall AWS diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the lowest water surface elevation that will occur based on the fishway design).

This is to prevent water from cascading through the diffuser, which can induce fish to leap at the surface disturbance.

5.3.7 Specific Criteria and Guidelines – Bedload Removal Devices

At locations where bedload may cause accumulations at the AWS intake, sluice gates or other simple bedload removal devices should be included in the design.

5.4 Transport Channels

5.4.1 Description and Purpose

A transport channel conveys flows between different sectors of the upstream passage facility, providing a route for fish to pass.

5.4.2 Specific Criteria and Guidelines – Transport Channels

5.4.2.1 Velocity range

The transport channel velocities should be between 1.5 and 4 ft/s (Gauley et al. 1966; Bates 1992), including flow velocity over or between fishway weirs inundated by high tailwater (Bell 1991).

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

5.4.2.2 Dimensions

The transport channels should be a minimum of 5 feet deep and 4 feet wide.

This is based on providing the narrowest, shallowest flow path that adult fish are known to move through readily while also displaying the least amount of fallback behavior and delay. In addition, this size of channel relates to the goal of keeping water velocities in the transport channel low.

5.4.2.3 Lighting

Ambient natural lighting should be provided in all transport channels, if possible. If ambient (natural) lighting is not available, acceptable artificial lighting should be used.

In laboratory tests, fish were presented with the choice of a large entrance (3.9 feet by 3.9 feet) that was dark or a smaller entrance (1.5 feet by 2 feet) that was lighted. Study results corroborate the understanding that fish prefer lighted entrances and channels: 80% of Chinook salmon, 90% of coho salmon, 69% of steelhead, and 86% of sockeye salmon chose the lighted entrance (Bates 1992).

5.4.2.4 Design (general)

Based on the literature and experiences of fish biologists at many facilities located in the WCR, the following features should be included in the design of transport channels:

- *The transport channels should be of open channel design (Bell 1991).*
- *Designs should avoid hydraulic transitions or lighting transitions (USFWS 1960; Bell 1991).*
- *Transport channels should not expose fish to any moving parts.*
- *Transport channels should be designed so that there is no standing water in the channel when the system is dewatered.*
- *Transport channels should be free of exposed edges that protrude from channel walls.*

5.5 Fish Ladder Design

5.5.1 Description and Purpose

The purpose of a fish ladder is to convert total project head at the passage barrier into passable increments and provide suitable conditions for fish to hold, rest, and ultimately pass upstream. Nearly all of the energy from the upstream ladder pool is dissipated in the downstream ladder pool volume, resulting in a series of relatively calm pools that migrating fish may use to rest and stage before ascending upstream. The criteria provided in this section have been developed to provide conditions to pass all anadromous salmonid species upstream with minimal delay and injury.

5.5.2 Common Types of Fish Ladders

Fish ladders or fishways, in one form or another, have been around for more than 300 years (Clay 1995). Over time, ladder designs have developed and evolved and have been adapted to meet site-specific conditions. For the purpose of this document, fish ladders are divided into the following two categories:

- Pool-style ladders, including:
  - Vertical slot
  - Pool and weir
  - Weir and orifice
  - Pool and chute
- Roughened (Baffled) chute-style ladders, including:
  - Denil steeppass
  - Alaska steeppass (ASP)

The following sections present brief discussions of criteria and guidelines for the more common styles of fish ladders.

5.5.2.1 Vertical slot ladder

The vertical slot configuration is a pool-style of fish ladder (Figures 5-3 through 5-5; Table 5-1). The vertical slot ladder is suitable for passage impediments that have tailrace and forebay water surface elevations that fluctuate within large ranges. The maximum head differential—typically associated with the lowest river flows—establishes the design water surface profile, which usually parallels the fishway floor gradient.

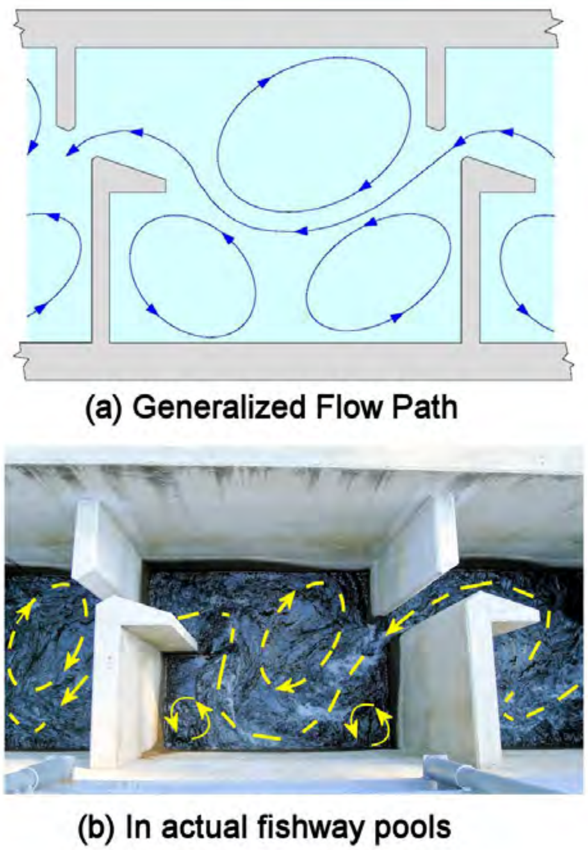


Figure 5-3. Plan view of a vertical slot ladder showing generalized flow paths

Figure 5-4. Oblique view of a vertical slot ladder baffle when dewatered

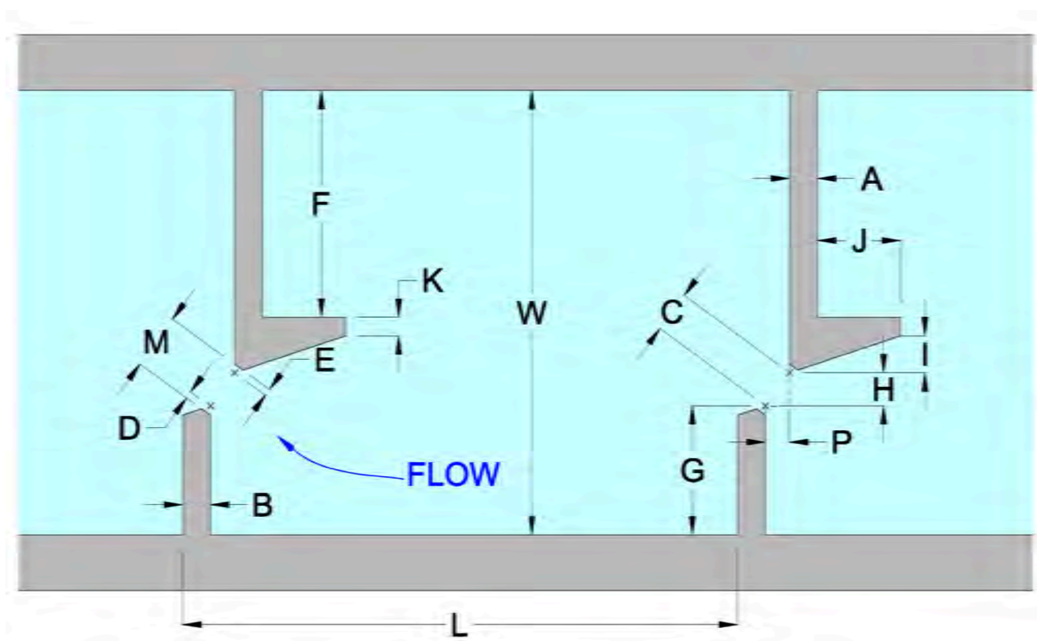


Figure 5-5. Dimensions of a typical vertical slot ladder pool

(Note that information for Figure 5-6 is provided in Table 5-1. "D" is the dimension of the layout points used during ladder design and construction (i.e., the framing and the form work for the concrete pours); it determines the chamfer for the slot and the width of the slot; and knowing "D" allows the designer to layout the complex angles used during construction.)

Table 5-1. Dimensions for vertical slot ladder components measured in feet.

Symbol		Dimension Nomenclature (Refer to Figure 5-6)			
L		Pool length	10'0"	10'0"	10'0"
W		Pool width	6'0"	8'0"	8'0"
A		Long baffle width[A]	0'6"	0'6"	0'6"
B		Short baffle width[A]	0'6"	0'6"	0'6"
M		Slot width	1'0"	1'0"	1'3"
C		Slot width layout points	0'9"	0'9"	0'9"
D, E		Dimension "C" layout points (separation from baffles)	0'1½"	0'1½"	0'3"
F		Long baffle wall length	3'1"	4'1"	4'1"
G		Short baffle wall length (wall to layout point)	1'3¾"	2'3¾"	2'3¾"
I		Flow deflector width change	0'7"	0'8"	0'7"
J		Flow deflector length	1'3"	1'6"	1'3"
K		Flow deflector upstream width	0'5"	0'4"	0'5"

Note:
A: Short baffle and long baffle widths may need to be increased in certain instances for structural integrity in large fishway installations.

The full-depth vertical slots allow fish passage at any depth (Clay 1995). Fish are assumed to be able to move directly from slot to slot in a straight path, although this has not been verified (Clay 1995). However, hydraulic studies have verified that velocity through the slot is constant throughout the vertical profile (Katopodis 1992). The vertical slot may not be well suited for species that require overflow weirs for passage or that tend to orient to walls such as American shad.

5.5.2.1.1 *Vertical slot width and depth*

For adult anadromous salmonids, slots should never be less than 1 foot in width. If larger Chinook salmon are expected to pass, the minimum slot width is 1.25 feet (Clay 1995). Bell (1991) recommends a minimum slot depth of 3 feet, although they are typically on the order of 5- to 6-feet deep to match the required pool depth.

The passage corridor typically consists of 1- to 1.25-foot-wide vertical slots between fishway pools. However, narrower slots have been recommended (Clay 1995) and used in applications for other fish species that are smaller than salmon or steelhead. In some situations, wider slots (or two slots per ladder weir) are used if AWS flow is not being added to the ladder.

Vertical slot ladders tend to require more water to operate properly compared with other styles of fishways because of the width and depth of the slot and the head differential between pools. Low sills can be added to the bottom of each slot to reduce the overall amount of flow in the ladder that is required. However, these sills may block the passage of species that prefer or need to travel along the floor of a ladder.

5.5.2.1.2 *Vertical slot geometry (pool size)*

Standard, proven design dimensions should be adhered to unless it can be proven through physical hydraulic modeling that changes do not affect the function of the ladder.

Vertical slot ladders are sensitive to changes in pool geometry (e.g., pool width, length, slope, and slot width; Clay 1995), and initial construction costs are higher than other types of ladders because of the more complex design and concrete placement.

5.5.2.2 Pool and weir ladder

The simplest style of fish ladder is the pool and weir ladder (Bell 1991); it is also one of the oldest styles of fish ladder. The pool and weir fish ladder passes the entire, almost constant, fishway flow through successive pools separated by overflow weirs that break the total project head into passable increments (Figure 5-6). This design allows fish to ascend to higher elevations by passing over weirs, and it provides resting zones within each pool. When passing this style of ladder, fish must leap or swim over the weir flow. Pools are sized to allow flow energy to be nearly fully dissipated through turbulence within each receiving pool (Clay 1995).

Figure 5-6. Examples of pool and weir ladders

(Note that the orifices in the weir wall on the left-side photo are to drain each of the pools and are not meant for fish passage.)

In contrast to vertical slot ladders, pool and weir ladders require nearly constant water surface elevations in the forebay pool to function properly (Bell 1991; Clay 1995). When the water surface elevation fluctuates outside of the design elevation, too much or too little flow enters the fishway. This flow fluctuation may affect upstream passage by causing fishway pools to be excessively turbulent or providing insufficient flow. To accommodate forebay fluctuations and maintain a consistent flow in the ladder, pool and weir ladders are often designed with an AWS (Section 5.3) and fishway exit control section (Section 5.7; Bell 1991). To accommodate tailwater fluctuations, pool and weir ladder designs may include an adjustable fishway entrance (i.e., adjustable geometry and attraction flow) and an AWS to provide additional flow to meet the channel velocity criterion (Section 5.4.2.1; Bell 1991).

5.5.2.3 Weir and orifice ladder

The weir and orifice fish ladder passes flow from the forebay through successive fishway pools connected by overflow weirs and submerged orifices, which divide the total project head into passable increments (Figures 5-7 and 5-8, Table 5-2; Clay 1995). Weir and orifice ladders are similar to pool and weir ladders in the following ways:

- Weir and orifice ladders require nearly constant water surface elevations in the forebay pool (unless adjustable components are included to accommodate the varying forebay level); water surface elevations outside of the design elevation result in too much or too little flow entering the fishway, which may affect fish passage due to turbulence or insufficient flow.
- Weir and orifice ladders are often designed with an AWS and fishway exit control section (Section 5.7), an adjustable fishway entrance (i.e., adjustable geometry and attraction flow), and an AWS to provide additional low diffusers to meet the transport channel velocity criterion (Section 5.4.2.1).

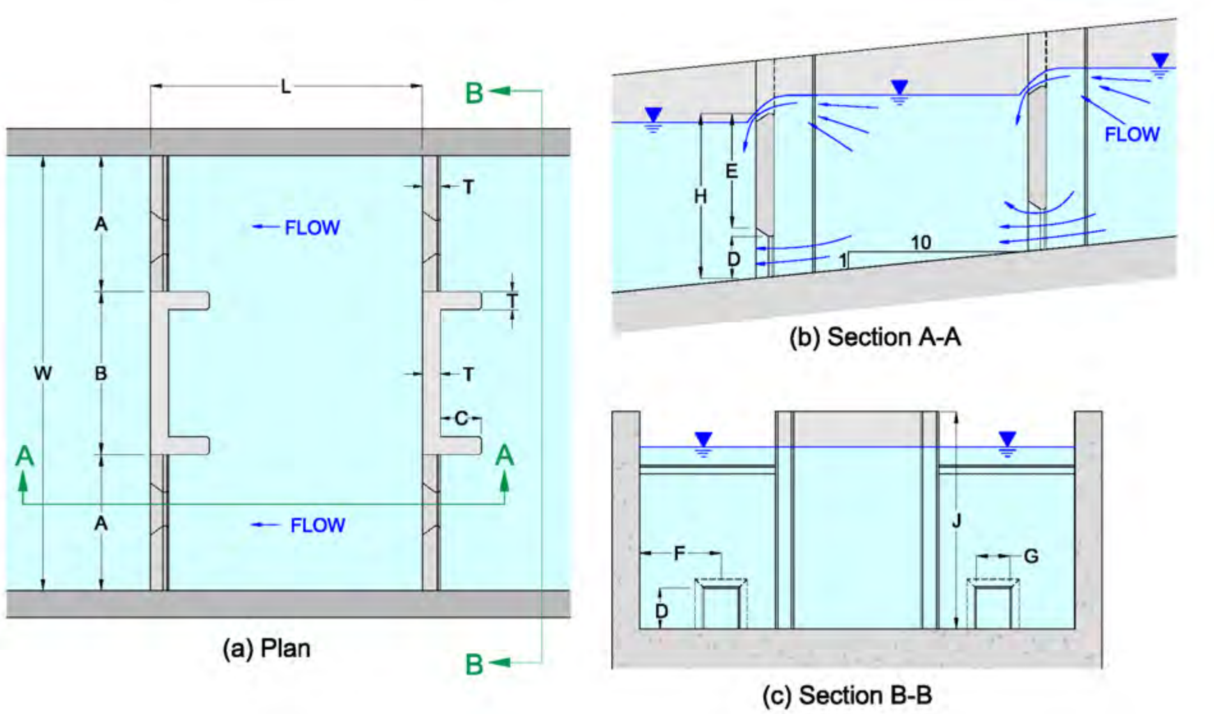


Figure 5-7. Ice Harbor-style weir and orifice ladder (adapted from Gauley et al. 1966

(Note that information for Figure 5-7 is provided in Table 5-2.)

(a) Looking downstream (b) Looking upstream

Figure 5-8. Overhead views of Ice Harbor-style weir and orifice fish ladders

Table 5-2. Dimensions for Ice Harbor fishways measured in feet

Symbol	Dimension Nomenclature (Refer to Figure 5-8)	Bell 1991	Gauley et al. 1966
L	Pool length	8–20	10
W	Pool width	6–20	16
A	Weir length	1.5–5	5
B	Center baffle width	W/2*	6
C	Flow stabilizer length	NA	1’6”
D	Orifice height	1’6”	1’6”
E	Baffle height above orifice	4’3”	4’6”
F	Wall to orifice center line	NA	3
G	Orifice width	1’3”	1’6”
H	Weir height	6	6
J	Wing baffle height	8	8
T	Weir and baffle thickness	NA	NA

Notes:
* See “W” in panel (a) of Figure 5-8.
Dimensions listed under Bell (1991) are taken from https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Bell_1991_Fisheries_handbook_of_engineering_requirements_and.pdf.
Dimensions listed under Gauley et al. 1966 are taken from the report located here: https://www.nwfsc.noaa.gov/assets/26/7778_08132014_135336_Gauley.et.al.1966.pdf.
NA: not available

When passing this style of ladder, fish have the choice of leaping or swimming over the weir or swimming through the orifice, and it is NMFS' experience that most salmonids prefer to swim through the orifice. The Ice Harbor ladder is an example of a weir and orifice fish ladder. This ladder design was developed in the 1960s for use at Ice Harbor Dam on the Snake River in Washington by the Bureau of Commercial Fisheries at USACE Fisheries-Engineering Research Laboratory (FERL), which was located at the Bonneville Dam on the Columbia River in Oregon (Figure G-1 in Appendix G). Fish passage research was conducted at FERL from 1955 until it was decommissioned in the 1980s (see Appendix I for a listing of reports of research conducted at the FERL). The research provided basic knowledge of the behavior, abilities, and requirements of fish in fish passage situations (Collins 1976).

Development and testing at FERL resulted in the design of the l-on-10 slope ladder for Ice Harbor Dam, which was studied in a full-scale section of the ladder consisting of six ladder pools. A prototype ladder was tested during its first year of operation at Ice Harbor Dam. The design is a pool and weir ladder with submerged orifices, flow stabilizers, and a non-overflow section in the middle of each weir (Figures 5-7 and 5-8). See Table 5-2 for typical dimension of this type of fishway. There is a 1-foot rise between pools, and the average water depth under normal operating conditions is 6.5 feet (Gauley et al. 1966). The Ice Harbor-style of ladder includes two rectangular orifices centered on and located directly below each overflow weir. The position and depth of the orifices were found to have a significant effect on the passage of fish through rectangular submerged orifices (Thompson et al. 1967). The orifice and weir combinations are located on each side of the longitudinal centerline of the ladder. Between the two weirs is a slightly higher non-overflow wall with an upstream-projecting flow baffle located at each end. An adaptation for lower flow designs is the half Ice Harbor ladder design, which consists of a weir, an orifice, and a non-overflow wall between fishway pools.

5.5.2.4 Pool and chute ladder

A pool and chute ladder is a hybrid that operates under varying river flow conditions. This ladder is designed to operate as a pool and weir ladder at low river flows and as a roughened chute-style fishway at higher river flows (Figure 5-9). This ladder is an alternative style of ladder for sites with a low hydraulic drop that must pass a wide range of streamflows with a minimum of flow control features. Placement of stoplogs—a cumbersome and potentially hazardous operation—is required to optimize operation of this ladder. However, once suitable flow regimes are established, the need for additional stoplog placement may not be required. Criteria for this type of ladder design are still evolving, and design proposals will be assessed by NMFS on a site-specific basis. Bates (1992) provides specific criteria and guidelines for this style of ladder where fish have the option of swimming over, or leaping the overflow weir, or swimming through the orifice. The lateral slope of the weirs presents fish with flow conditions that range from plunging flow near the edges to streaming flow towards the center of the ladder.

Figure 5-9. Pool and chute ladder dewatered (at left) and watered (at right)

5.5.2.5 Half Ice Harbor and half-pool and chute ladders

The flow rate available to pass through a fishway at small projects is often too low to take advantage of the benefits of the standard Ice Harbor or pool and chute ladder designs. In these situations, it is possible to design and construct weirs shaped as one-half of an Ice Harbor-style weir and orifice ladder or one-half of a pool and chute-style ladder (Figure 5-10). These designs share the same advantages and disadvantages as their full-sized counterparts and should meet all of the design criteria for each type of full-sized ladder. The hydraulic design process used for half-ladders is analogous to the design process used for full-sized ladders.

Figure 5-10. Half ladder designs for projects with reduced available fishway flows

(Note: panel on left is a half-Ice Harbor ladder weir and orifice design; panel on right is a half-pool and chute ladder with weir design.)

5.5.3 Specific Criteria and Guidelines – Fish Ladder Design

5.5.3.1 Hydraulic drop

The maximum hydraulic drop between fish ladder pools should be 1 foot or less (Bell 1991; Clay 1995). Where pink or chum salmon are present, the maximum hydraulic drop between pools should be 0.75 foot or less (Bates 1992; Clay 1995).

5.5.3.2 Flow depth

Fishway overflow weirs should be designed to provide at least 1 foot (± 0.1 foot) of flow depth over the weir crest (Clay 1995; WDFW 2000).

The depth should be indicated by locating a single staff gage in an observable, hydraulically stable location that is representative of flow depth throughout the fishway. The zero reading of the gage should be at the overflow weir crest elevation.

5.5.3.2.1 *Streaming flow*

Some fish species will not leap or are poor leapers and will refuse to pass or become delayed by plunging flow conditions in a ladder. They may also refuse to pass through the orifices in a ladder (e.g., all shad species). For those species, streaming flow should be created *between ladder pools to provide acceptable passage conditions. When pink or chum salmon are present, the upstream weir crest should be submerged by at least 0.5 foot by the downstream water surface level (Bates 1992). Where American shad are present, the upstream weir crest should be submerged by at least 0.3 foot by the downstream water surface level.*

Streaming flow occurs when the weir is backwatered by the downstream weir (Bates 1992; Katapodis 1992). The transition between plunging flow and streaming flow is hydraulically unstable and should be avoided according to Bell (1991) and Bates (1992) because passage can be delayed when flow is in this transition. Hydraulic instability occurs in the transition regime between the upper range of plunging flow and the lower range of streaming flow. The instability can also cause large oscillations that are transmitted throughout the fishway because energy is not dissipated in each pool of the fishway, which makes the streaming flow jet difficult to manage. For these reasons, streaming flow in a fishway should be used cautiously (Bates 1992).

Submerging the upstream weir crest by 0.3 foot is based on experience with adjusting ladder flows at Columbia River dams to pass American shad. In addition, Larinier and Travade (2002) state that a head of around 1.3 feet and streaming flow in an Ice Harbor-style ladder are needed for shad passage. Rideout et al. (1985) report substantial improvements in American shad passage at the Turners Falls dam fishway in Massachusetts when flow over weir crests was changed from plunging to streaming.

5.5.3.3 Pool dimensions

In general, pool dimensions should be a minimum of 8 feet long (upstream to downstream), 6 feet wide, and 5 feet deep. However, specific ladder designs may require pool dimensions that are different from the minimums specified in this criterion, depending on site conditions and ladder flows (see Clay 1995).

For small stream ladders, Bell (1991) provides minimum dimensions for some pool and weir fishway designs. The minimum pool should not be less than 6 feet long, 3 feet deep, and 4 feet wide. It is recommended that the fishway slope not exceed 1:8. For pools less than 8 feet in length, the drop between pools should be reduced proportionally. To allow for the proper dissipation of the orifice flow, the pool dimensions for a pool and orifice-style ladder should not be reduced (Clay 1995).

Ladder pools should be designed so that there is no standing water in the pools when the system is dewatered. The floors of the ladder should be sloped from the sides to the floor orifice to encourage fish to move downstream during salvage operations conducted when a ladder is dewatered for maintenance.

5.5.3.4 Turning pools

Turning pools (i.e., pools where the fishway direction changes more than 90 degrees) should be at least double the length of a standard fishway pool, as measured along the centerline of the fishway flow path. The orientation of the upstream weir to the downstream weir should be such that energy from flow over the upstream weir does not affect the hydraulic conditions at the downstream weir.

5.5.3.5 Pool volume

The pool volume within the fishway should provide sufficient volume (i.e., hydraulic capacity) to absorb and dissipate the pool-to-pool energy and accommodate the maximum daily run of fish (i.e., fish capacity; Appendix H).

Generally, the volume required to provide adequate hydraulic capacity governs pool sizing (Bell 1991; Bates 1992). To provide adequate hydraulic capacity, the fishway pools should be a minimum volume (of water) based on Equation 5-2.

$$V = \frac{(\gamma)(Q)(H)}{4\ ft\text{-}lb\ /ft^3/s} \tag{5-2}$$

where:

V = pool volume in ft^3
γ = specific weight of water, 64.2 lb per ft^3
Q = specific weight flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet

This pool volume should be provided under every expected design flow condition, with the entire pool volume having active flow and contributing to energy dissipation.

If large numbers of fish are expected to pass the fish ladder in a relatively short amount of time, overcrowding can occur, leading to delay. Delay in passage is minimized by providing ample volume to accommodate the peak of the run without overcrowding (Clay 1995). Therefore, it may be necessary to increase the individual pool volume to accommodate the peak run of fish. See Appendix H for sizing a fish ladder based upon run size.

5.5.3.6 Freeboard

The freeboard of the ladder pools should be at least 3 feet at high design flow.

5.5.3.7 Orifice dimensions

At sites where large salmonids are expected, the minimum dimensions of the orifice should be 18 inches high by 15 inches wide (Bell 1991), based on the Ice Harbor ladder design dimensions (Section 5.5.3.3).

The minimum dimensions of orifices where large salmonids are not expected should be at least 15 inches high by 12 inches wide.

The top and sides of the orifice should be chamfered 0.75 inch on the upstream side and chamfered 1.5 inches on the downstream side of the orifice to provide the most stable flow (Bates 1992).

For sites where Pacific lamprey are present, the floor of the fishway should provide a continuous, uninterrupted surface through the orifice. USACE (Portland District) has developed and installed an orifice with rounded edges to facilitate Pacific lamprey passage.

The primary concern with smaller orifices is the increased risk of plugging by debris (WDFW 2000).

5.5.3.8 Lighting

Ambient lighting should be provided throughout the fishway, and abrupt lighting changes should be avoided (Bell 1991). In enclosed systems, such as transport tunnels, provisions for artificial lighting should be included. In cases where artificial lighting is required, lighting in the blue-green spectral range should be provided. Artificial lighting should be designed to operate under all environmental conditions at the installation.

These lighting criteria are based in part on laboratory studies where a majority of Chinook and sockeye salmon and steelhead entered the lighted orifice when given a choice between a dark experimental orifice and a lighted control orifice where head was equal between the two orifices (Weaver et al. 1976).

5.5.3.9 Change in flow direction

At locations where the flow changes direction more than 60 degrees, 45-degree vertical miters (minimum 20 inches wide) or a 2-foot minimum, vertical radius of curvature should be included in the design of the outside corners of fishway pools (Bell 1991).

Bell reports that "Fish accumulate when pool hydraulic patterns are altered. If the design includes turn pools, fish will accumulate at that point. Square corners, particularly in turn pools, should be avoided as fish jump at the upwelling so created" (1991). Depending upon the pool configuration, size of the turning pool, and amount and velocity of the flow in the ladder, larger radii of curvatures may be necessary.

5.6 Counting Stations and Windows

5.6.1 Description and Purpose

Counting stations provide a location and facility to observe and enumerate fish utilizing the fish passage facility. Although not always required, a typical counting station includes a video camera or fish counting technician, crowder, and counting window (Bell 1991). Counting stations are often included in a fish ladder design to allow fishery managers to assess fish population status, observe fish size and condition, and conduct scientific research.

5.6.1.1 Operation

Counting stations should not interfere with the normal operation of the ladder and should not create excessive fish passage delay.

A decision to include a counting station as part of the ladder design should be carefully considered. Regardless of how well the counting station is designed, oftentimes fish hold and delay at counting stations because of conditions that change the facility such as crowding, lighting, and hydraulics. Instead of a counting station, other means of enumeration may be acceptable, including the use of submerged cameras and their associated lighting, adult PIT-tag detectors, and orifice counting tubes.

5.6.2 Specific Criteria and Guidelines – Counting Stations

5.6.2.1 Location

Counting stations should be located in a hydraulically stable, low velocity (i.e., around 1.5 ft/s), and accessible area of the upstream passage facility.

5.6.2.2 Downstream and upstream pools

The pool downstream of the counting station should extend at least two standard fishway pool lengths from the downstream end of the picket leads. The pool upstream of the counting station should extend at least one standard fishway pool length from the upstream end of the picket leads. Both pools should be straight and in line with the counting station (Bell 1991).

5.6.3 Specific Criteria and Guidelines – Counting Windows

5.6.3.1 Design and material

The counting window should be designed such that cleaning of the window can be accomplished completely, conveniently, and at a frequency that ensures window visibility will be maintained and accurate counting can be accomplished. The counting window material should be abrasion-resistant to accommodate frequent cleaning.

5.6.3.2 Orientation

Counting windows should be vertically oriented.

5.6.3.3 Sill

The counting window sill should be positioned to allow full viewing of the fish passage slot (from floor to water surface).

5.6.3.4 Lighting

The counting window design should include sufficient indirect, artificial lighting to provide satisfactory fish identification at all hours of operation and without causing passage delay.

5.6.3.5 Dimensions

The minimum observable length of the counting window in the upstream-to-downstream flow direction should be 5 feet, and the minimum height (depth) should be full water depth.

5.6.3.6 Counting window slot width

The width of the counting station slot (the area between the counting window and the vertical surface at the back of the slot) should be at least 18 inches. The design should include an adjustable crowder to move fish closer to the counting window (but not closer than 18 inches) to allow fish counting under turbid water conditions. The counting window slot width should be maximized as water clarity allows and when not actively counting fish.

5.6.3.7 Picket lead

A downstream picket lead should be included in the design to guide fish into the counting window slot, and it should be oriented at a deflection angle of 45 degrees relative to the direction of fishway flow. An upstream picket lead oriented at a deflection angle of 45 degrees to the flow direction should also be provided. Picket orientation, picket clearance, and maximum allowable velocity should conform to specifications for diffusers (Section 5.3.7).

Combined maximum head differential through both sets of pickets should be less than 0.3 foot. Both upstream and downstream picket leads should be equipped with witness marks to verify correct position when picket leads are installed in the fishway. A 1-foot-square opening should be provided in the upstream picket lead to allow smaller fish that pass through the downstream picket lead to escape the area between the two picket leads.

Picket leads may comprise flat stock bars oriented parallel to flow or other cross-sectional shapes, if approved by NMFS.

5.6.3.8 Transition ramps

If the counting window requires a false floor to force fish to swim higher in the water column to be more easily identified, then transition ramps should be included in a counting station design. The ramps should smoothly transition from the floor of the counting station pool to the false floor at the counting window and then back to the counting station floor.

These ramps provide gradual transitions between walls, floors, and the false floor in the counting window slot. The purpose is to minimize flow separations created by head loss that may impede fish passage and induce fallback behavior at the counting window. In situations where space is available, the transitions should be more gradual than 1:8, and where space is confined, a 1:4 transition should be used.

5.6.3.9 Water surface through the counting slot

A free water surface should exist over the length of the counting window.

5.7 Fishway Exit Control

5.7.1 Description and Purpose

This section describes and provides criteria for a ladder exit control channel for fish to egress the fishway and enter the forebay of a dam to continue upstream migration. The exit control channel may include the following features: add-in auxiliary water valves and diffusers, exit pools with varied flow, exit channels, a coarse trash rack that keeps large debris out of the ladder but allows fish to pass through the trash rack and exit the ladder, and fine trash racks and control gates on AWS systems. The exit control section of the ladder also attenuates fluctuations in forebay water surface elevation, thus maintaining hydraulic conditions suitable for fish passage in the ladder pools. Other functions that should be incorporated into the design of the exit control section include minimizing the entrainment of debris and sediment into the fish ladder. Different types of ladder designs (Section 5.5) require specific fish ladder exit design details unique to each type of ladder.

5.7.2 Specific Criteria and Guidelines – Fishway Exit Control

5.7.2.1 Hydraulic drop

The exit control section hydraulic drop per pool should range from 0.25 to 1 foot.

5.7.2.2 Length

The length of the exit channel upstream of the exit control section should be a minimum of two standard ladder pools.

5.7.2.3 Design requirements

Exit section design should utilize the requirements for AWS diffusers, channel geometry, and energy dissipation as specified in Sections 5.3, 5.4, and 5.5.

5.7.2.4 Closure gates

Any closure gate that is incorporated into the exit control section should be operated either in the fully opened or closed position (i.e., the gates cannot be partially open to regulate flow).

5.7.2.5 Location

In most cases, the ladder exit should be located along a shoreline, in a velocity zone of less than 4 ft/s, and sufficiently far enough upstream of a spillway, sluiceway, or powerhouse to minimize the risk of fish non-volitionally falling back through these routes (Clay 1995).

The distance the exit needs to be upstream of these hazards depends on bathymetry near the dam spillway or crest and associated longitudinal river velocities (Bell 1991).

5.7.2.6 Public access

Public access near the ladder exit should be prohibited.

5.8 Fishway Exit Sediment and Debris Management

5.8.1 Description and Purpose

As stated in Section 5.7.1, the design of the ladder exit should strive to minimize the entrainment of debris and sediment into the fish ladder. Floating and submerged debris can become lodged in ladder orifices or on weir crests, alter hydraulic conditions in these fish passage routes, and impact fish behavior and passage rates. Similarly, sediment transported into the fishway can deposit in low-velocity areas, alter hydraulic conditions, and impact fish passage. Removing debris and sediment from ladders can be difficult and costly. Therefore, preventing debris and sediment from entering the ladder from the forebay should be a goal of the ladder exit design.

5.8.1.1 Coarse trash rack

For facilities where maintenance is frequently required and provided, coarse trash racks should be included at the fishway exit to minimize the entrainment of debris into the fishway (Figure 5-9; Bell 1991).

5.8.2 Specific Criteria and Guidelines – Coarse Trash Rack

5.8.2.1 Velocity

The velocity through the gross area of a clean coarse trash rack should be less than 1.5 ft/s to reduce debris accumulation and thus facilitate cleaning of the racks regularly (Bates 1992).

Bell (1991) indicated there is no evidence of fish refusing to pass through trash racks at velocities normal to the trash rack of 2 ft/s or less.

5.8.2.2 Depth

The depth of flow through a coarse trash rack should be equal to the pool depth in the ladder exit channel.

5.8.2.3 Maintenance

At locations where manual cleaning is anticipated, the coarse trash rack should be installed at 1:5 slope (or flatter) for ease of cleaning (Bates 1992). The coarse trash rack design should allow for easy maintenance and provide access for personnel, travel clearances for manual or automated trash raking, and the removal of debris.

5.8.2.4 Bar spacing

The coarse trash rack on the ladder exit should have a minimum clear space between vertical flat bars of 10 inches if Chinook salmon are present, and 8 inches for all other species and instances. Lateral support bar spacing should be a minimum of 24 inches and should be sufficiently set back from the face of the coarse trash rack to allow trash rake tines to fully *penetrate the rack for effective debris removal. Coarse trash racks should extend to the appropriate elevation above water to allow debris raked from the trash racks to be easily removed.*

Bell (1991) recommends that the clear openings of a trash rack be adapted to the width of the largest fish to be passed, which is usually 12 inches for large salmon. Figure 5-11 shows an example of a sloping coarse trash rack on the exit channel of a small fishway.

Figure 5-11.Sloping coarse trash rack on a fishway exit channel

5.8.2.5 Orientation

The fishway exit coarse trash rack should be oriented at a deflection angle greater than 45 degrees relative to the direction of river flow.

5.8.3 Specific Criteria and Guidelines – Debris and Sediment

5.8.3.1 Coarse floating debris

Debris booms, curtain walls, or other provisions should be included in the design of a fishway if coarse floating debris is expected.

5.8.3.2 Debris accumulation

If debris accumulation is expected to be high, the fishway design should include an automated mechanical debris removal system. If debris accumulation potential is unknown, the *design should anticipate the need for debris removal in the future and include features to allow an automated mechanical debris removal system to be retrofitted to the design.*

5.8.3.3 Sediment entrainment and accumulation

The fishway exit should be designed to minimize sediment entrainment into the fishway and sediment and debris accumulation at the exit under normal operations.

5.9 Roughened (Baffled) Chute Fishways

5.9.1 Description and Purpose

This section discusses the baffled chute, which is another general type of fish passage system. It consists of a hydraulically roughened flume that has nearly continuous energy dissipation throughout its length.

5.9.2 Specific Criteria and Guidelines – Baffled Chutes

The baffled chute fishway utilizes a relatively steep, narrow flume with internal roughness elements that generate lower water velocities that allow the fish to swim through the fishway. Denil and ASP fishways are examples of baffled chute fishways that share a similar design philosophy. Baffled chute fishways are designed to operate with less flow and at steeper slopes than traditional ladders.

5.9.2.1 Uses

Denil and ASP fishways should not be used as the primary route of passage at permanent fishway installations in the WCR.

Baffle chute fishways are not considered a substitute for a permanent style of ladder (e.g., a pool and weir ladder) because of their tendency to collect debris and their limited operating range. Denil and ASP fishways are primarily used at sites where the fishway can be closely monitored and inspected daily. This includes off-ladder fish traps, temporary fishways used during construction of permanent passage facilities, and fishways operated temporarily each year to collect hatchery broodstock. Baffle chute fishways should not be used at locations or in situations where the downstream passage of adults or juvenile salmonids occurs.

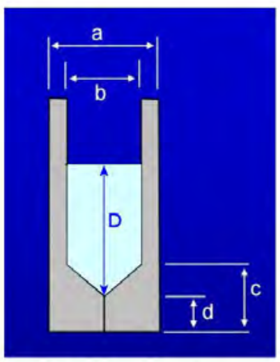
5.9.2.2 Debris

Denil and ASP fishways should not be used in areas where even minor amounts of debris are expected (Bell 1991).

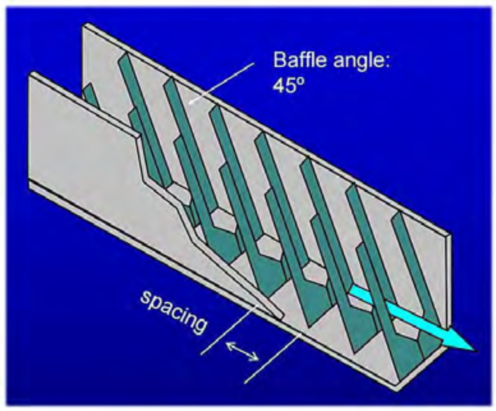
Debris accumulation in any fishway, in combination with turbulent flow, may injure fish or render the fishway impassable. Because of their internal baffle geometry and narrow flow paths, baffle chute fishways are especially susceptible to debris accumulation, creating a blockage to passage.

5.9.2.3 Design

Denil and ASP fishways are designed with a sloped channel that has a constant discharge for a given normal depth, chute gradient, and baffle configuration (Figure 5-12). Energy is dissipated consistently throughout the length of the fishway via channel roughness and results in an average velocity compatible with the swimming ability of adult salmonids. The passage corridor consists of a chute flow between and through the baffles. A wide range of flows are possible for Denil fishways depending on fishway size, slope, and water depth (Bates 1992).



Modified from Bates (1992)



a	b	c	d	spacing
4'	2'-4"	2'-0"	12"	2'-9"
3'	1'-9"	2'-6"	9"	2'-0"
2'	1'-2"	1'-0"	6"	1'-4"

Figure 5-12. Drawings, dimensions, and a photo of a Denil fishway

5.9.2.3.1 *Specific design information – Denil fishways*

The standard dimensions shown in Figure 5-12 and the following design information for Denil fishways is taken from Bates (1992):

- *NMFS recommends a maximum slope of 20%.*
  - The normal slope for a Denil-style fishway is 17% (Bell 1991), though they have been used at slopes up to 25% (Bates 1992).
- *Discharge through Denil fishways can be calculated using Equation 5-3 (Bates 1992).*

$$Q = 5.73D^2\sqrt{bS} \tag{5-3}$$

where:

Q = ladder flow, in ft^3/s
D = depth (feet) of flow above the vee baffle
b = clear opening in the baffle (feet)
S = slope (feet/feet)

- *The average chute design velocity should be less than 5 ft/s (Bell 1991).*
    - The most common size of Denil fishway used is the 4-foot-wide flume (Bates 1992).
- *Flow control is important though not as critical for a Denil fishway as for a weir and pool ladder. The forebay should be maintained within several feet to maintain good passage conditions in a Denil fishway.*
    - According to the velocity profiles developed by Rajaratnam and Katopodis (1984), centerline velocities increase towards the water surface in Denil fishways where the ratio of flow depth to width (D/b in Figure 5-13) is more than 3. The height of the Denil fishway is not limited; additional height adds attraction flow and operating range without additional passage capacity because of the higher velocities in the upper part of the fishway (Bates 1992).
- *Minimum depth in a Denil fishway should be 2 feet, and depth should be consistent throughout the fishway for all flows.*
    - Bates (1992) reports that Denil fishways are typically constructed with depths from 4 to 8 feet.
- *The standard length is 30 feet (Bell 1991).*
- *Denil fishways can be constructed out of plywood, steel, or concrete with steel or plywood baffles.*

5.9.2.3.2 *Specific design information – Alaska steeppass fishways*

The ASP fishway is a specially designed baffle chute fishway developed for use in a variety of locations in Alaska (Figure 5-14; Ziemer 1962). It is typically constructed in sections that can be bolted together on site, making the system portable.

(a) Downstream end. (b) Upstream end. (c) In operation.

Figure 5-13. Examples of ASP fishways

The following design information for ASP fishways is taken from Rajaratnam and Katopodis (1984):

- *Discharge through the ASP fishway can be calculated as shown in Equation 5-4:*

$$Q = 1.12S^{0.5}\, D^{1.55}\, g^{0.5} \tag{5-4}$$

where:

Q = flow (ft^3/s)
S = slope (ft/ft)
D = depth (feet) of flow above the floor vane
g = gravitational acceleration (32.2 ft/s^2)

Most of the following design information on ASP fishways is taken from Bates (1992), and standard ASP fishway dimensions are shown in Figure 5-14.

- *NMFS recommends a maximum slope of 28%.*
  - The normal slope is about 25%, but ASP fishways have been tested and used up to a slope of 33% (Bates 1992).
- *The average chute design velocity should be less than 5 ft/s.*
- *Flow control is very important for properly functioning ASP fishways. The forebay water surface cannot vary more than 1 foot without creating passage difficulties, and the tailwater should be maintained within this same range to prevent a plunging flow or backwatered condition from forming. Backwatering the entrance results in reduced entrance velocity and fish attraction (Bates 1992).*
  - For example, Slatick (1975) found that the median passage time for salmon increased fourfold, and 25% fewer salmon entered the fishway when the downstream end was submerged by 2.5 feet.
- *Minimum depth in an ASP fishway is 1.2 feet.*
- *The standard length of each unit is 10 feet. Individual units can be bolted together to create lengths of 20 to 30 feet.*
- *ASP fishways are usually constructed of heavy gauge aluminum.*

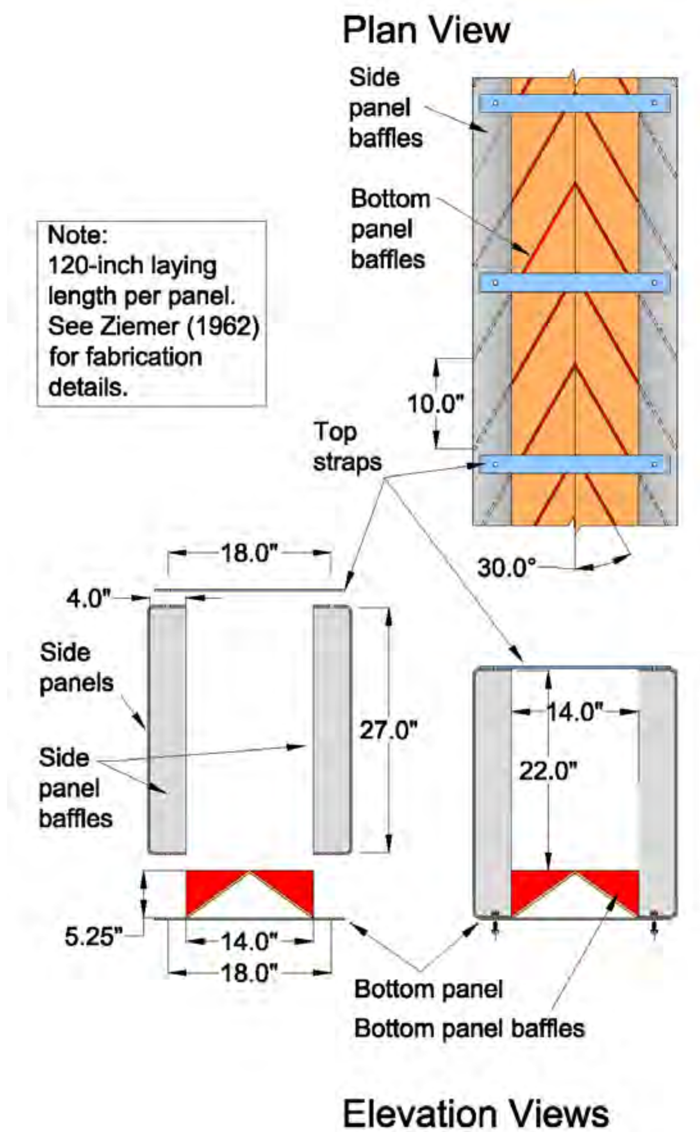


Figure 5-14. Plan and elevation views of a typical ASP fishway

5.9.2.3.3 *Special considerations for Denil and Alaska steeppass fishways*

The following unique aspects of Denil or ASP fishways must be carefully considered: intermediate resting pools, minimum resting pool volume, and exit locations.

- Intermediate resting pools:

If the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Resting pools (where water velocities are less than 1 ft/s) should be provided for Denil fishways longer than 30 feet in length (Bell 1991); resting pool size should be based on minimum pool size or EDF (energy dissipation factor) calculations. These guidelines also apply to ASP fishways longer than 30 feet in length.

Typically, there are no resting locations within a given length of Denil or ASP fishway. Once a fish starts to ascend a length of an ASP or Denil fishway, it must pass all the way upstream and exit the fishway or risk injury when falling back downstream. Therefore, if the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Clay (1995) recommends that resting pools be provided for every 12 feet of height ascended and that average velocity in the resting pool should not exceed 1 ft/s. NMFS recommends that the designer size the resting pool based on the minimum pool size necessary to achieve either an average velocity of 1 ft/s or an adequate pool size based on the expected run size, if known (Appendix H), or on the EDF formula for pool volume (Equation 5-5), whichever is larger.

- Minimum resting pool volume:

The minimum volume of the resting pool is calculated as shown in Equation 5-5, which is similar to Equation 5-2 in Section 5.5.3.5 except that the volume required is increased by a factor of 2 since this equation is for a resting pool.

$$V = (\gamma)(Q)\left(\frac{v^2}{2g}\right)/\left\{\left(2ft\,\frac{lbs}{s}\right)/ft^3\right\} \qquad (5\text{-}5)$$

where:

V = *volume, in ft^3*
γ = *specific weight of water, 62.4 lb per ft^3*
Q = *Denil or ASP flow, in ft^3/s*
v = *velocity of pool-to-pool flow, in ft/s*
g = *gravitational acceleration (32.2 ft/s^2)*

Blackett (1987) conducted experimental modifications to an ASP fishway at a 10-meter-high falls to improve sockeye salmon entry and passage. Sockeye salmon passage was equivalent between an ASP fishway of approximately 200 feet in length with no resting pools and an adjoining ASP fishway where three resting pools were incorporated into the design—although significant year-to-year differences in passage occurred amongst each ASP fishway. However, resting pools were beneficial for holding slower or descending salmon without blocking the passage of other salmon. Also, sockeye salmon passage was greater in the original ASP fishway with three resting pools than in another ASP fishway tested that contained a single resting pool.

- Exit locations:

Denil and ASP fishway exits should be located to minimize the potential for fish to fallback over the barrier.

5.10 Nature-Like Fishways

The nature-like fishway is a fishway type characterized by its use of natural materials (such as rocks and boulders) and incorporation of natural riverine characteristics in its construction and design (Katopodis et al. 2001; Wildman et al. 2003). Nature-like fishway design simulates the hydraulic conditions of natural channels, natural passage windows, and migration timing for target fish species. The resulting project should provide natural hydraulic conditions for target species (mimicking the geomorphic form and complexity found in natural channels the target species inhabit).

Nature-like fishways are thought to facilitate the passage of a wide assemblage of fish and aquatic species, sometimes purported to provide better passage than traditional methods (fish ladders). However, Castro-Santos (2011) concluded that nature-like fishway designs evaluated in his study were not superior to traditional fish ladders for the 23 fish species from the northeastern United States (of those that were evaluated). More recently, Landsman et al. (2018) compared the passage of salmonid and non-salmonid species at nature-like fishway and pool-and-weir fishways in eastern Canada and reported similar results. Nature-like fishways have been observed to pass anadromous and resident salmonids with varying degrees of success at projects of varying hydraulic complexity (Aarestrup et al. 2003; Calles and Greenberg 2005, 2009; Dodd et al. 2017).

At the project-scale, design variables related to nature-like fishways are nearly synonymous with more traditional fish ladder designs typically used at these same locations (such as a vertical slot or ice harbor). The main difference being that nature-like fishways are constructed using natural materials, not concrete. Like any other fishway, if the design variables between the tailrace and the forebay are improperly designed, the result may be adverse passage effects to the project. All project-scale passage variables should be properly analyzed, accounted for, and work together to provide safe, timely, and effective upstream passage for salmonids and other target species (the same expectation as had for any other style of fishway).

5.10.1 Experimental Applications

Nature-like concepts and methods are sometimes used in conjunction with more traditional fishway designs. When combining nature-like methods with traditional methods many of the passage assumptions and anticipated hydraulic conditions associated with traditional fishways do not hold, or are hard to predict. Combined designs are classified by NMFS as experimental. Experimental designs are addressed in Section 1.5 and should be vetted using the guidelines contained in Appendix C.

5.10.2 Design Methods

Nature-like fishways are intended to simulate passage conditions of a natural channel. Like natural channels, there is a high degree of hydraulic variability within the fishway. This high variability makes recommending a universal design approach challenging. The following guidelines will help designers better understand critical components of nature-like fishway design, regardless of the engineering methods and approaches implemented.

Nature-like fishway designs may simulate the form and roughness of a reference reach selected as a design template from a natural channel, or the design may rely on hydraulic analysis and physical modeling, or both. The following sources provide additional information on the hydraulic and geomorphic concepts and potential design methods used in nature-like fishway design: Acharya et al. 2000; Keils et al. 2000; Katopodis et al. 2001; Courtice et al. 2016.

5.10.3 Specific Criteria and Guidelines

The criteria contained in this section apply primarily to fish passage projects where the fishway is designed to provide passage around a dam or diversion.

5.10.3.1 Maximum average channel velocity

Maximum average channel velocity at the 5% exceedance flow should be no greater than 5 ft/s, regardless of channel slope. The relationship between channel roughness and channel slope should be carefully engineered to ensure this criterion is not exceeded.

Barnard (2013) indicates that at the 10% exceedance flow, high gradient streams in Washington State exhibit similar average channel velocities, regardless of channel slope, on the order of 4 ft/s. The velocity criterion in the section is presented to help designers express a more realistic relationship between channel slope and roughness in nature-like fishway designs. When channel slope and roughness have the proper relationship to maintain a 5 ft/s average channel velocity at the 5% exceedance flow, energy dissipation and turbulence are much more likely to be within the range observed in natural high gradient streams of similar slope and roughness. This criterion also simplifies and improves design and monitoring by providing a simple value to compare against hydraulic models and field measurements. An in-depth discussion on turbulence in higher gradient natural channels in contained in CH 6 of Barnard (2013).

The origin of the 4ft/s criterion used the 10% exceedance flow to back calculate EDF in high gradient natural channels. When using a 5% exceedance flow it seems reasonable to increase the maximum average channel velocity to 5 ft/s. When using a 1% exceedance flow, it seems reasonable to use a maximum average channel velocity of 6 ft/s. These assumptions are supported by data from Castro and Jackson (2001) which indicates the average bankfull channel velocity in the Pacific Northwest can be well represented as an average of 6 ft/s. Work by Love and Lang (2014) reported that annual exceedance values associated with a discharge equal to 50% of the 2-year return interval ranged between 0.2% and 1.8%. Annual exceedance flows between 10% and 1% exceedance are likely well represented by a range of average channel velocities between 4ft/s and 6ft/s.

5.10.3.2 Pool depth

If drop structures are used in the fishway, minimum pool depth should be 4 feet in the receiving pool of each drop structure.

5.10.3.3 Maximum hydraulic drop

Maximum hydraulic drop is 1 foot for adult salmonids and 0.5 foot for juvenile salmonids.

5.10.3.4 Maximum fishway slope

Maximum fishway slope is 5% for all salmonid species.

5.10.3.5 Channel stability

Beds and banks should be designed to be immobile at all anticipated fishway discharges.

5.10.3.6 Channel roughness

Simulated or modeled roughness values should be physically expressed in the post-construction roughness of the channel design. Actual fishway roughness should produce a maximum 5 ft/s average velocity at the high fish passage design flow. Designers should provide a summary discussion of how modeled roughness will be translated and transformed into actual project roughness.

Modeling requires the use of roughness values to estimate the effects of boundary roughness on water depth and velocity in channel design. NMFS has observed there can be large discrepancies between modeled roughness values and the actual roughness physical expressed in the design post-construction. These discrepancies are typical expressed as higher velocities, increased turbulence, unanticipated scour and erosion, and a fewer holding and resting areas than were expected. Individually and in aggregate these issues can adversely affect fish passage. It is expected that documentation of the methods, assumptions, and specifications used to detail and explain the roughness design process will result in fewer projects failing to meet passage requirements.

Channel roughness providing the bulk of fish passage benefits are best described and specified comparing the size of the elements to the depth of water at the high fish passage design flow. Large roughness elements will possess an exposed dimension above the thalwag that is analogous to the high fish passage design depth. Meaning once stable, the element should have a portion exposed to the air, or nearly exposed, at the high fish passage design flow. This relationship between water depth and roughness size is critical to providing the necessary energy dissipation and velocity reduction for fish to rest and move in higher gradient channels. Channels with low relative roughness (uniformly sized bed and bank material), are characterized as hydraulically smooth. Hydraulically smooth channels at high gradients provide little to no resting or holding areas for fish. Hydraulically smooth channels commonly fail to meet fish passage velocity criteria.

The above discussion was developed based on the relationship between natural D84 and D90 class material and bankfull depth for streams in Washington State with slopes greater than 2% (Barnard et al. 2013). Barnard et al. measured stream discharge and bed roughness, observing that the rock providing the bulk of velocity reduction and hydraulic diversity were those elements which had a dimension analogous to the bankfull depth of the channel. Over a diverse range of project sizes, NMFS has also observed that velocity conditions are most often passable when somewhere in the range of 20%-40% of the project surface area is occupied by roughness elements extending significantly into the water column at the bankfull discharge.

5.10.3.7 Technical components

The technical components, and their associated criteria, used in nature-like fishway project remain consistent with more traditional fish ladder designs and include the following:

Section 5.2, Fishway Entrance

Section 5.3, Auxiliary Water Systems

Section 5.6, Counting Stations

Section 5.7, Fishway Exit Control

Section 5.8, Fishway Exit Sediment and Debris Management

Section 5.11, Miscellaneous Considerations

Appendix H: Sizing Fish Ladder Pools Based on Energy Dissipation and Fish Run Size

5.10.4 Monitoring and Maintenance

A monitoring and maintenance plan for nature-like fishways is required. The frequency of monitoring and maintenance needed will be determined in consultation with NMFS. The plans should address how morphology and fish passage hydraulics will be monitored and modified, as needed, by developing an adaptive management approach that identifies triggers for when additional actions are to be implemented that address changes in nature-like fishway channel morphology and hydraulic conditions.

5.10.4.1 Passage assessment

Depending on project-specific considerations, monitoring may include an assessment of passage efficiency via fish tagging or fish counts. This monitoring criterion will be identified by NMFS on a project-by-project basis.

5.10.4.2 Channel stability

The loss or displacement of bed and bank material after a high-flow event does not necessarily equate with a failure of the nature-like fishway to maintain passage conditions. Any resulting loss or displacement of bed and bank material should be evaluated to determine the effects, if any, on passage criteria. Needed modification or repairs to bring the fishway into criteria should be discussed with NMFS and implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be approved by NMFS.

5.10.4.3 Channel velocity

Channel velocity should be verified through post construction monitoring. When average channel velocity exceeds 5 ft/s at the high fish passage design flow needed modifications or repairs to bring the fishway into criteria should be identified be discussed with NMFS and *implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be reviewed by NMFS.*

Two methods of measuring average velocity are used. First, longitudinal, or reach average velocity is measured. This is defined as the travel time of a particle beginning at the fishway exit and ending at the entrance, divided by the fishway length, and reported in ft/s. The velocity. Second, cross section average velocity is measured. Cross section velocity is measured at discrete sections of the fishway not associated with a hydraulic drop. Cross sections are measured every 40 feet of fishway beginning immediately upstream of the fishway entrance.

5.11 Miscellaneous Considerations

5.11.1 Security

Fishway facilities and areas should be secured to discourage vandalism, preclude poaching opportunity, and provide for public safety.

Security fencing around the facility and grating over the fishway may be required.

5.11.2 Access

Access for personnel to all areas of the fishway should be provided to facilitate operational and maintenance requirements. Walkway grating should allow as much ambient lighting into the fishway as possible. Consideration should be given to providing access for personnel to each pool of the ladder to support fish salvage operations.

5.11.3 Edge and Surface Finishes

All metal edges in the flow path used for fish migration should be ground smooth and rounded to minimize risk of lacerations. Concrete surfaces should be finished to ensure smooth surfaces, with 1-inch-wide, 45-degree corner chamfers.

5.11.4 Protrusions

Protrusions that fish could contact, such as valve stems, bolts, gate operators, pipe flanges, and permanent ladders rungs, should not extend into the flow path of the fishway.

5.11.5 Exposed Control Gates

All control gates exposed to fish (e.g., entrances in the fully open position) should have a shroud or be recessed to minimize or eliminate fish contact.

5.11.6 Maintenance Activities

To ensure fish safety during in-season fishway maintenance activities, all fish ladders should be designed to provide a safe egress route or safe holding areas for fish prior to any temporary (i.e., less than 24 hours) dewatering. Longer periods of fishway dewatering for *scheduled ladder maintenance should occur outside of the passage season and with procedures in place that allow fish to be evacuated in a safe manner.*

5.12 Operations and Maintenance Considerations

5.12.1 Activity Near the Ladder

There should be no construction or heavy activity within 100 feet of a ladder entrance or exit or within 50 feet of any other portion of the ladder, but this can be reviewed on a case by case basis.

5.12.2 Maximum Outage Period

A fishway should never be inoperable due to mechanical or operational issues for more than 48 hours during the fish passage season of any anadromous species.

6 Exclusion Barriers

6.1 Introduction

Upstream-migrating salmonids are often attracted to areas of a river where flow is concentrated or velocities are high such as the discharge from a hydroelectric powerhouse. This behavior may cause fish to attempt to ascend a barrier at locations where passage is poor or blocked, which could result in the following:

- Injuries (e.g., lacerations, abrasions) caused by
  - Brushing against rocks or structures while swimming in turbulent areas
  - Jumping and striking rocks or structural projections
- Direct or delayed mortality due to injuries
- Migration delays

Exclusion barriers are structures or devices that are designed and used to halt the upstream migration of fish (BOR 2006). These barriers can guide fish to an area where upstream migration is allowed or to holding, sorting, evaluation, and transportation facilities. They are also used to prevent fish from entering an area where no upstream egress or suitable spawning habitat exists. For example, exclusion barriers could be required to protect upstream-migrating salmon and steelhead from injuries or mortality caused by ascending powerhouse turbine draft tubes or tunnels. Exclusion barriers can also be used for the following:

- Preventing fish from entering return flow from an irrigation ditch; tailrace of a power plant; channels subject to sudden flow changes; and channels with poor spawning gravels, poor water quality, or insufficient water quantity
- Guiding fish to counting facilities as well as trap facilities for upstream transport, research, or broodstock collection

6.1.1 Fish Safety

Exclusion barriers should be designed to minimize both the potential for fish injury and mortality and migration delays.

Fish may be physically injured (e.g., lacerations, abrasions) when attempting to pass exclusion barriers in migration pathways (FERC 1995). Therefore, barrier design and operation should consider and eliminate sources of injury due to shallow depths, exposed components, and rough surfaces. Barriers that are poorly designed can cause fish to delay migration while undertaking multiple attempts to pass the barrier.

6.1.2 Barriers Used to Collect Information

Installing exclusion barriers solely for the purpose of collecting information needed for fisheries management will be discouraged, especially if ESA-listed fish are present in the watershed.

6.1.3 Other Species

Installing an exclusion barrier in river systems with multiple species of migratory fish should be carefully considered because some designs may inadvertently block the upstream and downstream movement of non-target species.

Conversely, exclusion barriers may also be used to restrict the movement of undesirable species into upstream habitat (Clay 1995) such as sea lamprey in the Great Lakes (McLaughlin et al. 2007).

6.1.4 Flow Range

All barriers should be designed to function safely over the expected design range of flow conditions for the site when target fish are present (BOR 2006).

6.2 Types of Exclusion Barriers

Barriers to upstream fish passage are either physical or behavioral (e.g., acoustic, chemical, thermal, or lighting). They can be natural or fabricated. Natural barriers consist mainly of waterfalls and debris jams, whereas fabricated barriers consist mainly of dams, culverts, and log jams (Powers and Orsborn 1985). This chapter focuses on fabricated physical barriers, which present fish with structures or conditions that block farther upstream migration.

Fabricated physical barriers are classified into three categories: diffusers, weirs, and drop structures (Figure 6-1). Picket and weir barriers rely on bars racks, pickets, porous rigid panels, screens, or fences to physically exclude fish from entering an area. Fixed bar racks and picket barriers have similar meanings and purposes, and fish passage designers often use these terms interchangeably. However, the term ‘picket barrier’ carries an added nuance—these barrier panels tend to guide fish in some preferred direction—in addition to blocking farther upstream passage. Figure 6-2 is a schematic illustration of a temporary fish weir that uses pickets to guide fish to a trap at the riverbank.

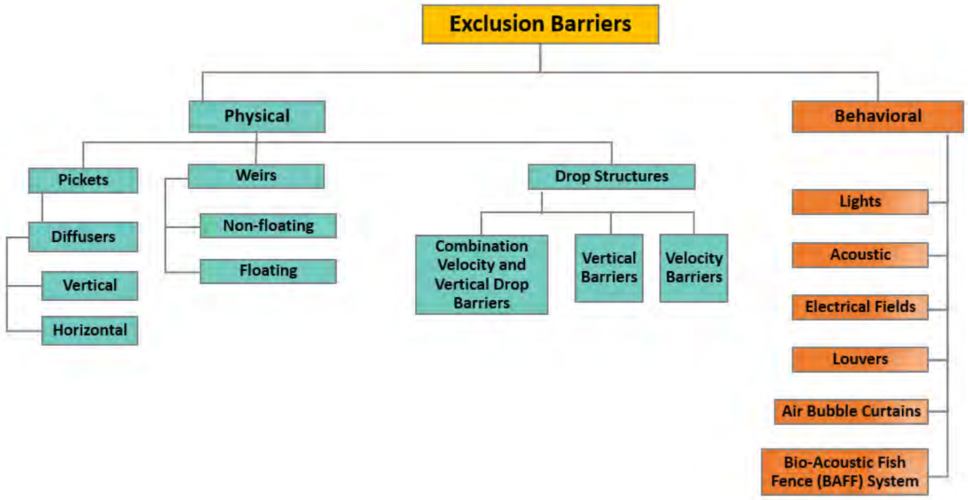


Figure 6-1. Classifications of exclusion barriers

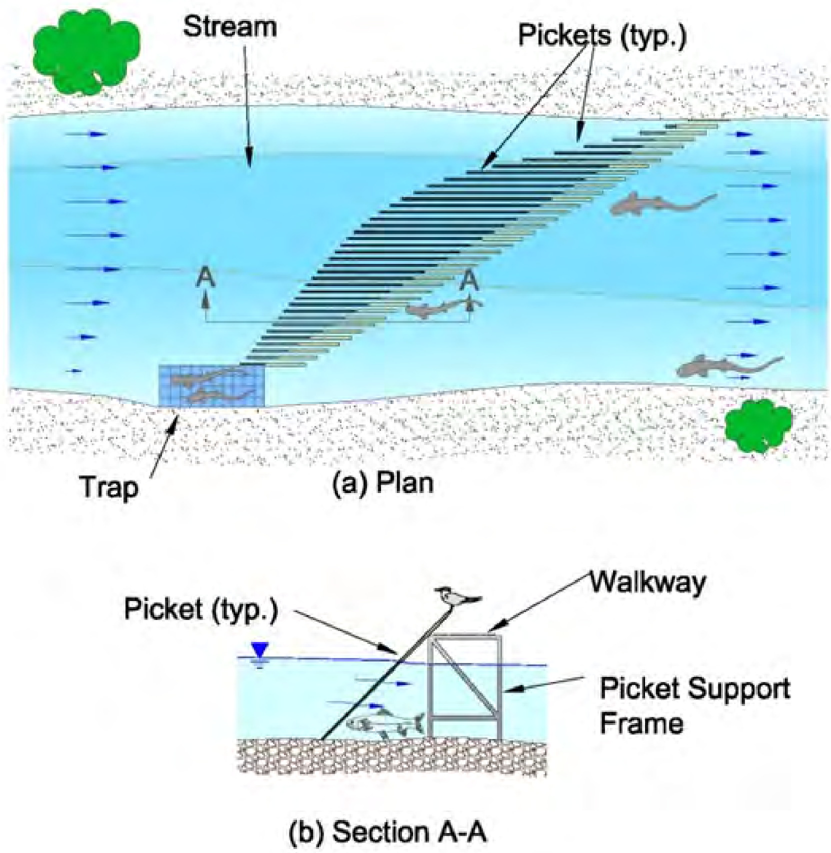


Figure 6-2. Fish weir constructed with pickets in plan (a) and section (b) views

Advantages of pickets and weir barriers include the following:

- They induce a small loss of head under clean and partially plugged conditions.
- They can function over a wide range of river flow stages.
- They can be designed to be removable.

Disadvantages of pickets and weir barriers include the following:

- Bar spacing that is too wide will not function effectively as a barrier, and bar spacing that is too narrow can collect debris more quickly than it can be removed. Striking a balance between the competing design objectives of excluding fish while not collecting more debris than can be managed may be difficult or impossible, depending on the river system and target fish species being excluded.
- Downstream juvenile and adult fish that need to pass the barrier can be excessively delayed and, in some designs, injured or killed. It is important to recognize that this type of barrier can cause injury and mortality to downstream migrants.
- Barrier components require periodic cleaning and are subject to rapid plugging (BOR 2006).

Drop structure barriers involve a combination of local hydraulic conditions downstream of a barrier and the swimming capabilities of the species and life stage to block migration (Powers and Orsborn 1985). They create hydraulic conditions that exceed the swimming or leaping capabilities of the fish to overcome the hydraulic condition. Examples include velocity barriers, vertical drop barriers, and velocity drop barriers. Hydraulic conditions at a specific site function as a barrier when one or more of the following conditions are present:

- Water velocity downstream from a barrier exceeds the swimming speed of fish.
- A standing wave develops downstream of the barrier that fish cannot pass through, or it forms too far downstream to allow the fish to rest before bursting upstream.
- A downstream plunge pool is too shallow to allow fish to jump the barrier.
- Barrier height exceeds jumping ability of fish.

Advantages of drop structure barriers include the following:

- These have lower maintenance requirements compared to picket and weir barriers.
- Debris passes over the barrier with flow (instead of plugging the barrier, which can be the case with structural barriers).
- All species and life stages of fish whose swimming capabilities are weaker than the species the barrier was designed to address are excluded.
- The passage of downstream migrants over drop barriers is usually safer than through picket and weir barriers.

Disadvantages of drop structure barriers include the following:

- They require a significant head to function properly.
- Their performance depends on maintaining a minimum head differential across the barrier.
- The pool upstream of the barrier structure may increase sediment deposition, which reduces channel capacity (BOR 2006).
- Drop structures may create a serious hazard to boaters and swimmers and precautions to protect boaters and swimmers should be included in the design.

Several reports contain additional information on the topic of exclusion barriers and fish swimming performance. Bell (1991) provides information on the swimming and jumping capabilities of various salmonid species. Powers and Orsborn (1985) provide equations for calculating maximum swim distances and estimating leap height and distance. Katopodis (1992) provides endurance curves for fish of various lengths for the two main modes of fish locomotion and a formula for calculating swimming distance. The two main modes of locomotion are anguilliform body shapes (e.g., lamprey and Burbot) and subcarangiform body shapes (e.g., anadromous salmonids and various freshwater species such as bass, suckers, and chub).

6.3 Picket and Weir Barriers

Physical barriers typically rely on a combination of low-velocity flow discharged through bar racks, pickets, diffusers, screens, or fences to physically block fish from entering an area. Picket and weir barriers include fixed bar racks, picket panels (Figure 6-3), diffusers (a specialized form of picket barrier usually used in AWS in fishways), horizontal outlet diffusers, and a variety of hinged, floating weir designs and framework-supported (rigid) weir designs. The clear opening between bars in bar rack panels or pickets in picket panels should be sufficiently narrow to create a barrier to the smallest-sized migrant fish being excluded from farther passage upstream. Depending on the design and site conditions, weir barriers may need to be removed during high-flow events to prevent structural damage, which potentially reduces the barrier's ability to prevent target fish from passing into undesirable areas.

Figure 6-3. Picket barrier panels under construction at the Slide Creek tailrace barrier located on the North Umpqua River, Oregon

Because both debris and downstream-migrating fish must pass through physical barriers, sites should be selected based on the following design objectives:

- Minimizing the entrainment of debris
- Maximizing the ability to remove debris
- Preventing the entrainment and delay of downstream-migrating fish and adult fish that fall back across the barrier
- Maximizing the ability to rapidly remove and bypass any fish that are entrained on the barrier
- Allowing the most advantageous orientation of the barrier (typically angled to guide fish to a collection point)

6.3.1 Risk of Fish Impingement

If adult fish are exposed to the upstream side of physical barriers, they have a high likelihood of being impinged. Therefore, these types of barriers cannot be used in waters containing species listed under the ESA unless they are continually monitored by personnel on site and have an approved operational plan and a facility design that allows impinged or stranded fish to be removed in a timely manner and prior to becoming injured. Also, these types of barriers should not be used at sites where adult fish are actively migrating downstream or may inadvertently pass over a nearby dam or weir in a downstream direction prior to reorienting again to continue their upstream migration.

In addition to blocking the upstream passage of adult fish, physical barriers can effectively block or injure fish migrating downstream (e.g., steelhead kelts, adult salmon that passed a dam and subsequently migrated back downstream, juvenile salmonids, and resident fish). This can impact population productivity and should be fully considered during the planning process.

6.3.2 Debris

Physical barriers should be continually monitored for debris accumulations, and debris should be removed before it concentrates flow and results in the velocity and head differential criteria being exceeded (Sections 6.3.3.2 and 6.3.3.3). Additionally, excessive debris loading could cause permanent damage to weir structures.

Allowing debris to accumulate on components of physical barriers results in increased water velocity through the remaining open areas. As debris accumulates, the potential for impinging downstream migrants increases progressively and can reach unacceptable levels that result in mortality and injury. Concentrating flow through the remaining open areas of the barrier (e.g., the open picket area) will also attract upstream migrants to these areas. This can increase the potential for injury due to adult fish jumping into structural components and for fish accessing unwanted areas because they jumped and landed over the barrier.

6.3.3 Picket Barriers and Fixed Bar Racks

Picket barriers and fixed bar racks create a uniform, low-velocity flow that is discharged through a series of bars or screens that cover the entire exclusion area.

The following specific criteria or guidelines apply to picket barriers and fixed bar racks.

6.3.3.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Openings larger than 1 inch may allow the heads of small salmon and steelhead to pass through the picket opening. This can lead to salmonids and other species becoming caught on the picket by their operculum that covers and protects the gills. Fish caught in this manner—between bars or pickets and gaps between panels or panels and abutments—often die because they are unable to extricate themselves off the picket.

6.3.3.2 Design velocity

The average velocity through pickets should be less than 1 ft/s for all design flows (Clay 1995). The maximum velocity through the pickets should be less than 1.25 ft/s, or one-half the velocity of adjacent passage route flows, whichever is lower. When river velocities exceed these criteria, such as due to increasing flows or debris accumulations, the picket barrier should be removed.

The average design velocity is calculated by dividing streamflow by the total submerged picket area over the design range of streamflows (Gauley et al. 1966). As discussed in Section 6.3.2, non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the barrier, potentially injuring the fish.

6.3.3.3 Head differential

The maximum head differential under fouled conditions should not exceed 0.3 foot above the normal head differential across the pickets that occurs under clean picket conditions. If this differential is exceeded, the pickets should be cleaned as soon as possible.

Excessive head differential (head loss) through the structure can cause a cascading effect of water through the pickets, which increases the likelihood of upstream migrating fish leaping at the structure. Clay (1995) and DOI (1987) provide formulas to calculate head loss through picket barriers and trash racks.

6.3.3.4 Debris and sediment

A debris and sediment removal plan should be considered in the design of the barrier that anticipates the entire range of conditions expected at the site. Debris should be removed before accumulations develop that violate the average design river velocity and head differential criteria (Sections 6.3.3.2 and 6.3.3.3, respectively).

6.3.3.5 Orientation of physical barrier

Physical barriers should be designed to lead fish to a safe passage route.

Leading fish to a safe passage route can be achieved by angling the structural barrier toward the route, providing nearly uniform velocities across the entire horizontal length of the structural barrier, and providing a sufficient level of attraction flow that leads fish to the route and minimizes the potential for fish being falsely attracted to flow coming through the picket barrier.

6.3.3.6 Picket freeboard

Depending on the angle of the pickets (from vertical), the pickets should be designed such that they extend out of the water and at least 2 vertical feet above the water surface at the upper design flow level.

The purpose of the picket freeboard is to prevent fish from leaping over the barrier. Note that if the angle of the pickets is relatively steep, a freeboard of 2 feet may be insufficient to block stronger fish from leaping over the pickets, depending on site-specific conditions.

6.3.3.7 Submerged depth

The minimum depth at the picket barrier at low design flow should be 2 feet for at least 10% of the river cross section at the barrier. Picket barriers should be sited where there is a relatively constant depth over the entire stream width.

6.3.3.8 Picket porosity

The picket array should have a minimum of 40% open area.

Picket barriers with insufficient porosity may generate excessive head loss for the given river velocity. This head loss is exhibited as a cascade of water as it passes through the pickets, which may induce fish to jump and increase the potential for injury at the barrier.

6.3.3.9 Picket construction and material

Pickets should comprise flat bars where the narrow edge of the bar is aligned with flow or round columns of steel, aluminum, or durable plastic. Other shapes may be approved by NMFS, but should not increase the risk of fish impingement.

Picket panels should be of sufficient structural integrity to withstand high streamflows and some debris loading without deforming (i.e., without exceeding the clear opening criteria cited in Section 6.3.3.1, compromising the cleaning system, or permanently changing the shape of the picket panel). Pickets that become permanently deformed should be repaired or replaced as soon as possible. Pickets that deform or bend to a point where the clear opening criteria cited in Section 6.3.3.1 is no longer met under the design flow and debris loading conditions incorporated into the design can create openings that allow fish to pass the barrier or become injured as they try to force their way through the pickets.

6.3.3.10 Sill

A uniform concrete sill, or an alternative approved by NMFS, should be provided to form a foundation for the pickets and ensure that fish cannot pass under the picket barrier.

6.3.4 Diffusers

Diffusers are a specialized type of picket barriers or fixed bar racks where a flow control or hydraulic baffling structure is incorporated into the design to regulate flow through the barrier or bar rack. Wall-oriented (i.e., vertical) and floor-oriented (i.e., horizontal) diffusers are most commonly used as part of the AWS in adult ladders to prevent adult fish from entering the AWS system or delaying their migration due to being attracted to AWS flow entering the ladder. Wall diffusers are also used as tailrace barriers to prevent fish from entering tailraces downstream of hydroelectric dams, while encouraging fish to continue to move upstream through another stream, river route, or channel.

The following specific criteria or guidelines apply to diffusers.

6.3.4.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish from passing through the bars or becoming injured (Bates 1992). The clear opening between pickets and between pickets and abutments should be less than or equal to 1 inch to block anadromous salmonids. These clear openings should be less than or equal to 0.75 inch to block Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Wall diffusers consist of vertically oriented diffuser panels of flat bar stock using non-corrosive materials. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel. If smaller fish species or life stages are present, smaller clear openings between the bars may be required.

6.3.4.2 Design velocity and orientation

The average velocity through a wall diffuser should be less than 1 ft/s for all design flows based on total submerged diffuser area. The maximum velocity at any point on the diffuser should be less than 1.25 ft/s, or one-half the velocity of flow in an adjacent passage route, whichever is lower. Diffuser velocities should be nearly uniform. The orientation of the diffuser should be selected that assists in guiding fish towards the safe passage route. The face of the diffuser panels (the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on results of laboratory studies where passage times of spring- and fall-run Chinook salmon and steelhead increased progressively with increased diffuser flows and where diffuser velocities increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

6.3.4.3 Porosity control baffles

Similar to juvenile fish screens, a *diffuser should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffuser can meet criteria.*

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.4.4 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

The dewatering screen system also removes debris from water being supplied to the diffuser.

6.3.4.5 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.4.6 Elevation

Wall-style diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the water surface elevation associated with the low flow selected for the design).

Maintaining a submerged wall-style diffuser prevents water from cascading through the diffuser, which can induce adult fish to leap at the surface disturbance and become injured when contacting the diffuser material and wall and delay their migration up the ladder.

6.3.5 Horizontal Outlet Diffusers

A horizontal outlet diffuser is a device that can be used to prevent fish from entering a drain or discharge pipe. They can also be used below a powerhouse at the turbine draft tube outlet to prevent adult fish from ascending up the draft tube discharge during unit start up or shut down or during normal operations if draft tube velocity is low (typically less than 16 ft/s; Figure 6-4). This type of diffuser also prevents fish from entering the draft tube and contacting the turbine runners, which may result in injury or mortality. If the turbine draft tubes are located in close proximity to the entrance of an upstream passage system (e.g., a fishway), a horizontal outlet diffuser system may be the appropriate choice for an exclusion system.

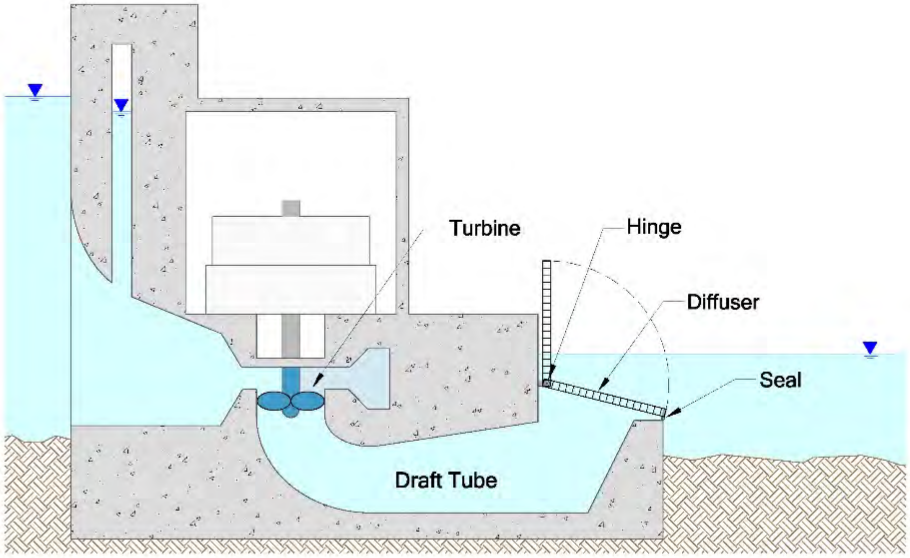


Figure 6-4. Layout of a horizontal outlet diffuser covering the entrance to a turbine draft tube

6.3.5.1 Design velocity

Average flow velocity exiting the horizontal outlet diffuser grating should be less than 1.25 ft/s and be distributed as uniformly as possible. The maximum point velocity should not exceed 2 ft/s.

6.3.5.2 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffusers can meet criteria.

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.5.3 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars, and between bars and abutments, should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to prevent Pacific lamprey from entering the chamber behind the diffuser. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Horizontal outlet diffuser panels consist of non-corrosive, horizontally oriented flat bar stock. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel.

6.3.5.4 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.5.5 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

Trash (bar) racks installed at the intake to the diffuser system and a juvenile fish screen (if installed) remove debris from water being supplied to the diffuser.

6.3.5.6 Submergence

Horizontal outlet diffusers should be submerged a minimum of 2 feet for all tailwater elevations.

6.3.6 Fish Weirs

Fish weirs are physical barrier systems that are constructed across a stream (Figure 6-2). The purpose of fish weirs is to prevent fish from passing upstream of the weir and guide upstream-migrating fish to a trap. The weirs are constructed of panels of metal or plastic pickets that extend from the bottom of the stream to an elevation several feet above the water surface. The clear spacing between the pickets is selected based upon the size of the target species being trapped. When viewed from above, weirs are usually placed at angles greater than 90 degrees from the main thread of the current (Figure 6-2). The trap is placed at the most upstream area of the weir. The angle between the direction of stream or river flow and the weir results in the weir being longer than if it was positioned perpendicular to the bank and reduces water velocity through the pickets.

6.3.6.1 Types of fish weirs

The two most commonly used types of weirs in the WCR are rigid (frame-supported) weirs and floating resistance board picket weirs (Figure 6-5). Weirs can be temporary or permanent.

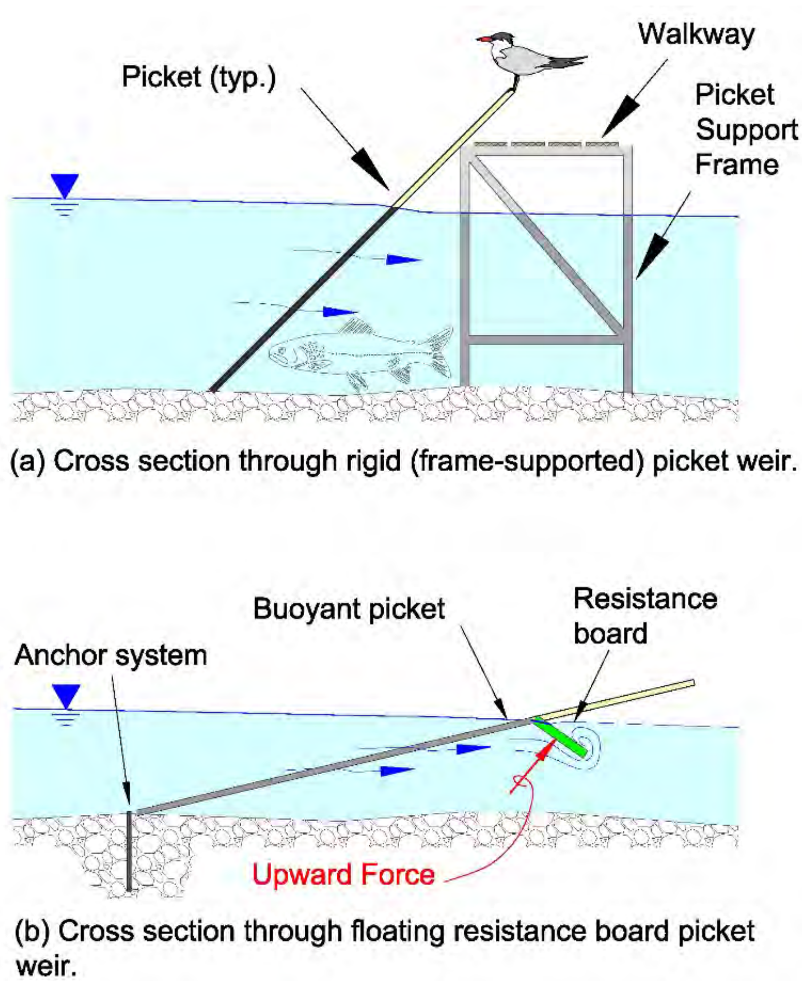


Figure 6-5. Cross sections of rigid and floating picket weirs

The pickets in rigid weirs are placed at an angle greater than 45 degrees above the water surface. Clean pickets in a floating weir have a very small angle above the water surface, and increased flow velocity and debris loading can further reduce the angle and can eventually submerge the floating weir panels.

Rigid weirs use panels of solid metal rods or hollow conduits that are supported by rigid frameworks (Figure 6-6). The supporting structures for temporary weirs can be light metal trusses or frames that are installed at the start of the fish passage season and are removed at the end of the trapping season. Permanent installations consist of foundations, frameworks, and abutments that stay in the river. However, the pickets at permanent installations are removed from the weir during periods when fish are not being trapped and during winter at locations that experience icing.

Figure 6-6. Elk Creek Dam picket weir (Elk Creek, Oregon)

The main advantage of rigid weirs is that the pickets are supported both along the river bottom and above the water surface, which may provide greater lateral stability and help to maintain constant spacing between the pickets. The main disadvantage of rigid weirs is that they are more susceptible to damage with increased debris loads experienced during high flows. High flows and debris can create sufficient force on the face of the panels such that the entire structure can be washed away. Some trap operators remove the pickets from the weir when they anticipate the occurrence of high flows.

Floating resistance board weirs are constructed using panels of hollow plastic piping or conduits that are capped at both ends to provide buoyancy. A resistance board at the downstream end of the pickets directs the local flow downwards, which creates an uplift force and a drag force on the pickets (Tobin 1994). In situations where the resistance board does not provide enough uplift (i.e., under conditions of low stream velocities), the board can be replaced with a long, linear float to support the picket panels. The pickets extend downstream and above the water surface to prevent fish from jumping over. The Alaska Department of Fish and Game has developed a user's manual for installing, operating, removing, and storing resistance board weirs used to count adult salmon migrating upstream based on direct experience, providing considerable information on this type of picket barrier (Stewart 2003).

The advantage of floating weirs is that they are less prone to damage over a wider range of flows and debris loads. High flows can also submerge the panels, which also tends to move debris off the panels and reduce the downstream pressure on the panels. The main disadvantages of floating weirs include the following:

- Debris can easily be trapped on top of the pickets due to the low angle of the panels.
- Fish can pass over the pickets when the pickets are submerged during high flows.
- The pickets may be more susceptible to lateral current forces because the pickets are supported only by the bottom of the river.
- In situations where adult fish are upstream of the weir and they fall back downstream, or they are migrating downstream, the fish can easily become stranded on the pickets and die due to

the low approach angle and force of the flow that tends to push the fish up onto the dry part of the pickets.

6.3.6.2 Site selection

Weirs should be constructed at sites that have the following characteristics (Zimmerman and Zabkar 2007):

- *Construction, operation, and maintenance activities can be conducted safely.*
- *The river should be wide and shallow (about 3 feet maximum depth at normal flows) with uniform flow distribution.*
- *The substrate should consist of gravel and small cobbles and be without boulders in the weir alignment.*
- *Traps should have sufficient flow depth during minimum expected river flow stages and be accessible during flood flows. More than one trap location may be required.*

The site should be low gradient and straight, with uniform depth and width, and have areas of sufficient depth for adult holding pools upstream and downstream of the weir (Hevlin and Rainey 1993).

6.3.6.3 Velocity

Water velocity at the river channel cross section of the weir location should be a maximum of 2 ft/s at low flows if a concrete apron is used (Hevlin and Rainey 1993), and velocity and depth should allow for safe access to the weir under normal flows (Zimmerman and Zabkar 2007)

6.3.6.4 Picket spacing and freeboard

The clear spacing between the pickets and the freeboard has the same requirements as those for other structural barriers (Sections 6.3.3.1, 6.3.4.1, and 6.3.5.2). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey.

6.3.6.5 Suitability at sites with downstream migrants and monitoring

Fish weirs are not suitable for sites with downstream-migrating adult fish (e.g., steelhead kelts, salmon that pass the structure but migrate downstream [i.e., fallback], and resident fish). If deployed in these situations, weir operators should provide around-the-clock monitoring and fish salvage efforts for as long as these barriers are in place (Section 6.3.1).

While blocking the upstream passage of fish, fish weirs can also block the migration of, or injure, fish migrating downstream (e.g., steelhead kelts, adult salmon, juvenile life stages, and resident fish) and prevent them from completing their life cycle. When weir pickets are at a low angle with respect to the water surface (i.e., floating weirs), downstream-migrating adult fish can become stranded as they are pushed downstream along the pickets and the water becomes shallow. Juvenile passage openings or structures should be provided as part of the design, or these weirs should be removed during the juvenile salmonid outmigration season. When rigid weirs are properly designed and sited, adult and juvenile fish that are migrating downstream are guided along the face of the weirs to the downstream apex of the weir and the shoreline where they can be trapped or released downstream.

6.4 Drop Structure Barriers

Drop structure barriers create conditions that target species are incapable of overcoming based on their swimming abilities or behavioral traits. A condition affecting swimming ability is the creation of a shallow, high-velocity flow for a significant distance, which most salmonids cannot pass. Hydraulic conditions can also interact with fish behaviors, including the reluctance of American shad to pass through a submerged orifice in a ladder or leap a ladder weir under plunging flow conditions. Both are examples of incorporating knowledge about the swimming ability and behavior of target species into facility designs so that the facility becomes a migration barrier. Note: Drop structures may create a serious hazard to boaters and swimmers, and precautions to protect boaters and swimmers should be included in the design.

6.4.1 Orientation of Drop Structure Barriers

As with physical barriers, drop structure barriers should be designed to lead fish to a safe passage route.

This can be achieved by angling the barrier toward a safe passage route and by providing the following:

- Nearly uniform velocities across the entire horizontal length of the barrier
- Sufficient attraction flow that leads fish into the safe passage route and minimizes the potential for false attraction

6.4.2 Upstream Impacts

Since this type of barrier creates an upstream impoundment, the designer should consider backwater effects upstream of the barrier that may induce loss of power generation, inundation of property, and sediment deposition in the impoundment.

6.4.3 Combination Velocity and Vertical Drop Barriers

6.4.3.1 Description and purpose

A combination velocity and drop barrier consists of a weir and concrete apron (Figure 6-7). Upstream passage is prevented by a shallow, high-velocity flow on the apron with an impassable vertical jump over the weir upstream of the apron. A fish that negotiates the apron and reaches the base of the weir is unable to pass the weir due to insufficient water depth needed to reorient its position and the lack of a pool needed to accelerate to leap over the weir sill (Wagner 1967; Weaver et al. 1976).

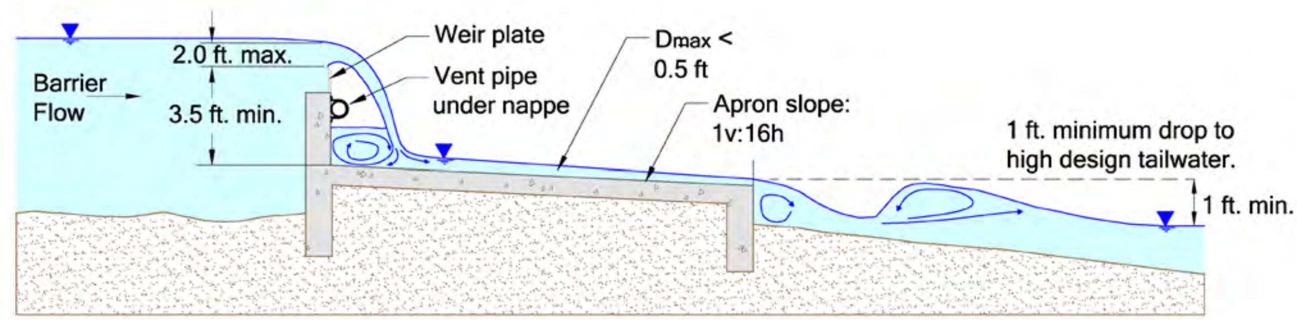


Figure 6-7. Cross section of a combination velocity and vertical drop barrier

6.4.3.2 Specific criteria and guidelines

6.4.3.2.1 *Weir height*

The minimum weir height relative to the maximum apron elevation is 3.5 feet (Wagner 1967).

This design assumes a straight, uniform, linear weir crest that will create uniform flow conditions on the apron. Labyrinth-style weirs are not allowed since they concentrate flow on the apron and create non-uniform flow conditions downstream.

6.4.3.2.2 *Apron length*

The minimum apron length (extending downstream from the base of a weir) is 16 feet.

This criterion is based, in part, on results of laboratory studies where adult Chinook salmon and steelhead were blocked by a velocity barrier dam with a 15-foot-long apron under two test conditions: 1) a vertical dam height of 3 feet with 1 foot of head; and 2) a vertical dam height of 4 feet with 2 feet of head (Slatick and Wagner 1989).

6.4.3.2.3 *Apron slope*

The minimum apron slope in a downstream direction is 1:16 (vertical:horizontal).

6.4.3.2.4 *Weir head*

The maximum head over the weir crest is 2 feet.

Other combinations of weir height and weir crest head may be approved by NMFS on a site-specific basis.

6.4.3.2.5 *Apron elevation*

The elevation of the downstream end of the apron should be greater than the tailrace water surface elevation corresponding to the high design flow (BOR 2006). There should be at *least 1 foot of elevation difference between the water surface elevation at the downstream end of the apron and the high design tailwater elevation.*

6.4.3.2.6 *Flow venting*

The flow over the weir should be fully and continuously vented along the entire weir length to allow a fully aerated flow nappe to develop between the weir crest and the apron (BOR 2006).

Full aeration of the flow nappe prevents an increase in water surface behind the nappe, reducing the opportunity for fish to stage and jump the weir.

6.4.3.2.7 *Flow depth on the apron*

Flow depth on the apron should not exceed 0.5 foot (Wagner 1967).

At sites where a maximum depth of 0.5 foot cannot be maintained, apron velocities of 20 ft/s in association with a sill height (i.e., minimum weir height relative to the maximum apron elevation) of 5.25 feet have been used successfully (Wagner 1967).[4]

6.4.3.2.8 *Minimum flow velocity over the apron*

A minimum velocity of 16 ft/s is recommended by Wagner (1967).

The recommendation by Wagner (1967) is based on Weaver (1963) who reported that Chinook salmon and steelhead could swim against a 16-ft/s velocity for a distance of at least 85 feet in a test flume.

6.4.4 Vertical Drop Barriers

6.4.4.1 Description and purpose

A vertical drop barrier functions as an exclusion barrier by providing head in excess of the leaping ability of the target fish species (Figure 6-8). Vertical drop barriers can be designed based on a concrete monolith, rubber dam, bottom-hinged leaf gate, or an alternative approved by NMFS.

[4] Wagner (1967) does not provide any additional information on this particular barrier configuration. If it is assumed that flow on the apron is 8 inches deep at 20 ft/s, the discharge per linear foot is approximately 13.5 ft^3/s. This translates to a maximum of 2.5 feet of head over a sharp crested weir. This barrier configuration should be biologically tested before a prototype facility is constructed.

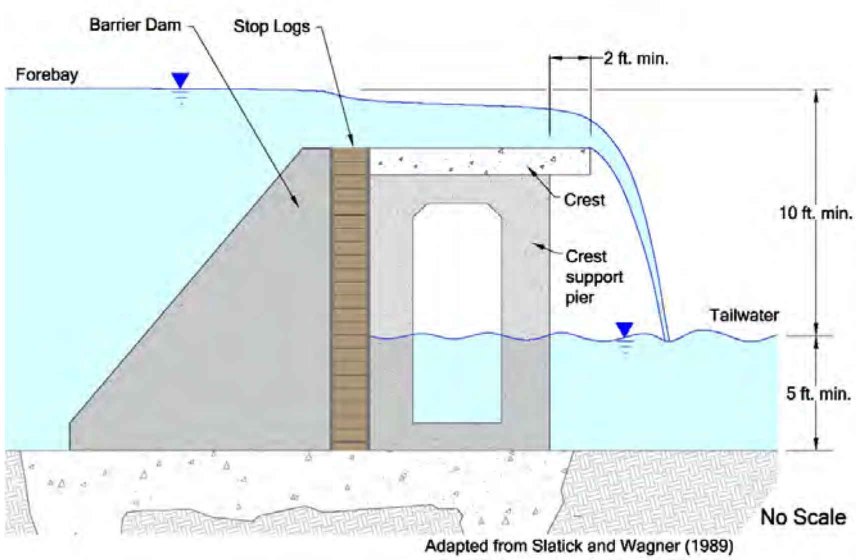


Figure 6-8. Cross section of a vertical drop barrier

6.4.4.2 Specific criteria and guidelines

6.4.4.2.1 *Minimum height*

The minimum height of a vertical drop structure should be 10 feet relative to the high design flow (Wagner 1967; Bell 1991; Clay 1995). This is measured as the water surface level of the forebay relative to the water surface level of the tailrace.

6.4.4.2.2 *Cantilever*

If the potential for injury to fish from leaping exists, the downstream crest of the barrier should extend over the tailwater at least 2 feet beyond any structural surfaces.

6.4.4.2.3 *Minimum flow depth*

Provisions should be made to ensure that fish jumping at flow over the vertical drop structure will land without contacting any solid surface and in a pool that is a minimum of 5 feet deep.

6.4.5 Velocity Barriers

Figure 6-9 shows a cross section of a velocity barrier and its main characteristics that include high water velocity and the long longitudinal length of the barrier over which the design velocity is maintained. The design approach is to provide a combination of water velocity, travel distance, and shallow depth that, taken together, exceed the swimming ability of the target fish.

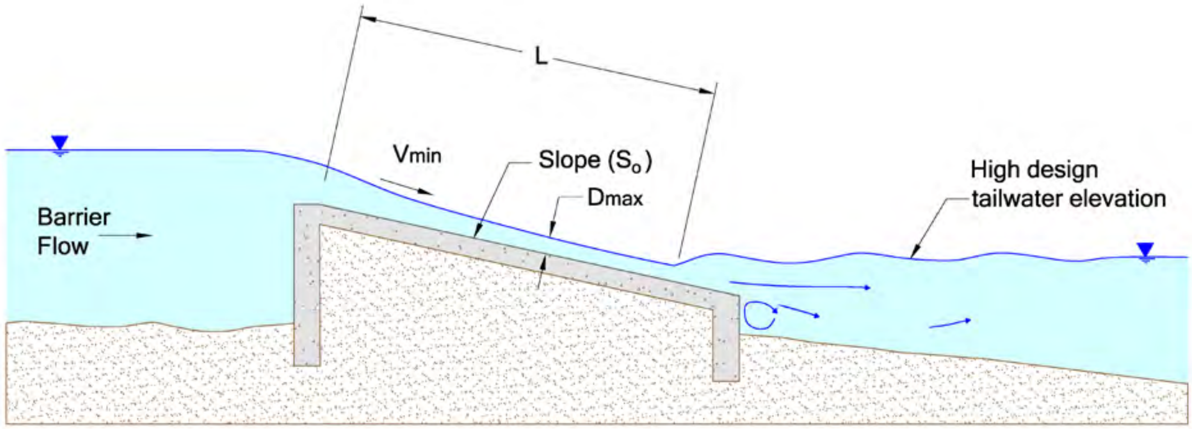


Figure 6-9. Cross section of a velocity barrier

Designing a velocity barrier to prevent the upstream migration of adult salmonids can be challenging due to their strong swimming capabilities. Experience has shown that salmonids will seek flow concentrations or discontinuities in flow (often near the edges of the flow) and use these features to find a route over this style of barrier. In addition to combining high velocity and shallow depth, the design should also create uniform flow conditions across the barrier, which can be difficult to achieve.

NMFS currently does not have criteria or guidelines for a velocity barrier.

NMFS will evaluate a proposed velocity barrier design based upon the hydraulic conditions created by the barrier and by comparing these conditions to the swimming capabilities of the target species. In general, velocity barriers are not recommended by NMFS because fish may spend a long time trying to negotiate the obstacle before seeking an alternate route, which delays the fish and may exhaust them in the process. As discussed in Section 6.3.3.5, barriers should also lead fish to a safe passage route, and NMFS will assess this when reviewing a proposed velocity barrier design.

6.5 Behavioral Barriers

Behavioral types of barriers, such as electric and acoustic fields, have had limited application and were ineffective in most cases (BOR 2006). While electric fields have been used as barriers for decades, persistent problems with early installations limited their widespread use (FERC 1995). These limitations included fish injury and mortality, safety, and effectiveness over a wide range of flow and environmental conditions (Clay 1961). Strobe lights and acoustical systems have been tested in various applications to block juvenile or adult fish from entering water intake systems. These systems were tested in the 1980s and 1990s and seemed promising at first (EPRI 1994) but were found to have limited effectiveness. Thus, electrical fields, strobe lights, acoustical systems, and other behavioral barriers are not widely used within the WCR and are considered experimental. Additional information regarding the various types of behavioral barriers and their performance and limitations may be found in Appendix C. Appendix C also provides information regarding the processes to be followed in order to use experimental devices such as behavioral barriers.

7 Adult Fish Trapping Systems

7.1 Introduction

Chapter 7 presents criteria and guidelines that address the design of new adult fish trapping systems. This chapter also includes criteria and guidelines that may apply to existing trapping programs that are being retrofitted. In both cases, traps should be designed to utilize known or observed fish behaviors to benignly route fish into a holding pool. The holding pool does not include a volitional exit, and once the fish are allowed or encouraged to exit the holding pool, they can be examined for research and management purposes and loaded into transportation tanks for transport to release locations or hatcheries.

NMFS typically prefers the use of volitional passage for upstream fish passage facilities, as opposed to non-volitional facilities and operations. Volitional passage is defined as the passage of fish under all naturally passable flows, whereby a fish can enter and exit any passage apparatus or structure under its own power, instinct, swimming ability, and migration timing. Non-volitional is defined as the collection, handling, transportation, and release of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or location.[5]

For some facilities, fish transportation is not a requirement and fish are trapped, monitored, sorted, and released from the trap to continue their upstream migration. For example, at some trapping facilities hatchery-origin fish are removed to protect wild-origin fish or collect hatchery broodstock. In the Pacific Northwest, certain areas within watersheds are designated as wild fish sanctuaries, and hatchery-origin fish should be collected and removed from traps located below these areas. Also, fish of a specific species or life stage or fish previously tagged for research purposes may also need to be collected and monitored at trap locations and then released.

The operational requirements for a trapping facility and its design are highly interdependent: management objectives for trap operation define the facility's functional design, and the objectives should be identified before trap design development can proceed. NMFS' primary objective is that a fish passage facility be designed and operated in a manner that the facility helps restore the viability of anadromous fish populations, which is why NMFS often prefers that volitional passage be used. Volitional passage facilities can operate 24 hours per day, 7 days per week, year-round.

However, there are instances where passing fish over a barrier using trap and haul techniques may be the only viable passage alternative. For example, thermal stratification can occur in

[5] An illustration of a trap and haul operation is available at http://www.westcoast.fisheries.noaa.gov/fish_passage/about_dams_and_fish/trap_and_haul.html.

reservoirs at high head dams during summer, resulting in temperature differentials between the fishway entrance and water released below the dam. This can affect how fish utilize volitional passage facilities, and a trap and haul program would provide passage to areas above the thermally stratified reservoir.

The success of collection and transport operations relies on a high degree of engineering, technical, and operational competence. The process is generally composed of the following distinct phases: (1) Collection, (2) Handling, (3) Transportation, and (4) Release. This sequence is sometimes abbreviated by the acronym 'CHTR'. The essential idea is to engineer effective system components for each phase, and to consistently execute operations to move fish in a safe and timely manner to designated release location(s). This section provides guidance on how to collect, handle and release fish from a collection facility. For all of these steps, careful attention must be given to maintenance of aquatic conditions and water quality to keep fish in good condition. It is very important to properly acclimate fish to any changing aquatic conditions or environmental transitions. Stressors associated with the aquatic environment (as experienced by the fish) must be minimized and carefully managed. All technical details for each phase of the overall process must be properly addressed.

7.2 Types of Traps

There are two types of traps. The first type is where a trap is an integral component of the primary route of fish passage above a barrier. Examples of these traps include the following:

- Traps located directly adjacent to a barrier
- Traps at the upstream end of a fish ladder
- Traps that serve as holding box associated with broodstock collection facilities in tributary streams in conjunction with intermittent barriers

A collection and transport facility located at the upstream end of a fish ladder is the most common application of this type of trap.

The second type of trap is an off-ladder design wherein the trap is situated adjacent to a ladder such that it is not the primary route of passage and does not interfere with the normal operation of the ladder. The ladder provides volitional passage from the tailrace to the forebay of the barrier under normal conditions, but when necessary or desired, all or some fish can be diverted into the trap.

For both types of traps, once fish are in a trap they can be accessed for a variety of purposes, including the following:

- Enumeration
- Evaluation for tags and injuries
- Sampling for genetic identification
- Sorting for various management purposes
- Transportation to various locations
- Tagging to support fisheries management or research

Fish that are enumerated or evaluated can be released back into the ladder or at another location.

7.2.1 General Criteria

Fish ladders should not be designed or retrofitted with in-ladder traps or fish loading facilities. Rather, fish holding and loading facilities should be placed in an adjacent, off-ladder location in order to route fish targeted for trapping purposes.

Fishway ladder pools typically do not meet the requirements of trap holding pools. Therefore, use of fishway ladder pools to site traps can create adverse impacts to the migrating fish. These impacts include elevated stress, delay, injury, or mortality caused by turbulence, jumping at water being supplied to the holding pool, and handling. Locating the trap off-ladder allows the facility to have the operational flexibility to readily switch between volitional ladder passage and trapping modes of operation.

7.3 Design Scoping

7.3.1 Purpose

Proposals to design new facilities or complete major upgrades to existing facilities should address the following issues, or at the very least show how the following issues were considered:

- *Describe the objective of the trapping operation and identify how the fish will be counted, collected (including the expected holding densities), handled, sampled for research or management purposes, transported (how and what frequency), and released.*
- *Identify the number of fish that will be targeted and the total number potentially present. This should include the expected peak number of fish per day, seasonal and daily fish returns, future fish return expectations, expected incidental catch, etc.*
- *Identify the target species, including ESA-listed species.*
- *Identify other species likely to be present at the trap, including ESA-listed species.*
- *Describe the environmental conditions expected to occur during trap operation such as water and air temperature, flow conditions (lows and peaks), and debris load.*
- *Describe the location, duration, frequency, predicted fish numbers, and scale of the trap and haul operations by developing an operations plan for the trap.*
- *Describe the facility's security mechanisms and procedures that will be in place in the operations plan.*
- *Identify when, what and how many fish will be taken to what location and for what purpose for the entire trapping season.* (Many times different species or origins have different destinations from the trapping facility. Understanding the fish disposition for each species, run type and origin plays a huge role in the facility design (e.g. number of holding tanks and raceways).)
- *Describe the maximum duration of delay or holding within the trapping system for target and non-target species and life stages.*
- *If a Hatchery and Genetic Management Plan, ESA Section 4(d) Limit 7 Scientific Research and Take Authorization application, ESA Section 7(a)(2), or ESA Section 10(a)(1)(A) permit application exists, show how one of these documents was used as the basis for design of a*

trapping facility. At least one of these types of documents will have to be developed for most trapping facilities and will be available for designing the facility.

7.4 Fish Handling Criteria

Section 7.4 provides criteria and guidelines that are applicable to handling fish in traps.

7.4.1 Nets

The use of nets to capture or move fish should be minimized or eliminated. If individual adult fish need to be moved, then they should be placed into rubber tubes with one end sealed. The tube should be partially filled with sufficient water to keep the head and gills of the fish submerged. Avoid handling the fish by hand, unless they have been adequately sedated. All fish should be handled with extreme care.

7.4.2 Anesthetization

Fish should be anesthetized before being handled.

The method of anesthetization for ESA-listed anadromous salmonids may be specified by the appropriate ESA permit, which should be in place prior to any directed take of listed species. The type of anesthetic to be used can be selected by agreement with NMFS during the design process and prior to submittal of an ESA permit request. Determination of the method and anesthetic used should be decided early in design, since each has different infrastructure requirements.

Once the anesthesia is selected protocols should be written to guide appropriate application of the chemical to allow for safe handling while minimizing the risk of over-exposure and mortality. The protocol should include details on water temperature and adjustment of dosage based on water temperature. Finally, a water temperature maximum should be set when fish handling will not be done.

7.4.2.1 Recovery

Fish that have undergone anesthetization should be allowed to recover from the effects of the anesthetic before being released (Section 7.5.10).

Fish require time to recover from the effects of anesthesia. The amount of recovery time needed will depend on several variables including the exposure time to the anesthesia, the water temperature (and general water quality conditions), and the individual sensitivity of the fish. Warm water temperatures and prolonged exposure to anesthetic will result in extended recovery times.

Fish should be monitored to ensure they are recovering. Signs of recovery include fish that are consistently upright and oriented, display normal gilling activity, and are responsive to stimuli.

During recovery fish should be protected from risk of impingement or accidental release back to the river (see specific guidance in Section 7.5.10).

7.4.3 Non-Target Fish

New or upgraded trapping facilities should be designed such that non-target fish can bypass the anesthetic tank.

7.4.4 Frequency

Unless otherwise agreed to by NMFS, all fish (i.e., adults and juveniles of all species and sizes) should be removed from the trap holding pool and raceways at least once every 24 hours whenever the trap is in operation. When either environmental (e.g., water temperature extremes, low dissolved oxygen, or high debris load) or biological conditions (e.g., migration peaks or delay) warrant, fish should be removed more frequently to preclude overcrowding or adverse water quality conditions from developing (Section 7.5.5.2).

7.4.5 Personnel

Trap personnel that handle fish should be experienced or trained to ensure that fish are handled safely.

7.5 Trap Design Criteria

Section 7.5 provides criteria and guidelines that apply to trap design.

7.5.1 Trap Components

Trap systems should include the following components:

- *Removable diffusers or gates located within the fish ladder to block passage and guide fish into the trap*
- *A holding pool; a transition channel or port that connects the fish ladder to the holding pool; and a trapping mechanism as described in Section 7.5.4 (attraction flow is discharged via devices described in Section 7.5.4)*
- *A gate to prevent fish from entering the trap area during crowding operations*
- *A fish crowder (and brail if needed) to encourage adult fish to exit the off-ladder holding pool and enter sorting and loading facilities*
- *Separate holding pool inflow supply and outflow facilities*
- *Distribution flume used in conjunction with false weir or steeppass systems to enable fish to exit the holding pool*
- *A lock or lift (or hopper) for loading fish onto the transportation truck*
- *A flume, pipe, or ladder to return fish either to the ladder or to the dam forebay where they can continue their upstream migration (when returning fish to the ladder, fish should be allowed to volitionally enter the ladder from a resting pool)*

7.5.2 General

7.5.2.1 Location

The entrance to trap facilities should be located in a hydraulically stable, low-velocity (i.e., approximately 1.5 ft/s), accessible area of the upstream passage facility, similar to the requirements for a counting station (Section 5.6).

This location allows fish to be more easily directed toward the trap entrance without excessive turbulence.

7.5.2.2 Flow

Fish ladders should not experience any significant change in fishway flow volume during trap operations.

Fish ladders are often designed to operate within a narrow range of flows; thus, changing the flow volume during trap operations can often compromise the function of the ladder. Depending on the design, it may be necessary to add or remove flow from the ladder in order to adjust for the operation of the trap.

7.5.2.3 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such a neoprene padding covered by UV stabilized rubber, may also be required to minimize fish injuries.

7.5.2.4 Fish safety

Provisions should be included in the facility design to provide guaranteed safety to the fish or a method or manner to release fish back to the river in case of emergency (e.g., power outage or loss of water supply).

Fish safety provisions may include guaranteed water supply, water level and water supply alarms, aeration systems, and backup pumps and generators.

7.5.3 Pickets

Pickets are used to prevent fish from entering a specific area (e.g., AWS) or to guide fish to a particular area (e.g., toward a counting window for enumeration or a trap entrance).

7.5.3.1 Design velocity

The average velocity through pickets should be less than 1 ft/s for all flows (Clay 1995).

The average design velocity is calculated by dividing flow by the total submerged picket area. Non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the pickets, potentially injuring the fish.

7.5.3.2 Material

Pickets should be constructed of non-corrosive materials. Panels may consist of flat bars (where the narrow edge of the bar is aligned with flow) or round columns of steel, aluminum, or durable plastic. All surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

7.5.3.3 Bar spacing

The maximum clear spacing between picket bars is 1 inch for adult trapping facilities. At sites where lamprey may be present, pickets should have a maximum 0.75-inch clear spacing between bars.

At sites where smaller fish are present, a smaller spacing between bars may be required.

7.5.3.4 Pickets in off-ladder holding pools

Off-ladder holding pools should include intake and exit pickets designed to prevent adult fish from exiting the holding pool. These should conform to the criteria identified in Section 6.3. The design of off-ladder holding pools should also include an adjustable overflow weir located downstream of, or in conjunction with, the entrance pickets to control the water surface elevation in the holding pool.

7.5.3.5 Blocking pickets

Removable pickets installed within the ladder to block fish from ascending further and route them into an off-ladder trapping pool should be angled toward the off-ladder trap entrance and comply with the criteria listed in Sections 5.3.7 and 5.6.3.7. Pickets installed within ladders should be completely removed from the ladder when trapping activities are not occurring.

7.5.4 Trapping Mechanisms

7.5.4.1 Description and purpose

There should be a mechanism that allows fish to enter, but not volitionally exit, a holding pool. The most commonly used mechanisms include finger weirs, Vee trap fykes, or false weirs (Section 7.5.8).

The maximum velocity over finger traps is 8 ft/s. The amount of flow over the top of a finger weir is usually 2 to 6 inches but varies based upon species. The height of a finger weir varies but is usually in range of 6 to 10 inches (Bell 1991). When using finger traps, an escape area should be provided at both ends to prevent fish from being held against the fingers and killed (Bell 1991).

For a Vee trap, Bell (1991) recommends a minimum velocity of 4 ft/s. The opening at the apex is usually around 8 inches but may need to be larger or smaller depending upon the species present. Being able to adjust this opening can be very beneficial.

Figure 7-1 shows a schematic of a finger weir. Figure 7-2 shows a cutaway of a Vee trap.

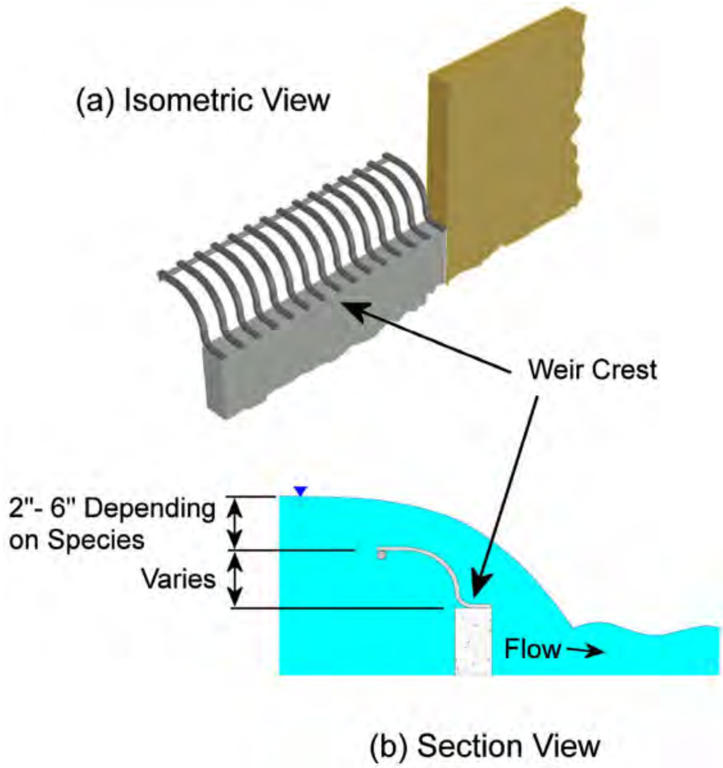


Figure 7-1. Finger weir schematic

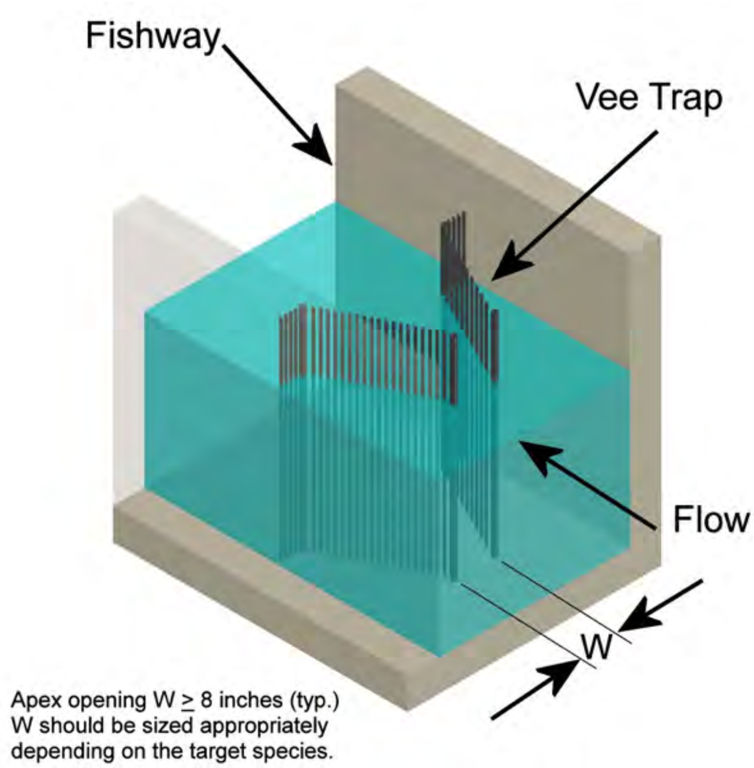


Figure 7-2. Cutaway of a Vee trap

7.5.4.2 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such a neoprene padding (covered by UV stabilized rubber), may also be required to minimize fish injuries.

7.5.4.3 Materials and bar spacing

Materials and bar spacing should conform to Sections 7.5.3.2 and 7.5.3.3.

7.5.4.4 Closure

Trapping mechanisms should be able to be closed temporarily to avoid spatial conflict with brail crowding and loading operations. The trapping mechanisms should be designed to safeguard against fish gaining access to unsafe areas such as areas behind a crowder or under a floor brail.

7.5.5 Holding Pools

Holding pools and raceways are used to provide safe areas where fish can be held and accumulated until the facility operators are prepared to process them (for actions such as sorting, evaluation, or transportation).

7.5.5.1 Water quality

Holding pool water quality should be equal to or exceed that of the ambient waters from which fish are trapped.

Key water quality parameters include water temperature, oxygen content, and pH. The purpose of this criterion is to provide fish with a safe, healthy holding environment.

7.5.5.2 Trap holding pool capacity

The following criteria should be followed with regard to trap holding pool capacity:

- *Trap holding pool capacity is based on the number and poundage of fish that can be safely held in a given pool volume for a given time period as well as water quality and quantity.*
- *The number of fish is determined by the maximum daily number of fish passing through the ladder or facility, or by the number of fish expected to be trapped and held prior to being transported.*
- *Fish poundage is determined by multiplying the weight of the average fish targeted for trapping by the maximum number of fish expected to occupy the trap. Note that the poundage calculation may entail calculations for a number of different fish species.*

7.5.5.3 Short-term holding

Trap holding pools should be sized to provide a minimum volume of 0.25 ft^3/lb of fish. Trap water supply flow rate should be at least 0.67 gallon per minute (gpm) per adult fish for the predetermined adult fish trap holding capacity.

These criteria apply to conditions when water temperatures are less than 50 degrees Fahrenheit (°F), dissolved oxygen is between 6 and 7 parts per million, and fish are held less than 24 hours (Senn et al. 1984; Bell 1991; Bates 1992). For example, to hold 100 lb of fish for less than 24 hours, the holding pool would need to provide a volume of 25 ft^3 (100 lb × 0.25 ft^3/lb of fish) at 50°F. These criteria are based on the long-term holding requirements presented by Senn et al. (1984), which have been modified and adapted to short-term holding conditions. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.4 Long-term holding

Trap holding pool water volumes and water supply rates should be increased by a factor of 2 (0.5 ft^3/lb of fish and at least 1.34 gpm per adult fish, respectively).

For example, to hold 100 lb of fish for more than 24 hours (but less than 96 hours), the holding pool would need to provide a volume of 50 ft^3 (100 lb × 0.5 ft^3/lb of fish) at 50°F. Long-term holding should not exceed 96 hours. Trap and haul facilities are not intended for the long-term holding of adults (e.g., hatchery broodstock). However, NMFS will consider additional information or research regarding adult fish holding times and densities, if provided. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.5 Holding pool capacity when water temperatures are greater than 50°F

If water temperatures are greater than 50°F, the poundage of fish held should be reduced by 5% for each degree above 50°F (Senn et al. 1984). The trap capacity and average weight of targeted fish values to be used in a design are subject to approval by NMFS.

For short term holding (less than 24 hours) at 60°F, to hold 100 lb of fish, the holding pool would need to provide a volume of 50 ft^3. For long term holding (greater than 24 hours but less than 96 hours) at 60°F, the holding pool would need to provide a volume of 100 ft^3.

Extreme care should be taken when water temperatures are above 68°F during trap operations.

Table 7-1 is provided for reference.

Table 7-1. Holding Pool capacity when water temperature exceeds 50°F

Temp (°F)	Short Term Holding (0.25 lb/$ft^{3)}$	Short Term Holding (0.25 ft^3/lb)	Long Term Holding (0.5 lb/$ft^{3)}$	Long Term Holding (0.5ft^3/lb_
50	4.00	0.25	2.00	0.50
51	3.80	0.26	1.90	0.53
52	3.60	0.28	1.80	0.56
53	3.40	0.29	1.70	0.59
54	3.20	0.31	1.60	0.63
55	3.00	0.33	1.50	0.67
56	2.80	0.36	1.40	0.71

57	2.60	0.38	1.30	0.77
58	2.40	0.42	1.20	0.83
59	2.20	0.45	1.10	0.91
60	2.00	0.50	1.00	1.00
61	1.80	0.56	0.90	1.11
62	1.60	0.63	0.80	1.25
63	1.40	0.71	0.70	1.43
64	1.20	0.83	0.60	1.67
65	1.00	1.00	0.50	2.00
66	0.80	1.25	0.40	2.50
67	0.60	1.67	0.30	3.33
68	0.40	2.50	0.20	5.00
69	0.20	5.00	0.10	10.00

7.5.5.6 Trap holding pool inflow

The following criteria should be followed with regard to trap holding pool inflow:

- *Inflow should be routed through an upstream diffuser designed in accordance with the criteria identified in Section 5.3.7.*
- *The maximum average velocity through the diffuser that is acceptable is 1 ft/s for vertical diffusers and 0.5 ft/s for horizontal diffusers.*
- *Horizontal diffusers should be used when supplying water directly to fish holding pools to reduce the potential for fish jumping at the diffuser flow (Bell 1991).*
- *For both vertical and horizontal diffusers, baffling and other methods of energy dissipation should be used to prevent excessive turbulence and surging, which may induce adult jumping within the trap.*
- *Flow distribution through the diffuser should not cause fish to crowd into a particular area of the holding pool. However, when fish are being crowded for handling or routing, it is best to take advantage of their natural behavior and concentrate the water supply near the end of the pool where fish are being encouraged to move to as part of the operation.*

7.5.5.7 Shading

Consideration should be given to providing shading for holding pools and raceways.

Shading can reduce stress and jumping in adult fish and can reduce the potential for sun burn (Bell 1991).

7.5.5.8 Holding pool water depth

The minimum depth of water in the holding pool is 5 feet.

This is the same minimum depth criterion as is specified for fish ladder pools.

7.5.5.9 Adult jumping

Trap holding pool designs should include provisions that minimize adult jumping, which may result in fish injury or mortality.

Examples of provisions that reduce jumping include the following (Bell 1991):

- Incorporating a high freeboard on holding pool walls of 5 feet or more (note that Bell [1991] recommends incorporating up to 6 feet of freeboard into the facility design)
- Covering or shading the holding pool to keep fish in a darkened environment
- Providing netting over the pool that is strong enough to prevent adults from breaking through the mesh fabric
- Providing sprinklers above the holding pool water surface to break up the water surface and reduce the ability of fish to detect movement above the trap pool
- Designing the corners of the holding pools to have a minimum radius of 18 inches
- Ensuring that water from distribution flumes and pipes does not drop directly into the holding pool
- Ensuring that there are no areas of strong horizontal light nor dark areas present on the surface of the holding pool

7.5.6 Crowders

Crowders are porous panels that can be deployed into a holding pool and used to move fish horizontally to the end of the pool for collection by a hopper or lift, or to encourage the fish to leave the holding pool. Crowders can be pushed by personnel or mechanically operated.

7.5.6.1 Bar spacing

Holding pool crowders should have a maximum clear opening between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch. The side and bottom seals of the crowder panel should allow the crowder to move without binding and should prevent fish from entering the area behind the crowder panel.

If smolt-sized juvenile salmonids or other small fish are expected to be retained in the adult holding pool, the maximum clear bar spacing of the crowder panel (and brail if present) should be reduced to 0.25 inch, and any gaps around the sides the crowder panels should not exceed 0.375 inch.

Often, smaller-sized fish find their way into and become caught in the adult trap holding pool. Provisions should be incorporated into the trap design to safely remove smaller-sized fish from the holding pool and return them to the river.

7.5.6.2 Material

Crowder panels should be constructed of non-corrosive materials. The use of galvanized material should be avoided if possible, and otherwise minimized. Panels may consist of fish screen material such as profile bar or perforated plate material, flat bars where the narrow edge *of the bar is aligned with flow, or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.*

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.6.3 Crowding process and crowding speeds

For mechanical crowders, the beginning of the crowding process can be automated, but at the end of the process when fish densities are high the crowder should be manually controlled.

Speeds for horizontally oriented crowders are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum crowder speed should not exceed 2 ft/s and should be adjustable.

Crowders are often controlled by a variable frequency drive (VFD). VFDs allow for crowder travel speed to be slowly increased or decreased. This moves the equipment to crowd, but not stress, adult fish in the holding pool. Further, it eliminates erratic (jerking) crowder movement provided with a simple on-off switch. Crowder speeds are also sometimes controlled by a switch to toggle between fast and slow speeds. In all cases, the VFD should be programmed not to increase the crowder or brail speed beyond a maximum level.

7.5.6.4 Coverage

Crowders should be able to cover (crowd) the entire holding pool and should not leave any areas where fish may escape the crowding process.

Being able to crowd the entire holding pool ensures that all fish can be removed from the pool and that no fish spends more time than necessary in the holding pool.

7.5.6.5 Fish entering the holding pool while crowding

If the crowder cannot be removed from the holding pool, it is important that fish do not enter that portion of the holding pool located behind the crowder during crowding operations.

Fish should not be able to access the area behind the crowder where they could become trapped resulting in injury or death.

7.5.7 Brails

Brails are porous panels that can be used to move fish vertically in a holding pool or fish lock. For large holding pools, they are often used in conjunction with a crowder to encourage fish to exit the holding pool.

7.5.7.1 Floor brails

The following criteria should be followed with regard to floor brails:

- *Floor brails should be composed of screen material that is sized according to the life stage and species present to preclude injury or mortality from occurring to target and non-target fish species. Gap openings along the sides of the brail should not exceed 1 inch.*
- *For adult salmonids, brails should have a maximum clear spacing between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch, and seals should be installed that cover all gaps. The side and bottom seals of the crowder panel should allow the crowder to move without binding and prevent fish from moving underneath the brail.*
- *If juvenile salmonids (i.e., smolt-sized fish) or other small fish are expected to be caught in the holding pool, consideration should be given to including a separator system and juvenile sanctuary area as part of the brail system. Also, the maximum clear spacing between bars of the brail should be reduced to 0.25 inch, with side tolerances of no more than 0.375-inch opening or the openings sealed with a brush material.*

7.5.7.2 Material

Brail panels should be constructed of non-corrosive material. The use of galvanized material should be avoided if possible, and otherwise be minimized. Panels may consist of fish screen material such as profile bar or perforated plate material; flat bars where the narrow edge of the bar is aligned with flow; or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.7.3 Slope

The sides and the floor of the brail should be sloped toward the holding pool egress point to encourage adult fish to move off the brail.

7.5.7.4 Lifting

The brail should not be used to lift fish out of the water.

7.5.7.5 Brail speed

Brail speeds are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum brail speed should not exceed 2 ft/s and should be adjustable. The beginning of the brailing process can be automated, but at the end of the process when fish densities are high, the brail should be manually controlled.

7.5.7.6 Fish lock brails

When floor brails are used in association with fish locks (Section 7.6.2), the floor brail hoist should be designed for both manual and automatic operation and should allow the brail to move at a maximum rate of 2.3 ft/s (both upward and downward). Also, the brail should be able to be operated at speeds that match changes in water surface elevation. Automated operation is allowed only when the water depth above the brail is 4 feet or more. At water depths less than 4 feet, operation of the brail should be conducted manually.

These criteria are designed to minimize stressing fish during crowding between the floor brail and the point where water in the lock exits over an egress weir.

7.5.8 False Weirs

A false weir is a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to volitionally move into a specific area (Figure 7-3). The device usually creates a strong upwelling flow that simulates flow cascading over a weir. Fish are attracted to the cascading flow and swim through the upwelling into the distribution flume. Care should be taken when locating a false weir to avoid light-to-dark transition at the location of the false weir (shadows) or movement by operator personnel around the false weir. These conditions could cause a fish to reject (not enter) the false weir.

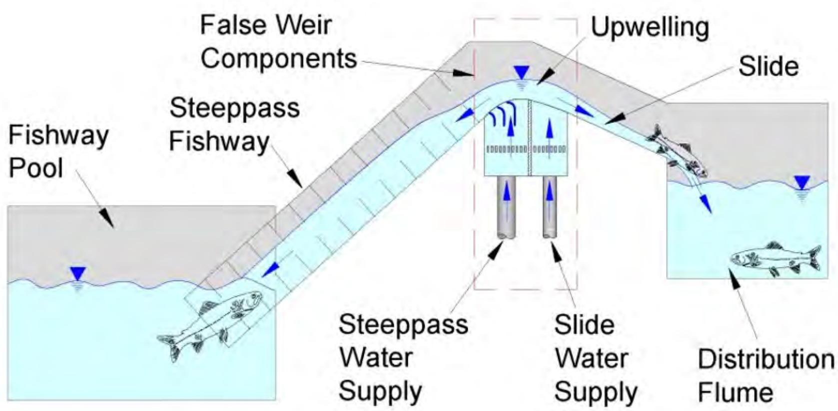


Figure 7-3. Cross section of a false weir

7.5.8.1 Depth

Water depth over the crest of the false weir should be at least 6 inches to facilitate fish egress from the holding pool.

7.5.8.2 Water Supply and Dewatering

The false weir design should include independent water control for both the weir side (steeppass water supply side in Figure 7-3) and flume side (slide water supply in Figure 7-3). Additionally, the slide side of the false weir should include a dewatering screen/system to allow the operator to trim the flow down the slide/flume.

Tuning the amount of flow over the false weir to encourage fish movement while having the ability to limit the amount of flow down the flume is very important. Too much flow down the flume, may allow the fish to try to swim against the flow until exhaustion (Section 7.5.9.3). Achieving the balance between sufficient weir flow and reduced flume flows can be impossible with a common water supply. The addition of a drain between the weir supply and the flume supply is very helpful and allows the operator to maximize attraction flow entering the holding pool. Finally, the independent water control and drain allows the operator to continue to supply the flume with flow both before and after the weir is turned on and off, respectively.

7.5.8.3 Adjustability

The false weir and the downstream water level should have enough adjustability to backwater the false weir and create a streaming flow condition, rather than a plunging flow condition over the weir.

Incorporating this adjustability in the design of the false weir allows the operator to adjust conditions at the false weir to allow adult fish to swim through the weir, rather than having to leap at it to pass the weir. Care should be taken when raising the downstream water surface elevation to ensure this does not adversely affect hydraulic conditions in the trap facility further downstream of the false weir.

7.5.8.4 Fish entering a distribution flume

In situations where fish are entering a distribution flume after passing over a false weir, the ability to change the amount of flow coming from the false weir should be rapid and easy to change in order to regulate the movement of fish over the weir.

Oftentimes it is necessary to control (i.e., meter) the number of fish passing through the false weir so operator personnel can identify and sort fish into various holding tanks. Having the ability to rapidly change the amount of flow coming from the false weir allows the operator some control over how many fish enter the false weir at time. Operator-controlled neoprene doors that open and close in front of, or vary the width of, the entrance to the false weir can be used to allow the operator to more efficiently meter fish through the false weir. Care should be taken in providing sufficient freeboard (around, above, through and downstream of the false weir), since very strong leapers (like steelhead) can jump much higher than the water level on the weir crest.

7.5.8.5 Edges

Provisions, such as neoprene padding (covered by UV stabilized rubber), should be installed around a false weir to protect fish that make an inaccurate leap at the weir from being injured.

7.5.8.6 Gravity flow

A gravity flow (i.e., not pumped) water supply should be used for false weirs and steeppass ladders to prevent fish from potentially rejecting the trap component due to the production of noise or vibration from a pump or motor. At sites where it is necessary or *desirable to use a pumped water supply, care should be taken to isolate the pump noise and vibration from affecting the fish.*

7.5.9 Distribution Flumes and Pipes

7.5.9.1 General

A distribution flume (or pipe) should be used whenever fish are routed from one area to another.

Distribution flumes are used to convey fish to anesthetic tanks, recovery tanks, pre-transport holding tanks, fish ladders, and project forebays. They are also used to convey fish to various locations after they pass through false weirs.

7.5.9.2 Smoothness

The flume should have smooth joints, sides, and bottom, with no sharp or abrupt edges and no abrupt vertical or horizontal bends.

7.5.9.3 Wetted surfaces, water depth, and velocity

The following criteria should be followed with regard to wetted surfaces, water depth, and velocity:

- *The flume should have continuously wetted surfaces.*
- *For flumes less than 50 feet in length, water depth in the flume should be between 1 and 3 inches, and water velocity should be between 6 and 8 ft/s.*
- *For flumes that are longer than 50 feet, a closed pipe with open channel flow should be used for the entire length of the flume. The water depth in the pipe should be between 2 and 4 inches (a depth of 4 inches is preferred), and water velocity should be greater than 8 ft/s, but less than 15 ft/s.*
- *Site-specific adjustments to these values may be required.*

The combination of low water depth and high velocity is intended to prevent adult fish from holding in the pipe or swimming upstream in the pipe. If the pipe is above ground, observation ports with removable covers should be provided so that conditions in the flume can be observed and the pipe can be accessed for maintenance and debris removal. If the pipe is located belowground, access ports should be provided for inspection and maintenance.

7.5.9.4 Outfalls

When distribution flumes lead to holding tanks or raceways, care should be taken so that adults entering the tank do not hit the walls, floor, or end of the tank or collide (land on top of) with other fish. A dewatering drain should be located immediately upstream of the outfall to eliminate flow from the outfall which can cause false attraction and jumping.

When a distribution flume is used to return adults to the river, the criteria for juvenile outfalls (Section 8.6.4) should be followed (i.e., the bypass flow should not impact the river *bottom or other physical features at any stage of river flow, and the maximum bypass outfall impact velocity should be less than 25 ft/s).*

7.5.9.5 Bends

Horizontal and vertical radii of curvature should be at least 5 times the width of the flume to minimize the risk of fish-strike injuries. A removable flume cover should be provided when flumes go through bends greater than 30 degrees in alignment.

Removable covers are necessary to prevent active fish from leaping out of the flume and allow personnel to inspect the flume for debris accumulation in the bend.

7.5.9.6 Size

The minimum inside diameter of the distribution flume should be 15 inches for fish weighing 20 lb or less and 18 inches for fish weighing 20 lb or more.

The minimum sidewall height of a distribution flume is 24 inches.

This height is in addition to the radius of the flume. For example, the minimum total height of a 15-inch diameter flume would be 31.5 inches (24 inches plus half of the diameter at 7.5 inches), as measured from the invert of the flume.

7.5.9.7 Length

Distribution flumes should be as short as possible.

7.5.9.8 Flume structure

Overhead structures that are part of the flume, such as overhead bracing to stiffen the walls of the flume or gate operation arms, should be eliminated if possible, or minimized. If overhead structures are necessary, they should be located above the top of the flume sidewalls or 30 inches above the invert of the flume, whichever is greater.

7.5.10 Anesthetic Recovery Pools

The following criteria should be followed with regard to anesthetic recovery pools:

- *Anesthetized fish should be routed to a recovery pool to allow the fish to be monitored prior to release to ensure they have fully recovered from the anesthesia.*
- *Fish that are recovering from anesthesia should not be routed directly back to the river where unobserved mortality may occur.*
- *Recovery pool inflow should satisfy the water quality guidelines specified in Section 7.5.5.*
- *Recovery pool hydraulic conditions should not result in partially or fully anesthetized fish being impinged on an outflow grating or any other hazardous area.*
- *A recovery pool should allow fully recovered fish to volitionally exit the pool.*
- *The recovery pool should have a brail or crowder system to force fish from the recovery pool if necessary.*

Often, fish require time to recover from effects of anesthetic. Anesthetized fish released directly to an uncontrolled environment (i.e., directly back to the river or into a ladder) often fail to orient themselves upright and sometimes sink to the bottom where they may suffocate or are swept downstream. It is important to provide fish recovering from anesthetic with a safe recovery area where they can be monitored by personnel. Some indications that fish are fully recovered include they are upright and oriented, display normal gilling activity, and are responsive to stimuli. If a fish appears to be struggling to recover or appears distressed, it may be necessary to retrieve the fish and revive it. Revival may involve manually ventilation of the gills by gently moving the fish forward and backward in the water. The ability of a fish to volitionally exit the recovery pool is an indication that the fish has recovered sufficiently from the anesthetic. Fish should not be forced out of the recovery pool for at least 30 minutes after exposure to anesthetic.

7.6 Lifting Devices

Section 7.6 provides criteria and guidelines that apply to fish lifting devices.

7.6.1 Fish Lifts and Hopper Passage Systems

A fish lift is a mechanical system that utilizes a hopper and hoist to allow fish to be trapped at one elevation and raised to a higher elevation. Once raised to the higher elevation, fish can be loaded into a transport tank or truck for release at a remote location, routed to a monitoring and sorting facility, or released above a dam directly into the forebay.

7.6.1.1 Maximum hopper loading densities

The hopper water volumes should be greater than or equal to 0.15 ft^3/lb of fish estimated to occur at the maximum fish load. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991).

Hopper loading densities are designed to ensure that a sufficient volume of water is available to fish to be raised safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

7.6.1.2 Hopper freeboard

The distance from the water surface in the hopper to the top of hopper bucket should be greater than the water depth within the hopper.

This is to reduce the risk of fish jumping out of the hopper during lifting operations.

7.6.1.3 Sump

When a trap design includes a hopper sump into which the hopper is lowered during trapping, side clearances between the hopper and sump sidewalls should not exceed 1 inch to *minimize access to the area below the hopper. Flexible side seals or brushes should be used to ensure that fish do not pass below the hopper.*

It is very important that the hopper and gates around the sump provide a positive seal and do not allow fish to get into the sump area. If fish do get into this area, they can be very difficult to remove due to the water depth and confined area.

7.6.1.4 Fish hopper egress opening

The fish egress opening from the hopper into the transport tank should have a minimum horizontal cross-sectional area of 3 square feet and a smooth transition to minimize the potential for fish injury.

7.6.1.5 Safeguarding fish

Fail-safe measures should be provided to prevent fish entering the holding pool area from accessing the area occupied by the hopper before the hopper is lowered into position. The interior surfaces of the hopper should be smooth to eliminate fish injuries.

7.6.2 Fish Lock

A fish lock is a mechanical-hydraulic system that utilizes a water chamber or tower to raise fish from one elevation to another. It allows fish that are collected (trapped) at a lower elevation to be raised to a higher elevation by increasing the water level in the chamber or tower until it reaches a predetermined elevation where fish can be released. The fish can be brailed (i.e., crowded) to the higher elevation and then loaded into a transport truck for release at a remote location, routed to a monitoring and sorting facility, or released directly above a dam into the forebay (Clay 1995).

Section 7.6.2.1 outlines the process for routing fish from a holding pool to the forebay or transport vehicle using a fish lock.

7.6.2.1 Holding pool crowding

The following criteria and guidelines should be followed with regard to holding pool crowding:

- *Fish are crowded into the lock; the crowder should meet up with the entrance to the lock so that no fish can become trapped or crushed between the crowder and the lift structure or closure gate.*
- *When the closure gate to the fish lock chamber is shut it should create a uniform surface with the interior of the lock so that the brail can pass the gate without creating excessive gaps that could allow fish to get past the brail.*
    - The closure gate is the gate that seals the lock chamber from the holding pool.
- *Once the closure gate is shut, the crowder should be backed up to reduce the stress on the fish.*

- Crowding, especially the last part of the crowd when fish are forced from the holding pool, can be very stressful to the fish. If there is a break in the crowding operation for some reason (lifting and operating the hopper for example), the crowder should be backed off to reduce the stress on the fish.

- *Flow to fill the lock should be introduced into the lock through floor diffusers below the floor brail.*
  - As the water level rises within the lock, it will ultimately reach an equilibrium elevation with a control weir or false weir.
- *The floor brail should be raised only after the water surface elevation in the lock is at an equilibrium with the control weir or false weir. If the brail is being operated while the fish lock is being filled, the speed of the brail should not exceed the rate of change in water surface elevation. The brail should be greater than 4 feet from the water surface until the water level reaches equilibrium with the control or false weir. The brail should not be used to lift fish out of the water (Section 7.5.7.4).*
  - Speeds for brails (vertically oriented crowders) are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools, but can range up to 2.3 ft/s for vertical fish locks.
- *Fish should exit the lock via a false weir or through the overflow water draining over the control weir.*
- *Fish and water that pass over the control weir or false weir can be routed using a distribution flume to other destinations, including an anesthetic tank, sorting or holding pools, or a transportation vehicle.*
  - Floor dewatering screens in the distribution flume can be used to drain off excess flow just before fish are delivered to anesthetic tanks, holding pools, or transportation vehicles.

7.6.2.2 Lock inflow chamber

The lock inflow chamber located below the lowest-floor brail level should be of sufficient depth and volume (Section 5.5.3.5) to limit turbulence into the fish holding zone when lock inflow is introduced. The inflow sump should be designed so that flow upwells uniformly through add-in floor diffusers (Section 5.3.7; Bell 1991).

Properly designed lock inflow chambers will limit turbulence and unstable hydraulic conditions within the lock that may agitate fish.

7.7 Single Holding Pool Traps

Single pool traps are often used in tandem with intermittent exclusion barriers (Figure 6-5) for broodstock collection from small streams. These trapping systems are used to collect, sort, and load adult fish. Key criteria for single holding pool traps are as follows:

- *The trap holding pool water volume should be designed according to Section 5.5.3.5 to achieve stable interior hydraulic conditions and minimize jumping of trapped fish.*
- *Intakes should conform to Section 5.3.2.*

- *Sidewall freeboard should be a minimum of 4 feet above the trap pool water surface at high design streamflow.*
- *The trap holding pool interior surfaces should be smooth to reduce the potential for fish injury.*
- *A description of the proposed means of removing fish from the trapping pool and loading them onto a transport truck should be submitted to NMFS for approval as part of the ESA incidental take permit application.*

7.8 Upstream Transportation Criteria

Section 7.8 provides criteria and guidelines that are applicable to truck transportation equipment and facilities.

7.8.1 Maximum Transport Tank Loading Densities and Time

Transport tank loading water volumes should be greater than or equal to 0.15 ft^3/lb of fish at the maximum fish loading density to provide a sufficient volume of water for fish safety. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991). Every effort should be made to reduce the amount of time fish spend in a transport tank.

These loading densities are to ensure that a sufficient volume of water is available in the tank for fish to be transported safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

Due to the high loading densities in transport tanks and the stress it may create, every effort should be made to minimize the amount of time the fish spend in these tanks. Fish should not be held for long in a transport tank while waiting for other fish to be processed or while waiting for other fish to fill the tank.

7.8.2 Transport Tanks

To minimize handling stress, truck transport tanks should be compatible with the hopper design. If an existing vehicle will be used, the hopper should be designed to be compatible with existing equipment. If the transport tank opening is larger than the tube or hopper opening, a cap or other device should be designed to prevent fish from jumping at the opening. Truck tanks for hauling adults should be closed systems, and the tanks should be kept full to prevent sloshing (Bell 1991).

7.8.2.1 Fish transfer from hopper to tank

The transfer of fish should be made water-to-water. The design of the hopper and transport tanks should allow for hopper water surface control to be transferred to the truck *transport tank during loading so that water and fish do not plunge abruptly from the hopper into the fish transport tank.*

7.8.2.2 Transport tank egress

The fish egress opening from the transport tank should have a minimum cross-sectional area of 2 square feet (Clay 1995). The bottom of the transport tank should be sloped (front to back and side to side) toward the release opening and have a smooth transition that minimizes the potential for fish injury.

7.8.2.3 Oxygen and temperature requirements

Depending upon site-specific conditions, the transportation tank should have the capability to maintain dissolved oxygen levels between 6 and 7 parts per million. The transportation tank should also contain water chillers to maintain ambient water temperature if the transport cycle time could result in unhealthy increases in the water temperature in the tank or temperature differential between the tank water temperature and the ambient water temperature where the fish are released exceed the water tempering described in Section 7.8.3.5.

Many existing fish transport trucks do not include water chillers because they are designed for short transport trips during which the water temperature conditions in the tank do not result in temperature changes that exceed the water tempering requirements when the fish are released. Water tempering can be performed using chillers or mixing with cooler or warmer water at loading or release sites.

7.8.3 Release Location

After being transported, fish should be released in a safe location with sufficient depth and good water quality.

The criteria and guidelines in Sections 7.8.3.1 through 7.8.3.6 apply to release locations.

7.8.3.1 Direct release from a transport tank

Fish should not be dropped more than 6 vertical feet during release. The receiving water should be at least 3 feet deep, and fish should not contact the bottom. The impact velocity of fish entering the receiving water should be less than 25 ft/s.

7.8.3.2 Release pipe from a transport tank

For locations where release pipes are required, the minimum diameter for a release pipe is 24 inches (30 inches is preferred). The end of the release pipe should not be submerged. The internal surface of the pipe joints should be smooth to the touch to prevent descaling and injury to fish. The release pipe elevation criteria, receiving water depth, and impact velocity are the same as for fish being released directly from a transport tank (Section 7.8.3.1).

Depending on how fish are released from the transport tank, the entrance to the release pipe may have to be larger (e.g., 36 inches), or a funnel or flume should be created that smoothly transitions from the release tank outlet to the release pipe. Care should be taken to minimize the possibility of a fish leaping out of the system during transfer from the tank to release pipe.

7.8.3.3 Release water

Water should be supplied to the release pipe prior to fish being released and also used to flush the last fish out of the pipe.

7.8.3.4 Water quality

Water quality (i.e., water temperature and dissolved oxygen) at the release site should be representative of the general water conditions in the river in the vicinity of the release site.

7.8.3.5 Water tempering

Fish should not be subjected to rapid temperature changes. Temperature differentials between the transport tank and release location should be no more than 2 degrees Celsius (°C). If tempering is required to meet this criterion, changes in temperature should not exceed 1°C every 2 minutes or 5°C per hour. Tempering may take longer when temperatures are further away from the optimal temperature for the target species and life stage.

Changes in water temperature that occur too rapidly or are beyond the normal survival range of fish may cause thermal trauma (Post 1987). Mortality associated with rapid temperature changes may occur in the short term from loss of equilibrium (Bell 1991) and increased predation (Groot et al. 1995). Over longer time periods, thermal stress can act as an additive stressor and increase susceptibility to disease (Piper et al. 1982). Fish adapt more rapidly when the temperature change is nearer their thermal optimum than when the change is further away from that temperature (Schreck and Moyle 1990). Rapid changes in temperature have more significant negative effects at the upper end of a fish's temperature tolerance. As temperatures increase, fish are more active and have greater potential for self-inflicted injury, oxygen consumption is higher, and the saturation level of oxygen is lower, which increases the possibility of hypoxia (Murphy and Willis 1996).

7.8.3.6 Release site egress

The release site should provide direct and simple egress for fish into the river for continued migration upstream.

8 Fish Screen and Bypass Facilities

8.1 Introduction

Chapter 8 provides criteria for designing fish screen facilities for hydroelectric, municipal, irrigation, and other water-withdrawal projects that prevent fish (primarily young fish, fish with poor swimming capabilities, and larvae) from being entrained into water diversions. The objectives of these criteria are to develop fish screen facility designs that prevent fish impingement on the outward face of all fish screen material, do not increase predation above background levels, and ensure the structural integrity and longevity of all facility components is maintained. This allows the facility to be operated within its design criteria and protects fisheries resources over the design life of the project.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other that salmonids, NOAA will consider deferring to the more conservative criteria on a case by case basis.

The criteria are to be used when designing new facilities or performing major retrofits to existing facilities. The criteria are also to be used for temporary diversions such as water drafting operations (Section 8.7) and when stream flow is to be routed around a construction site. In addition, information presented in Chapter 1, Introduction; Chapter 3, Design Development; and Chapter 4, Design Flow Range, of this document apply to the design of fish screen and bypass facilities.

8.1.1 100% Flow Screening

All facilities that divert or use water from a body of water should convey 100% of the diverted flow through a fish screen or bypass that is designed, constructed, tested, and operated using the criteria contained herein.

The application of these criteria to existing fish screen facilities is addressed in Section 8.2.

8.1.2 Deviation from These Criteria

The criteria can be adjusted by NMFS as needed to meet the specific requirements of a project. It is the responsibility of the applicant to provide compelling evidence in support of any proposed waiver (Section 1.6) or modification of a criterion to NMFS early in the design process and well in advance of a proposed federal action. Appendix C (Experimental Technologies) *provides additional information on the NMFS approval process for unproven fish passage technologies.*

There may be cases where site constraints or extenuating circumstances weigh in favor of a deviation or waiver of these criteria. Extenuating circumstances may include environmental factors that affect a fish's swimming ability or condition such as abnormally warm or cold waters or waters low in dissolved oxygen.

The swimming ability of target fish species and their life stages are primary considerations in designing effective fish screen facilities. The swimming abilities of fish vary with species, age-class, size, and duration (i.e., endurance) and type of swimming activity required (e.g., sustained versus burst swim speed). Bell (1991) provides information on swimming speeds for multiple fish species and age-classes and for different functional speeds (cruising, sustained, and darting). Swimming ability also depends upon a number of biological and physical factors, including the physical condition of individual fish; water quality parameters, such as dissolved oxygen concentration and water temperature; and ambient lighting conditions. For example, swimming effort may be reduced by 60% at oxygen levels that are one-third of saturation, and temperatures above and below the optimum range for any species affect swimming effort (Bell 1991). Adverse temperatures may reduce swimming effort by 50% (Brett et al. 1958).

8.1.3 Experimental Technology

The process to evaluate experimental screening technology is described in Appendix C. Proponents of new, unproven fish passage designs (i.e., designs not meeting the criteria and guidelines contained in this chapter) should provide NMFS with the types of information identified in Section 1.5.

NMFS considers several categories of screen designs that are currently in use to be experimental technologies. These include Eicher screens, modular inclined screens, and Coanda intake screens. Infiltration galleries may be considered an acceptable alternative for excluding fish at water diversions, but these are not considered positive exclusion barriers. Therefore, they are not addressed in this chapter. Information on the design and use of infiltration galleries is presented in Appendix B. The design and use of experimental technologies may be considered on a case-by-case basis through discussions with NMFS and in accordance with the procedures outlined in Appendix C.

8.2 Existing Fish Screens

8.2.1 General

If a fish screen was constructed prior to the date of this document, but in accordance with the NMFS criteria that were established on August 21, 1989, or later, NMFS considers these screens to be compliant provided that all of the following conditions have been met:

- *The entire screen facility functions and is operated as designed.*
- *The entire screen facility has been maintained and is in good working condition.*

- *When screen material wears out, it is replaced with screen material meeting the current criteria stated in this chapter (Section 8.5.8). To comply with this condition, structural modifications may be required to retrofit an existing facility with new screen material.*
- *Mortality, injury, entrainment, impingement, migration delay, or other harm to anadromous fish caused by the facility has not been observed.*
- *Emergent fry are unlikely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.*
- *When biological uncertainty exists, access to the diversion site by NMFS is permitted by the owner or operator of the facility for verification that the criteria in this chapter are being met.*

8.3 Project Design Review

The most effective approach to designing fish screening and bypass projects is to have NMFS included in all phases of the design. This can occur by having NMFS participate in a technical advisory team convened for the project or having NMFS review and comment on project designs, or both. While both the preliminary and final designs should be developed in cooperation and interaction with engineering staff from NMFS WCR Environmental Services Branch (Section 3.2), it is especially important that NMFS be involved in the preliminary design phase of a project. This is to ensure that the design parameters needed to produce a functional fish passage project are established early in the design process.

The project design process is most efficient when design criteria are identified and accepted by NMFS while a project is in its infancy. The entire project design development process and information typically required for a preliminary design are discussed in Chapter 3.

8.4 Structure Placement

All screen facilities should be designed to function properly and protect fish from being entrained into the water diversion throughout the full range of hydrologic conditions expected to occur at the location.

For in-stream facilities, the full range of conditions is normally from the minimum stream flow during which water diversions may take place, up to a 100-year flood event. In situations where streambanks will overtop allowing flow into the canal outside of the screen area at flows lower than the 100-year flood event, the screen may be designed to resist overtopping up to the lower flows. NMFS may require the facility operator to capture and relocate fish that become stranded behind a fish screen.

8.4.1 In-Stream Installations

Where it is physically practical and biologically desirable to do so, the fish screen should be constructed at the point of water diversion, and the screen face should be oriented parallel to the streamflow.

Several physical factors may preclude a fish screen from being located and constructed at the water diversion. These include excess channel gradient; the potential for large debris to damage the screen facility; access for personnel and equipment to conduct facility maintenance, operations, and repair; unsuitable soils for constructing a fish screen facility at the point of diversion; and the potential for heavy sediment accumulations.

Depending on site-specific conditions, in-stream screens may be subject to increased damage by debris. However, they typically offer the following advantages:

- They do not require a formal bypass system.
- They keep migrating fish in the streamflow.
- They may reduce fish proximity to the screen face.

8.4.1.1 Bankline screens

For screens constructed at the edge of a stream (Figures 8-1 through 8-3), the screen face should be aligned with the adjacent bankline, and the transition between the native streambank and the fish screen face should be shaped to minimize turbulence and eddying in front, upstream, and downstream of the screen. For inclined, flat plate screen designs, the screen angle should not be greater than 45 degrees from vertical, and the top of the screen should be submerged a minimum of 1 foot at low stream design flow. The design should also minimize any adverse alteration of riverine and riparian habitat.

Figure 8-1. Aerial view of the Garden City-Lowden 2 water diversion on Walla Walla River near Touchet, Washington (Notes: River flow is from left to right. The bankline screen is located at the head end of the canal, just upstream of the spillway and adult ladder exit.)

Figure 8-2 Bankline screens at the Garden City-Lowden 2 diversion on the Walla Walla River near Touchet, Washington, under construction

Figure 8-3 Bankline vertical flat plate fish screen sized for 3,000 ft3/s (Glenn-Colusa Irrigation District) along the Sacramento River in California (Note: the screen is shown in operation (left) and during construction (right).)

8.4.2 In-Canal Installations

All screen facilities installed within canals should include an effective fish bypass system (Section 8.6) to collect and transport screened fish safely back to the river with minimum delay (Figure 8-4). In instances where the returned bypass flow represents a substantial proportion of the remaining instream flow downstream from the water diversion, the bypass outfall should be placed as close to the point of diversion as practicable to minimize the length of the dewatered stream channel.

Where installation of fish screens at a diversion entrance is not desirable or is deemed impractical, the screens may be installed at a suitable location in the canal downstream of the water diversion. Locating the bypass outfall as close to the point of diversion as possible reduces the length of dewatered stream channel.

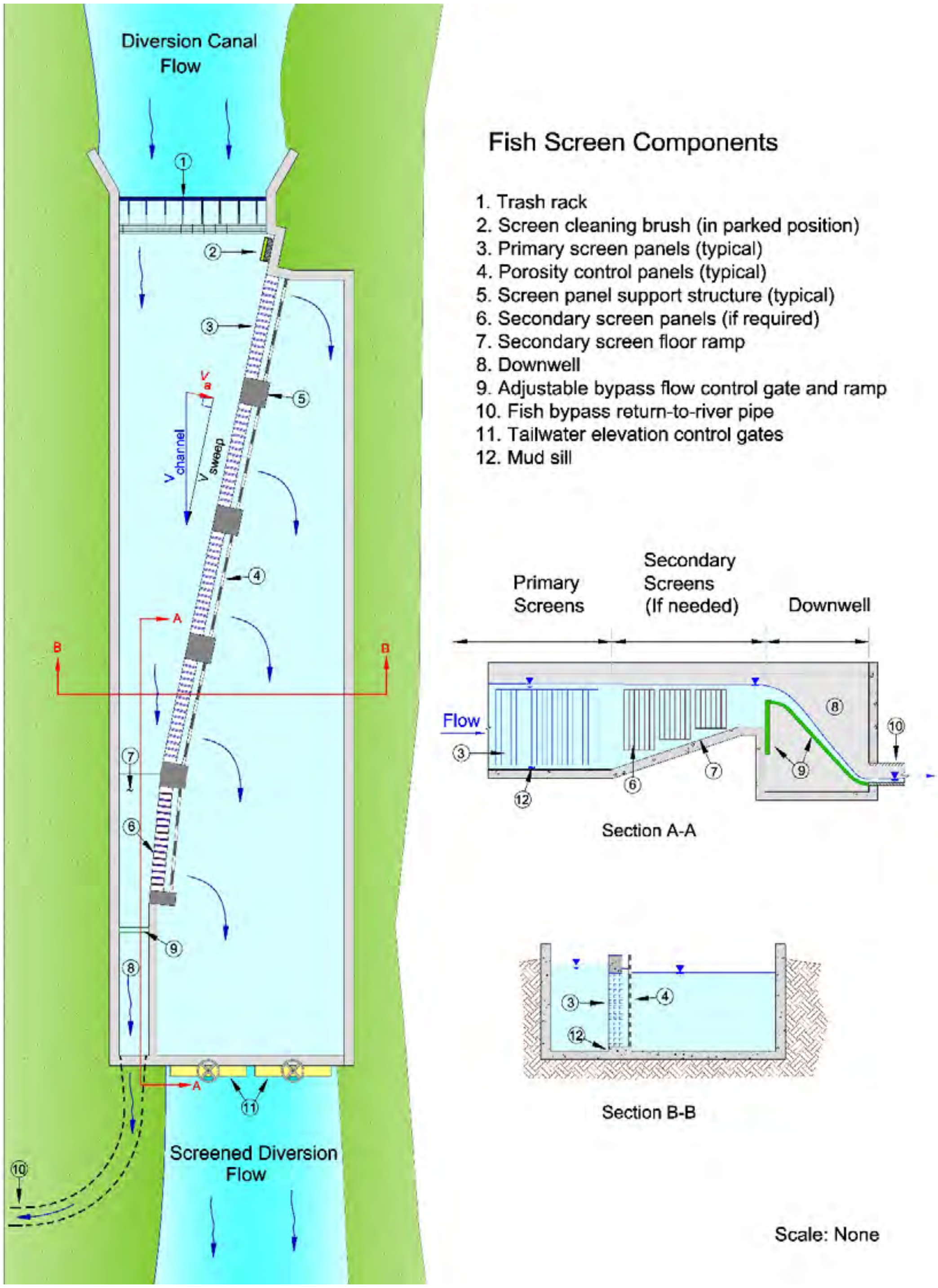


Figure 8-4 Schematic of a typical in-canal fish screen system layout and components at water diversions

Figure 8-5 Vertical plate screen facility under construction in a diversion canal located on the Santiam River near Stayton, Oregon

8.4.2.1 Headworks Control Gates

Canal flow should be controlled with gates located downstream from the screen (Figure 8-4, tailwater control gates). If headworks gates must be used to throttle flow, they should not create a head differential greater than 12 inches. Submerged headworks control gates should be operated fully closed or open at least 12 vertical inches.

Fish can be injured if forced to pass through a small opening created by a partially open headgate. Head drops greater than one foot through gates can prevent bidirectional movement of fish. Higher heads can create high water velocities and pressure differentials that may injure fish from shear stresses or impacts with hard surfaces.

8.4.2.2 Headworks trash rack

All in-canal screens should have a trash rack at the canal headworks to minimize the amount of debris that will reach the fish screen structure (Bell 1991). Trash racks should have openings that are at least 10 inches wide for Chinook salmon passage and 8 inches wide for all other salmonid species.

Additional trash rack design criteria are provided in Section 5.8 of this document. Bell (1991) recommends that openings be 12 inches wide for large salmon.

8.4.3 Lakes, Reservoirs, and Tidal Areas

Intakes in lakes, reservoirs, and tidal areas should be located offshore where feasible to minimize shoreline-oriented fish from coming into contact with the facility. When possible, intakes should be located in areas with sufficient ambient velocity to minimize sediment *accumulation in or around the screen. Intakes in reservoirs should be at an appropriate depth to reduce the number of juvenile salmonids that encounter the intake.*

The appropriate depth for intakes in lakes, reservoirs, and tidal areas will be determined on a case-by-case basis. One factor that will be considered when locating these intakes is that although juvenile salmonids are surface oriented, they may congregate in colder water located at depth if surface waters are too warm.

8.4.3.1 Required submergence

For facilities in lakes, reservoirs, and tidal areas, the facility should be placed such that the screen area is adequately submerged to meet the design approach velocity criterion at the historical low water conditions (Section 8.5.7).

8.5 Screen Design Specifications

8.5.1 Approach Velocity

The design approach velocity for active screens should not exceed 0.4 ft/s for fish screens where exposure time is limited to less than 60 seconds, or 0.33 ft/s where exposure time is greater than 60 seconds (Smith and Carpenter 1987; Clay 1995). The design approach velocity for passive screens, as described in Section 8.5.6, should not exceed 0.2 ft/s (Cech et al. 2001).

For the purposes of this document, approach velocity, "V_a" in Figure 8-4, is defined as the water velocity component normal (perpendicular) to the screen surface. The minimum amount of screen area required is calculated by dividing the maximum diversion rate (in ft^3/s) by the design approach velocity (in ft/s). The porosity of the screen is not considered in the calculation of approach velocity. The operating approach velocity for any fish screen at any diversion rate may be calculated by dividing the current diversion flow rate by the effective screen area (Section 8.5.2).

Exposure time is defined as the time it takes a particle to traverse the length of the fish screen when moving at the speed of the sweeping velocity (Section 8.5.3). The design approach velocity criteria have been shown to minimize juvenile fish contact with, and impingement on, screen materials. This includes the impingement of emergent fry under cold water temperature conditions. (Appendix E provides a discussion of how to measure approach velocity.)

Note that these criteria apply to salmonids. Other species may require different approach velocity standards. For example, in California, the U.S. Fish and Wildlife Service requires that a design approach velocity of 0.2 ft/s be used at locations where Delta smelt (*Hypomesus transpacificus*) are present.

8.5.2 Effective Screen Area

The effective screen area is defined as the total wetted screen area minus the area occluded by major structural elements. The minimum effective screen area required is defined as the maximum screen flow divided by the allowable approach velocity. For rotary drum screens, *the effective screen area is defined as the vertical projection of the wetted screen area minus the vertical projections of the area occluded by major structural elements.*

When calculating effective screen area, components (bars and rods) that make up the screen material are not considered to be “major structural elements” as long as the screen porosity remains greater than 27% when considering those structural elements. Major structural elements are elements of the facility that support the screen panels or cylinders.

8.5.3 Sweeping Velocity

The design sweeping velocities should never be less than the design approach velocity and should not decrease along the length of the screen.

Sweeping velocity is defined as the water velocity component parallel to the face of a fish screen (Figure 8-4). A swift sweeping velocity may help move fish and debris past the fish screen and reduce the chance of impingement of juvenile salmonids on the screen material (Cech et al. 2001). Based on laboratory studies, (Cech et al. 2001) a high sweeping velocity (2 ft/s) minimized juvenile Chinook salmon contacts with screens during daylight conditions and maximized downstream passage during day and night conditions. Sweeping velocities between 0.8 and 3 ft/s are generally considered to be optimal. Higher sweeping velocities may be desired to prevent fish from swimming upstream out of the fish screen forebay.

8.5.3.1 In-canal screens

In-canal screens should be angled across the canal to provide a sweeping velocity within the optimal range for the entire range of design conditions (Clay 1995). For screens shorter than 6 feet in length, the screen may be arranged perpendicular to canal flow. The sweeping velocity should remain constant or increase, but may not accelerate faster than 0.2 feet per second per foot (ft/s/ft) toward the bypass entrance.

Studies show juvenile salmonids may resist entering a bypass system when encountering a sudden acceleration in water velocity (Haro et al. 1998). The acceleration criterion is designed to gradually guide fish toward and into the bypass entrance.

In some situations, angling of the screen for sweeping velocity optimization may best be accomplished using a vee-shaped arrangement, as shown in figure 8-5.

Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s/ft of length.

8.5.3.2 On-river screens

Designers have less control over sweeping flow for screens built in a river or on the bank of a river; however, designers should make every attempt to ensure that sweeping velocity does not decrease along the length of the screen. This is to encourage fish to move past the facility and reduce the chance that sediment will deposit along the length of the screen.

8.5.3.3 Quiescent and tidal areas

To mitigate for a lack of sweeping velocity in quiescent and tidal areas, designers should use a design approach velocity not greater than 0.33 ft/s when calculating the effective screen area.

Fish screens in lakes and tidal areas usually cannot meet the sweeping velocity criteria for in-canal or on-river screens. A lower approach velocity is required for these types of screens to allow fish to volitionally swim away from the screen face.

8.5.4 Flow Distribution

The screen design should provide for nearly uniform flow distribution over the screen surface, thereby minimizing approach velocity over the entire screen face. The designer should demonstrate how a uniform flow distribution will be achieved. The maximum deviation from the target design approach velocity is 10%.

Achieving a uniform flow distribution eliminates localized areas of high velocity that have the potential to impinge fish and debris. Methods that could be used to achieve uniform flow distribution include incorporating porosity control features on the downstream side of screens that can be adjusted and training walls to direct flow into the design. Large facilities may require hydraulic modeling to identify areas of flow distribution that are of concern to NMFS.

8.5.4.1 Porosity controls

To ensure uniform flow distribution, most screens should be equipped with some form of tunable porosity controls (i.e. baffles) placed immediately behind the screen. Screen porosity controls should be tuned to achieve approach velocity criteria at the earliest opportunity available. For screens greater than 10 feet tall, NMFS may require that the baffles be capable of controlling flow through the lower parts of screen panels independently of the upper parts. The use of louver-style porosity control baffles should be limited to flat plate screens 6 feet in height or shorter.

A fish screen facility equipped with adjustable baffles to distribute flow uniformly over all wetted screen area is not considered complete until it undergoes a hydraulic evaluation to adjust the baffles. NMFS will determine one or more operating scenarios under which the hydraulic evaluation should take place. For most facilities, hydraulic evaluations should take place at or near the maximum diversion rate but there are cases where a lower diversion rate may be justified. In rare cases, a hydraulic evaluation may be required at two or more operating scenarios to account for various operating conditions such as, but not limited to, the following examples:

- A possible worst-case scenario for a fish screen may be when head waters are too low to submerge all screen area. In such cases, the fish screen hydraulics may need to be studied at a low water condition under a reduced diversion rate.
- At a high-water condition under the full diversion rate.
- At a low water condition under the full diversion rate.

The most common porosity control devices used to date have been louvers, where the angle of the louver can be varied to control the quantity of water flowing through the screen in front of the louver. However, it has been shown that it can be difficult to achieve uniform flow when using louver baffles (e.g., AECOM 2009). A newer method provides a more effective means of tuning screen velocity and flow distribution. It consists of sliding, overlapping porosity plates that are in contact with each other (Figure 8-6). As the moveable plate (vertically adjustable slotted plate; Figure 8-6) is adjusted, it obscures a progressively larger percentage of the perforations of the fixed plate (the stationary slotted plate; Figure 8-6). These panels (baffles) are typically installed in sections no greater than 2 feet wide, which provides fine-scale porosity adjustments for the screen as a whole. Porosity plates with square or slotted openings provide linear adjustability unlike porosity plates with circular openings (i.e., the change in porosity is linearly proportional to the distance the adjustable plate is moved). The adjustable and stationary slotted plates (parts 2 and 3, respectively, in Figure 8-6) should be of the same material or of different materials with similar coefficients of thermal expansion to maintain relative positioning over a range of temperatures. Ultra-high-molecular-weight (UHMW) polyethylene has a high coefficient of thermal expansion and should not be paired with aluminum or steel for this purpose. Using UHMW for both panels works well as the two sheets will slide easily and prevent leakage between sheets, but both panels should be manufactured under identical conditions to ensure holes align well. Metal panels may warp during fabrication which may prevent the panels from mating well.

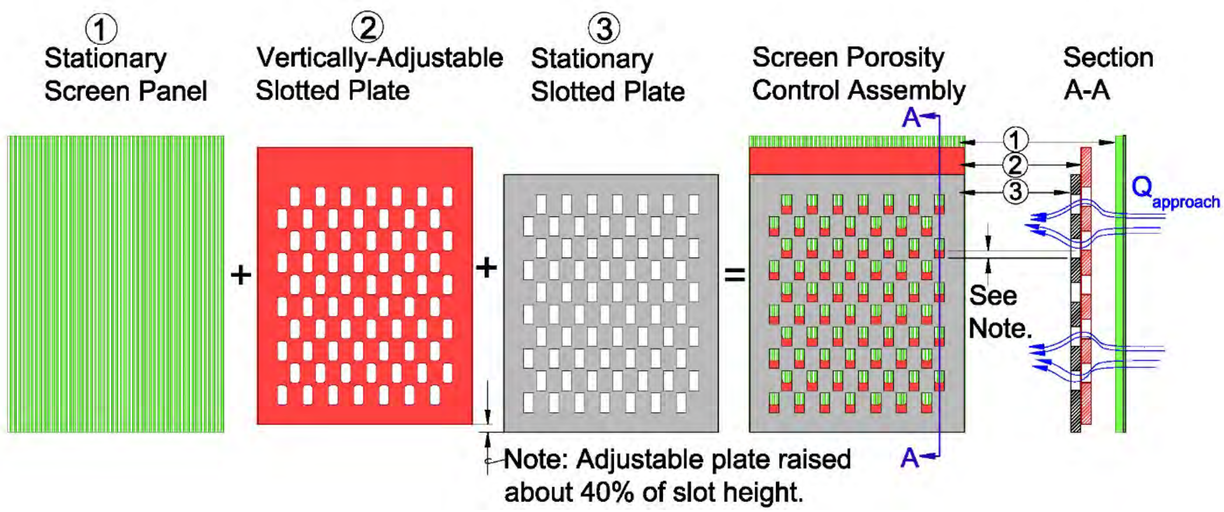


Figure 8-6 Schematic diagram of sliding, overlapping porosity plates used to control porosity and achieve uniform flow conditions through fish screens

8.5.5 Active Screen Cleaning Systems (Active Screens)

All new fish screens should incorporate an automated cleaning system unless the project meets the requirements for passive screens listed in Section 8.5.6.

8.5.5.1 Screen cleaning systems (in-canal or on-river screens)

Screen cleaners should be capable of removing debris from the entire screen surface at least once every 5 minutes and should be operated as required to prevent debris accumulation. Cleaning systems should be designed to operate continuously or on an adjustable timer. On larger screens, the cleaning system should also be triggered whenever the head differential across the screen exceeds 0.3 foot over the clean screen condition. The cleaning system and operations protocol should be effective, reliable, and satisfactory to NMFS. Physical cleaning systems that use a travelling brush or wiper should provide a means for the brush to move away from the screen face at the downstream end of brush travel to allow for the release of accumulated debris.

Fish screens operate most efficiently when they are clean and free of impinged material and attached growth such as algae or sponges (Bell 1991). Fish screen material with a porosity of about 50% will result in negligible head loss at the design approach velocity values identified in Section 8.5.1. Head loss across a screen due to impinged debris increases with the loss of screen open area at a geometric rate (BOR 2006). With increasing head loss, the force impinging debris (or fish) on the screen material also increases, making cleaning the screen more difficult. A screen experiencing 0.3 foot of head loss under an operating approach velocity of 0.4 ft/s may have less than 10% open area due to debris impingement. Under this condition, any weak-swimming fish coming in contact with the screen would experience injury or death due to the excessive forces acting on its body. Additionally, the water diversion would begin to experience significant reduction in diversion rate, and the facility could experience structural damage. Systems to monitor head differential across a screen should be designed to distinguish head loss due to debris impingement from loss caused by wave action or other transient disturbances.

Automated screen cleaning systems are generally categorized as physical, hydraulic, or pneumatic. Physical cleaning systems use a brush or other wiper device to physically remove impinged debris and attached growth and have a long history of successful deployments. NMFS recommends the use of a physical cleaning system for most screen applications; however, there are instances when a hydraulic or pneumatic cleaning system may be more practical.

Hydraulic cleaning systems use high-pressure water jets to remove debris from the screen face and rely on a current (or trash removal systems in the case of traveling belt screens) to remove debris from the vicinity of the screen facility. However, hydraulic cleaning systems do not remove attached growth as effectively as physical cleaning systems and may stimulate the growth of some types of algae.

Pneumatic cleaning systems use compressed air to lift debris from the screen face and rely on a current to remove debris from the vicinity of the screen facility. Pneumatic cleaning systems provide a cleaning force by displacing water primarily in the upwards direction; therefore, air burst cleaning systems in horizontal cylindrical screens may not remove debris impinged on the bottom of those screens. Pneumatic cleaning systems cannot completely remove attached growth and may stimulate the growth of some types of algae. If a screen material were to become occluded with attached growth, the compressed air can impart tremendous buoyant forces on the screen material and the facility overall. Screens employing a pneumatic cleaning system should consider the buoyancy force of trapped air when designing facility foundation and structural components. An additional problem faced by pneumatic cleaning systems is that they are frequently undersized and cannot provide the required volume of air to clean the entire screen face. This is exacerbated by the tendency for the air bubbles to take the path of least resistance, which can often be the clean portions of the screen. Because pneumatic cleaning systems only lift debris from a screen, adequate sweeping flow should be present to move debris downstream away from the water intake.

8.5.5.2 Screen cleaning systems for screens in quiescent and tidal areas

At locations that do not have sufficient sweeping velocity, fish screens should be equipped with an automated cleaning system that is capable of removing debris from the body of water, rather than one that may merely push debris to one side or the other.

Effective cleaning systems rely on the sweeping flow, sometimes combined with the mechanical action of the cleaner, to carry the debris downstream and away from the screen face. Cleaning systems that merely push debris to the side of the screen face are inappropriate for low-velocity locations. This is because without a means to collect and remove debris, the debris lifted from the screen face is likely to become impinged again on the screen face. Additional measures are recommended in these situations to keep floating debris away from the face of a fish screen. Cleaning systems that push debris to the side of a screen are best suited for situations where sweeping flow is present that will carry any debris away from the screen.

8.5.6 Passive Screens

A passive screen, meaning a screen without an automated cleaning system, may only be used when all of the following criteria are met:

- *The combined rate of flow at the diversion site is less than 3 ft^3/s.*
- *Sufficient ambient river velocity exists to carry debris away from the screen face.*
- *The site is not suitable for an active screen.*
- *Uniform approach velocity conditions exist at the screen face, as demonstrated by laboratory analysis or field verification.*
- *The debris load is low.*
- *A maintenance program exists that is approved by NMFS and implemented by the water user.*
- *The screen is frequently inspected, and debris accumulations are removed as site conditions dictate.*
- *For cylindrical screens, sufficient stream depth exists at the site to provide a water column of at least 1 screen radius around the screen surface.*
- *The screen is designed to be easily removed for maintenance and to protect it from flood events.*

8.5.7 Screen Submergence and Clearance

Fish screens should be submerged sufficiently to maintain adequate wetted screen area to meet the approach velocity design criterion whenever the diversion is in operation; additional submergence is required in some circumstances.

Effective screen area will be reduced if screen area becomes exposed due to a drop in the water surface. (Section 8.5.2) Under this condition the diversion rate should be adjusted and maintained such that the operating approach velocity does not exceed the design approach velocity criteria at any given time.

8.5.7.1 Vertical flat plate screens

Fish screen facilities with flat, vertical screen panels, or panels inclined less than 20 degrees from vertical, should be designed to remain fully submerged over the entire range of expected water surface elevations. Facility designs may allow for vertical screen panels, or panels inclined less than 20 degrees from vertical, to become partially exposed when water surface elevation is lowered so long as the operating approach velocity does not exceed the design approach velocity.

8.5.7.2 Inclined flat plate screens

Fish screen facilities with flat plate screens installed at an incline of more than 20 degrees but less than 45 degrees from vertical should be designed to remain fully submerged over the entire range of expected water surface elevations. The top of the screen should be submerged a minimum of 1 foot at low stream design flow.

The tops of inclined flat plate screens need to be sufficiently submerged at low stream design flow to prevent hydraulic conditions from forming at the interface between the screen and the water surface that could trap and impinge debris and fish.

8.5.7.3 Rotary drum screens

For rotary drum screens, the design submergence should be between 65% and 85% of the drum diameter. In many cases, stop logs may need to be installed downstream of the drum screens to achieve the design submergence criteria. The stop logs should be located at least two drum diameters downstream from the back of the drum.

Submergence levels greater than 85% of the drum diameter increase the possibility of entrainment over the top of the screen, fish impingement on the screen, and the subsequent entrainment of any fish impinged on the narrow screen area above the 85% submergence level due to the almost horizontal angle of impact of surface-oriented fish. Submergence levels that are less than 65% may reduce the self-cleaning capability of the screen due to the inability of material to temporarily adhere to the screen face and be carried over the top of the screen. Clay (1995) recommends that submergence be between 66% and 75% of the screen diameter. Examples of rotary drum screens are shown in Figures 8-7, 8-8, and 8-9.

Figure 8-7 Large-sized rotary drum screen at the Sunnyside Canal located on the Yakima River near Yakima, Washington

(Note: The person standing upstream of a drum and an intermediate bypass entrance. Water flow direction is from the foreground to the background of the photograph.)

Figure 8-8 Medium-sized rotary drum screen at the Burlingame Diversion located on the Walla Walla River near Walla Walla, Washington

Figure 8-9 Rotary drum screens installed in a water diversion canal and operated (i.e., powered) by paddle wheels

8.5.7.4 Cylindrical screens

Cylindrical screens (other than rotary drum screens) should be submerged to a depth of at least 1 screen radius below the minimum water surface and have a minimum of 1 screen radius clearance between the screen surfaces and natural or constructed features.

These clearances provide escape routes for fish to avoid the draw of water passing through the screen material.

8.5.7.5 End-of-pipe screen submergence and clearance

All end-of-pipe screens should have adequate submergence below the water surface and adequate clearance from the streambed and any structure to provide an escape route for fish approaching the screen. For cylindrical-shaped screens, 1 screen radius or 6 inches, whichever is greater, is normally adequate submergence and clearance.

Submergence and clearance requirements for screens with other shapes will be determined by NMFS on a case-by-case basis. An example of an end-of-pipe screen is shown in Figure 8-10.

Figure 8-10 Typical end-of-pipe screen equipped with "wagon wheels" to elevate the screen off the stream bottom

8.5.7.6 End-of-pipe screen design

All end-of-pipe screens should meet the approach velocity criteria described in Section 8.5.1 and should be located in areas with sweeping velocities great enough to aid in moving fish and debris away from the intake. All end-of-pipe screens should be oriented to take maximum advantage of sweeping velocity in moving fish and debris away from the screen face.

For the purposes of this document, an end-of-pipe screen is defined as a fish screen of any shape that may be attached to the end of a pipe or hose.

8.5.7.7 Horizontal flat plate screens

Design criteria specific to horizontal screens are provided in Section 8.8.

8.5.7.8 Conical screens

Design criteria specific to cone screens are provided in Section 8.9.

8.5.8 Screen Material

Screen materials should be corrosion-resistant and sufficiently durable so as to maintain a smooth, uniform surface over the course of long-term use. Perforated plate surfaces should be smooth to the touch, with the openings punched through in the same direction as the water flow.

Screen materials commonly used include stainless steel, aluminum, plastic, and antifouling alloys containing copper and other metals.

8.5.8.1 Opening size

The maximum screen opening allowed is based on the shape of the opening:

- *Circular screen face openings should not exceed 3/32 inch in diameter (Neitzel et al. 1990a).*
- *Slotted screen face openings should not exceed 0.069 inch (1.75 millimeters [mm]) in the narrow direction (Mueller et al. 1995).*
- *Square screen face openings should not exceed 3/32 inch as measured on a diagonal (Neitzel et al. 1990b).*

8.5.8.2 Open area

The percent open area (porosity) for any screen material should be at least 27%.

8.5.8.3 Gaps

Screens and associated civil works that are exposed to fish should be constructed such that there are no gaps greater than 0.069 inch (1.75 mm). For traveling belt screens or other screens with moving screen material, screen seals should be sufficient to prevent gaps larger than 0.069 inch (1.75 mm) from opening during screen operations.

Clay (1995) notes that care is required in the construction, adjustment, and operation of rotary drum screens. The drum should be fitted carefully in the box to eliminate spaces around the edges that are larger than the openings in the screen mesh.

8.5.9 Civil Works and Structural Features

8.5.9.1 Smoothness

All concrete and steel surfaces, including edges and corners, in areas fish have access to should be smooth to the touch and free from burrs and sharp edges. These can injure fish or people that come in contact with the structure.

8.5.9.2 Pressure differential protection

Larger fish screen structures should be equipped with fail-safe systems that protect the structure from large pressure differentials across the screen face, should the screen become plugged. If a fail-safe system is tripped, the diversion operation should cease until the system can be reset and protection from entrainment into the diversion is restored.

The fail-safe systems installed so that the structural integrity of the facility is never compromised may include governors that reduce the water diversion rate when the pressure differential exceeds a given value. Fused blow-out panels, slide gates, and pressure relief valves may also be acceptable solutions for preventing excessive pressure differentials that can result in screen facility failure.

8.5.9.3 Placement of screen surfaces

The face of all screen surfaces should be placed flush with any adjacent screen bay, pier noses, and walls to the greatest extent possible.

This is needed to allow fish to have unimpeded movement parallel to the screen face and unobstructed access to bypass entrances and routes.

8.5.9.4 Structural features

Structural features should be provided to protect the integrity of fish screens from large debris and to protect the facility (Bell 1991).

A trash rack, log boom, sediment sluice, and other measures may be required to protect the structural integrity of a fish screen, especially for on-river screens.

8.5.9.5 Civil works

The civil works should be designed in a manner that prevents undesirable hydraulic effects, such as eddies and stagnant flow zones, that may delay or injure fish or provide predator habitat or openings that allow predators to access the facility.

8.5.9.6 Canal dewatering and fish salvage

For in-canal screens, the floor of the screen civil works should be designed to allow fish to be routed back to the river safely when the canal is dewatered. An acceptable fish salvage plan should be developed in consultation with NMFS and included in the O&M plan.

Canal dewatering and fish salvage may be accomplished via the bypass system or by using a small gate and drain pipe, or similar provisions, to drain all flow and fish back to the river. The operations and maintenance plan should address the rate at which water can be drained back to the river to allow fish to move volitionally to the river to minimize stress. Trained personnel should be on site to rescue stranded fish. A rescue plan may need to consider collect lamprey larvae (ammocoetes) that may be living in sediments deposited in a diversion canal, and possibly even in sediments behind a fish screen.

8.6 Bypass Systems

Bypass systems are required for in-canal screens to provide a safe and efficient means of routing fish from the area in front of in-canal screens to the stream from which they were diverted.

8.6.1 Bypass Design

Bypass systems should work in tandem with the fish screens to move all fish present (target and non-target species and all life stages) from the area in front of the screens and return them back to the stream or river (or to a holding pool, in the case of collection and transport facilities) with a minimum of injury and delay (Clay 1995).

8.6.2 Bypass Entrance

The bypass entrance should be located at the downstream terminus of the fish screens and should be designed to allow downstream migrants to easily locate and enter the bypass (Clay 1995). The screen and any guidewalls should naturally funnel downstream migrants and flow to the bypass entrance. For screens that are less than 6 feet in length and are constructed perpendicular to canal flow, the bypass entrance(s) may be located at either end (or both ends) of the screen.

8.6.2.1 Flow control

Each bypass entrance should be capable of controlling the flow rate through that entrance. If an orifice plate is used, the opening should have smooth, rounded-over edges and the opening should be large enough to safely pass the largest fish that may be entrained into the diversion canal. For steelhead kelts, the opening should be at least 8 inches in the smallest dimension.

Typically, an overflow weir is used to regulate flow through the entrance. Orifice plates are discouraged from being used because they may hinder fish from moving into the bypass and they are more likely to clog with debris.

8.6.2.2 Minimum velocity

The minimum bypass entrance flow velocity should be greater than 110% of the maximum canal velocity upstream from the bypass entrance. At no point may flow decelerate along the screen face or in the bypass channel. Bypass flow amounts should be of sufficient quantity to ensure these hydraulic conditions are achieved whenever downstream passage is required.

8.6.2.3 Lighting

Lighting conditions upstream of a bypass entrance should be ambient and extend downstream to the structure or device controlling bypass flow. In situations where transitions from light to dark conditions or vice versa cannot be avoided, they should be gradual or occur at a point in the bypass system where fish cannot escape the bypass and return to the canal (i.e., at a location where bypass flow velocity exceeds fish swimming ability).

8.6.2.4 Dimensions

For diversions greater than 3 ft^3/s, the bypass entrance should extend from the floor of the canal to the water surface and be at least 18 inches wide (Ruggles and Ryan [1964] as cited in Clay [1995]). For diversions of 3 ft^3/s or less, the bypass entrance should be a minimum of 12 inches wide. The bypass entrance should be sized to accommodate the entire range of bypass flow, utilizing the criteria listed in Section 8.6.

8.6.2.5 Weirs

For diversions greater than 25 ft^3/s and where weirs are incorporated into the bypass entrance, the minimum water depth over the weir is 1 foot; however, a depth of 1.5 feet over a weir is preferred. Similarly, weir width should be a minimum of 1.5 feet; greater widths are preferred.

Juvenile outmigrating salmonids appear to be less reluctant to go over a weir when water depth over the weir is greater than 1 foot (Manning et al. 2005). As a general rule and based on field observations, NMFS believes that water depth over a weir should be at least 1 foot, but if additional flow is available, a depth of 1.5 feet or even 2 feet is preferred. Manning et al. (2005) reported significantly faster travel times for steelhead moving through a dam forebay when the crest of an inflatable spillway was deformed and water depth and velocity over the spillway were increased. Water depth increased from 0.13 foot to 2.4 or 3 feet, and water velocity increased from 0.2 ft/s to 3.9 or 4.6 ft/s during test replicates. Also, wider passageways are preferred; the recommended minimum width is 1.5 feet.

8.6.2.6 Intermediate bypass entrances

The fish screen design should include intermediate bypass entrances if the design approach velocity is greater than 0.33 ft/s and the sweeping velocity may not convey fish to a terminal bypass entrance within 60 seconds, assuming that fish are transported along the length of the screen face at a rate equal to the sweeping velocity.

Clay (1995) notes that if the screen is extremely long, it may be advisable to place bypass entrances at intervals across the face.

8.6.2.7 Training walls

All intermediate bypass entrances should have a training wall to guide fish into the bypass system.

8.6.2.8 Flow acceleration

All bypass entrances should be designed to gradually accelerate flow into the bypass entrance and between the entrance and the flow control device at a rate not to exceed 0.2 ft/s per linear foot.

Juvenile salmonids have been observed to resist moving with water flow that accelerates too quickly (Haro et al. 1998). Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s per linear foot.

8.6.2.9 Secondary dewatering screens

Secondary dewatering screens should meet all design criteria (e.g., approach velocity, sweeping velocity, cleaning, and screening material) of the primary screens.

Secondary dewatering screens may be used within the bypass system to reduce bypass flow.

8.6.3 Bypass Conduit and System Design

8.6.3.1 Bypass conduit

Depending on the site-specific conditions, the bypass conduit can be either U-shaped flume or round pipe.

8.6.3.2 Surface smoothness

The interior surfaces and joints of bypass flumes or pipes should be smooth to the touch to provide conditions that minimize turbulence, the risk of catching debris, and the potential for fish injury.

Pipe joints may be subject to inspection and approval by NMFS prior to completion of the bypass. Every effort should be made to minimize the length of the bypass pipe while meeting the hydraulic criteria listed in Sections 8.6.3.4 through 8.6.3.6.

8.6.3.3 Bypass pipe diameter

The minimum bypass pipe diameter is 10 inches.

The bypass flume or pipe diameter is a function of the bypass flow and slope, and the diameter incorporated into the bypass pipe design should achieve the velocity and depth criteria identified in Sections 8.6.3.5 and 8.6.3.6. Bypass flume or pipe hydraulic characteristics should be calculated to determine a suitable pipe diameter.

8.6.3.4 Bypass flow rate

The minimum design bypass flow is 5% of the total diverted flow rate unless otherwise approved by NMFS.

While the minimum bypass flow is 5% of the total diverted, larger bypass flow proportions will aid in cleaning the fish screen and will guide fish toward the bypass system more quickly.

8.6.3.5 Bypass velocity

Water velocity in the bypass conduit should be between 6 and 12 ft/s for the entire operational range of bypass flow, and should always be greater than 2 ft/s. If higher velocities are approved by NMFS, special attention to pipe and joint smoothness should be demonstrated by the design.

Bypass systems with velocities that are less than 2 ft/s can accumulate sediment deposits within the bypass system.

8.6.3.6 Water depth

The design minimum depth of free surface flow in a bypass pipe should be at least 40% of the bypass pipe diameter unless otherwise approved by NMFS.

8.6.3.7 Closure valves

Closure valves cannot be used within the bypass system unless specifically accepted by NMFS.

8.6.3.8 Pumps

Fish should transition through bypass system components via gravity flow and never be pumped. Use of a pump would only be acceptable if NMFS required the installation of a bypass where insufficient head was available to support gravity flow.

8.6.3.9 Downwells and flow transitions

Downwells should be sized based on an EDF between 8 to 10 ft-lb/ft³/s. Fish should never free-fall within a bypass system pipe or enclosed conduit. Downwells should be designed to produce a free water surface when turbulence, geometry, and alignment aspects of the design are considered.

Equation 8-1 should be used to calculate downwell volume.

$$V = \frac{(\gamma)(Q_{bypass})(H)}{EDF} \tag{8-1}$$

where:

V = pool volume (ft^3)
γ = unit weight of water (62.4 lb/ft^3)
Q_{bypass} = bypass flow, in ft^3/s
H = height of drop between water surfaces, in feet
EDF = energy dissipation factor, from 8 to 10 ft-lb/ft^3/s

8.6.3.10 Pressurized flow

Flow in all types of fish conveyance structures should be open channel (i.e., not pressurized). Bypass systems should be vented or open to the atmosphere. If a pressurized bypass conveyance is required by site constraints, pressures in the bypass pipe should remain equal to or above atmospheric pressures. Transitions from pressurized to non-pressurized conditions within a bypass pipe, and vice versa, should be avoided.

8.6.3.11 Bends

The ratio of bypass pipe center-line radius of curvature (R) to pipe diameter (D), or R/D, should be greater than or equal to 5. If mitered pipe fittings are used to change conveyance direction, the maximum miter angle allowed is 15 degrees (11.25 degrees is preferred). If multiple miter joints are used to change the direction of the conveyance more than 15 degrees, *each miter joint should be separated by length(s) of pipe that are sufficiently long to achieve the required ratio of R/D for the bend assembly as a whole.*

In situations that involve super-critical flow velocities, R/D ratios greater than 5 may be required. Bends should be minimized in the layout of bypass systems due to their potential to facilitate debris clogging and produce turbulence.

8.6.3.12 Debris management

Bypass pipes or open channels should be designed to minimize debris clogging, sediment deposition, and facilitate their inspection and cleaning as necessary.

8.6.3.13 Access for maintenance

Access for maintenance inspections and debris removal should be provided at locations in the bypass system where debris accumulations may occur. Bypass systems greater than 150 feet in length should include access ports at appropriate spacing to allow for the detection and removal of debris.

Alternate means of providing for bypass pipe inspection and debris removal may be considered by NMFS.

8.6.3.14 Natural channels and fishways

Natural channels and fishways may be used as a bypass transit channel under limited circumstances and only upon approval by NMFS.

Use of natural channels and fishways as juvenile fish bypasses expose fish to increased delay and predation (compared to a typical bypass system). Use of a natural channel will require that adequate water depth and velocity, flow volume, protection from predation, and good water quality conditions can be provided. The potential for increased predation is typically extremely high for natural channels due to the high concentration of fish in a small amount of flow in the bypass system and area. Additionally, sufficient flow would be required to mitigate for any seepage occurring within the bypass system while maintaining adequate water depth and velocity. If a natural channel is to be used, special consideration needs to be given to where the bypass channel connects to the river.

8.6.3.15 Sampling facilities

Sampling facilities installed in the bypass conduit should not impair the operation of the facility during non-sampling periods in any manner.

Refer to Appendix F for additional information on the design of juvenile fish sampling facilities.

8.6.3.16 Hydraulic jumps

There should be no hydraulic jump(s) within a bypass system.

8.6.4 Bypass Outfalls

8.6.4.1 Location

Bypass outfall locations should meet the following conditions:

- *Bypass outfalls should be located to minimize predation by selecting an outfall location that is free of eddies and reverse flow and does not place bypassed fish into an area of known predator habitat (Bell 1991).*
- *The point of impact for bypass outfalls should be located where ambient river velocities are greater than 4 ft/s when in operation (Shively et al. 1996).*
- *Bypass outfall locations should provide good egress conditions for juvenile fish exiting the bypass and re-entering the stream channel (Bell 1991).*
- *The bypass flow should not impact the river bottom or other physical features at any stage of river flow. Bypass outfalls should be located where the receiving water is of sufficient depth to ensure that fish injuries are avoided at all river and bypass flows.*
- *The bypass outfall should not release fish into areas where conditions downstream from the bypass discharge point will pose a risk of injury, predation, or stranding (Bell 1991). For example, bypass outfalls should avoid discharging fish into areas from which they can enter reaches where flows run subsurface. Also, bypass outfalls should not discharge in the vicinity of any unscreened water diversion or near eddies that may be habitat for predator fish.*

8.6.4.2 Impact velocity

Maximum bypass outfall impact velocity (i.e., the velocity of the bypass flow as it enters the receiving water) should be less than 25 ft/s, including both the vertical and horizontal velocity components (Bell 1991).

Impact velocity may be greater for very large bypass flows that discharge a confined jet that plunges deep into the receiving waters and results in fish deceleration occurring over a longer distance compared to a broader jet not plunging far into the receiving water. For example, Johnson et al. (2003) reported no injuries to juvenile Chinook salmon that were returned to the Columbia River in bypass flow greater than 1,000 ft^3/s and when impact velocities ranged up to 50 ft/s.

8.6.4.3 Predation prevention

Predator control systems may be required in areas with a high potential for avian predation.

Predation suppression systems include bird wires (thin wires) strung over the bypass outfall area to prevent predatory birds from flying near the outfall or diving at fish exiting the outfall and high-pressure water spray nozzles over the outfall area to deter birds.

8.6.4.4 Adult fish attraction to bypass discharge

Bypass outfall discharge into the receiving water should be designed to avoid attracting adult fish to the discharge. If the potential exists that adult salmonids may be attracted to and *jump at the bypass outfall discharge, the design of the bypass outfall should include a provision for adult fish to land safely in a zone or location after jumping.*

8.7 Water Drafting

Water drafting is the practice of pumping water for short durations from streams or impoundments at low pumping rates to fill water trucks or tanks, often for dust suppression or wildfire management. Water drafting may also be used to dewater a construction site or temporarily divert water around a construction site. When dewatering a construction site an approved dewatering plan should be followed to rescue and relocate stranded fish.

The specifications below are primarily for the protection of juvenile anadromous salmonids in waters where they are known to exist. However, they may also be applied to protect a host of other aquatic organisms.

8.7.1 Water Drafting Operating Guidelines

When engaged in water drafting operations, the following restrictions apply:

- *Operations are restricted to 1 hour after sunrise to 1 hour before sunset.*
- *The pumping rate should not exceed the lesser of 350 gpm or 10% of the streamflow.* The operator should measure streamflow prior to initiating pumping to ensure the pumping rate will not exceed 10% of streamflow.
- *Pumping should be restricted to locations where the water is deep and flowing; pumping from isolated pools should be avoided.*
- *Pumping should not result in a drawdown of the water surface elevation by more than 10% in the area where pumping is taking place nor in any riffles downstream.*
- *Pumping should be terminated when the water truck or tank is full.*
- *An operator should be present during pumping operations and observe stream conditions during pumping to ensure the above restrictions are being met.*
- *A fish screen should be used when pumping. Fish screens should meet guidelines for end-of-pipe screens of this document (Section 8.5.7.5). The operator should be capable of cleaning debris from the fish screen when needed and possess the equipment necessary to do so.*
- *Water drafting truck parked on streambeds, floodplains, or within a riparian corridor should use drip pans or other devices such as absorbent blankets, sheet barriers or other materials as needed to prevent soil and water contamination from motor oil or hydraulic fluid leaks*

8.7.2 Fish Screens for Water Drafting

Design and operation criteria and guidelines for use of fish screens required during pumping operations for water drafting are described in Section 8.7.2.1 through 8.7.2.6.

8.7.2.1 Design

Fish screens for water drafting may be off-the-shelf designs or custom fabricated. The fish screen should be sturdy enough to not compromise the integrity of the screen during pumping when the screen becomes clogged with debris.

The screens may be cylindrical or rectangular in shape as long as the other screen criteria are met.

8.7.2.2 Cleaning

Fish screens for water drafting do not need to have an automated cleaning system; however, an operator should regularly clean the screen during the pumping operation to maintain the minimum amount of screen area that is required to not be occluded with debris.

8.7.2.3 Approach velocity

The design approach velocity should not exceed 0.33 ft/s.

Based on a pumping rate of 350 gpm, the screen for this flow rate should have at least 2.4 ft^2 of surface area.

8.7.2.4 Uniform flow

Screens should be designed to draw water relatively uniformly over the entire screen area.

Screens may require internal baffles to achieve this criterion.

8.7.2.5 Screen porosity and openings

The screen material should have a porosity of at least 27% and have openings consistent with criteria provided in Section 8.5.8.1. The screen surface should be smooth to the touch.

The size of screen openings depends on the shape of the openings.

8.7.2.6 Screen support and submergence

Fish screens should be supported off the stream bottom by at least 6 inches and be submerged by at least 6 inches (Figure 8-10).

8.8 Special Case: Horizontal Screens

Horizontal flat plate screens operate fundamentally differently than conventional cylindrical and vertically oriented screens. This fundamental difference relates directly to fish safety. When inadequate flow depth exists with vertically oriented screens, the bypass will usually remain operational, and there is only a slight increase in the potential for fish to become impinged on the surface of the screen. In contrast, when the water level on horizontal screens drops and most or all diverted flow goes through the screens, the bypass flow is greatly reduced or ceases completely and there is a high likelihood that fish will become impinged and expire on the screen surface.

8.8.1 NMFS Engineer Involvement

Since site-specific design considerations are required, NMFS should be consulted throughout the development of a horizontal screen design.

NMFS considers horizontal screens to be biologically equivalent to conventional screens if the design and operation of a horizontal screen meets the criteria and conditions listed in Section 8.8.

8.8.2 Design Process

The horizontal screen design process should include an analysis to verify that sufficient hydrologic and hydraulic conditions exist within the stream so as not to exacerbate a passage impediment in the stream channel or in the off-stream conveyance (including the screen facility and bypass system). This analysis should conclude that all of the following criteria can be achieved for the entire fish passage season, as defined in Chapter 2. If the criteria listed here in Section 8.8 cannot be maintained per this design analysis, a horizontal screen design should not be used at the site. If this analysis concludes that the removal of the bypass flow required for a horizontal screen from the stream channel results in inadequate passage conditions or unacceptable loss of riparian habitat, other screen design styles should be considered for the site and installed at the site if the other screen styles will reduce the adverse effects to passage or riparian habitat.

8.8.3 General Criteria

The screen and bypass criteria specified in Chapter 8 apply to horizontal screens. The exceptions to these general criteria are noted in Section 8.8.4.

8.8.4 Specific Criteria

As described in Section 8.8, horizontal flat plate screens are fundamentally different than conventional cylindrical and vertically oriented screens. Specific criteria and guidelines that apply only to horizontal screens are described in Sections 8.8.4.1 through 8.8.4.13.

8.8.4.1 Site limitation

Horizontal screens should be installed in an off-river canal.

Due to the need for very precise hydraulic controls, horizontal screens are not suitable for in-river or in-stream installations.

8.8.4.2 Flow regulation

For a horizontal screen facility to function properly, the site should provide a headgate facility that maintains a water diversion rate that is sufficient and consistent enough to allow the fish screen and bypass system to meet the criteria listed in this section (Section 8.8.4).

8.8.4.3 Channel alignment

Horizontal screens should be installed such that the approaching conveyance channel is parallel to, and in line with, the screen channel (i.e., there is no skew), and uniform flow conditions exist across the upstream edge of the screen. A straight channel should exist for at least 20 feet upstream of the leading edge of the screen, or for a distance of up to two screen channel lengths if warranted by approach flow conditions in the conveyance channel. Horizontal screens should be installed such that a smooth hydraulic transition occurs from the approach channel to the screen channel and there are no areas of abrupt flow expansion, contraction, or separation.

Flow conditions that require a longer approach channel include turbulent flow, supercritical hydraulic conditions, or uneven hydraulic conditions in a channel cross section.

8.8.4.4 Bypass flow depth

The bypass flow should pass over the downstream end of the screen at a depth of at least 1 foot.

8.8.4.5 Bypass flow amount

Bypass flow amounts should be sufficient to continuously provide the hydraulic conditions specified in this section and those specified in Section 8.6. In general, for diversion rates of less than 100 ft^3/s, approximately 15% of the total diverted flow should be used as bypass flow. For diversion rates greater than 100 ft^3/s, approximately 10% of the total diverted flow should be used for bypass flow. Small horizontal screens may require up to 50% of the total diverted flow be dedicated for bypass flow. The amount of bypass flow should be approved by NMFS.

Bypass flow is used for transporting fish and debris across the plane of the screen and through the bypass conveyance back to the stream.

8.8.4.6 Diversion shut-off

If hydrologic analysis demonstrates that the diverted flow rate could drop below the flow rate required to satisfy the diversion and supply the bypass with its full design flow rate, the horizontal screen design should include a means to automatically shut off the diversion flow or a means to route all diverted flow back to the originating stream.

8.8.4.7 Sediment removal

The horizontal screen design should include a means to simply and directly remove sediment that accumulates under the screen without compromising the integrity of the screen while water is being diverted.

8.8.4.8 Screen approach velocity

Screen approach velocity should be less than 0.25 ft/s and uniform over the entire screen surface area. If the horizontal screen is equipped with an automated mechanical screen cleaning system, screen approach velocity should be less than 0.4 ft/s and uniform over the entire screen surface area.

The best available science regarding horizontal screens is evolving. Therefore, NMFS may require a lower approach velocity or may specify a minimum ratio of sweeping velocity to approach velocity. Recent prototype development has demonstrated that better self-cleaning of a horizontal screen is achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1, and approach velocities are less than 0.1 ft/s.

8.8.4.9 Screen sweeping velocity

Sweeping velocity should be maintained or gradually increase for the entire length of screen. Sweeping velocity should never be less than 2.5 ft/s or an alternate minimum velocity approved by NMFS that is based on an assessment of sediment load in the water diversion system.

Higher sweeping velocities may be required to achieve reliable debris removal and to keep sediment mobilized.

8.8.4.10 Post-construction inspection and testing

Upon completion of screen construction and watering up of the system, velocity testing should be performed to ensure that approach velocity is uniform over the entire screen area. For the purpose of this test, uniform is defined as all test velocities falling between 90% and 110% of the nominal screen approach velocity. Sweeping velocity should also be verified to be in a uniformly downstream direction to ensure that fish and debris are bypassed rapidly.

8.8.4.11 Monitoring and maintenance

Daily inspection and maintenance (if required) should occur on the screen and bypass system to maintain operations consistent with these criteria.

8.8.4.12 Post-construction monitoring

Post-construction physical and operational monitoring of all components of new horizontal screen facilities should occur for at least the first year of operation and cover all periods of operation.

8.8.4.13 Inspection log

An inspection log should be kept for each horizontal screen. A copy of the inspection log should be provided annually to the NMFS design reviewer upon request, who will review the inspection log and may make recommendations for the next year of operation. The inspection log should include:

- *Inspection dates, times, and the observer's name*
- *Water depth at downstream end of the screen (i.e., the entrance to the bypass)*
- *Debris present on the screen, including any sediment retained in the screen openings*
- *Fish observed on or passing over the screen surface*
- *Operational adjustments and maintenance performed on the facility*

8.9 Special Case: Conical Screens

Conical (or cone) screens were developed for small water diversions in shallow tidal areas. They have been installed on pumped and gravity diversions since 1996. The conical shape provides a large amount of screen area in a small footprint (Figure 8-11). The screen units sit on a constructed steel or concrete platform connected to a diversion pipe. They have rotating brush cleaning systems that are driven by hydraulic or electric motors, some of which run off batteries charged by solar panels. Turbine-driven units, where the cleaning system is driven by a propeller installed in the conveyance pipe and mechanically connected to the cleaning system through a large gear reducer, have been used successfully in a few cases. For turbine-driven units, screen cleaning does not occur unless water is being diverted. A turbine-driven cleaning system may not be appropriate for seasonal use unless the units are removed seasonally.

Figure 8-11 Conical screen

Conical screens were designed for use on inverted siphons in tidal areas where the screen units would be partially exposed at lower tides. Because they were used only on siphons, as the source water stage decreased on an ebb tide and screen area became exposed, the rate of diversion decreased proportionally so the operational approach velocity never exceeded the design approach velocity. As a side benefit, the daily exposure to air and sunlight helped keep the screen surface free of algal growth.

8.9.1 Locations

Conical screens should be sited in locations where fish have a clear escape route past a screen. They should not be installed in enclosed vaults or in close proximity to a structure that prevents fish from freely moving away from the screen.

8.9.1.1 Maximum ambient velocity

Conical screens are acceptable for use in lakes, reservoirs, backwater channels, and tidal areas where the ambient velocity does not exceed 1 ft/s. They may be used where the current is greater than 1 ft/s if other (i.e., superior) screening alternatives are not available, an appropriate flow distribution baffle system is used, and the design is acceptable to NMFS.

8.9.2 Approach Velocity

The maximum design approach velocity for conical screens is 0.33 ft/s.

The minimum effective screen area required for an installation may be determined by dividing the maximum diversion rate in ft^3/s by 0.33 ft/s.

8.9.3 Flow Uniformity

Conical screens have been equipped with two types of baffle systems to distribute flow over all screen area. Early screens used an inverted cone design that divided the interior space into upper and lower areas. That design performed well in quiescent water with a narrow plenum, but field testing in a live stream showed that the inverted cone baffle did not balance flows well when flow was moving past the screen. In fact, the approach velocity on the leading edge of the screen unit could exceed the design value even when not diverting water because stream flow could enter the upstream side and exit the downstream side. To solve this problem, a new baffle design was developed.

The BOR's Technical Service Center near Denver, Colorado, developed a relatively complex baffle system with vertical dividers and a central flow balancing cylinder to distribute intake flow more evenly into four hydraulically-isolated quadrants (Hanna 2011). The vertical dividers prevented stream flow from passing completely through the screen unit. The manufacturer routinely includes a simplified internal baffle based on the USBR design in all of their conical screens.

BOR also tested an external baffle system to control how water approaches and passes into a conical screen (Hanna 2013). The external baffle concept created more uniform flow into the screen but debris could accumulate on the baffles in a riverine setting; therefore, NMFS recommends the use of an internal baffle system to allow stream flow to move debris and fish away from the diversion intake.

8.9.4 Effective Screen Area

All screen area submerged greater than 6 inches may be considered as effective screen area (Figure 8-12). If conical screens become exposed to air, the rate of diversion should be reduced to meet the design approach velocity criterion (Section 8.9.2) due to the reduced effective screen area.

When conical screens become exposed to air in tidal or backwater environments, the top 6 inches of screen material below the water surface may become occluded by debris.

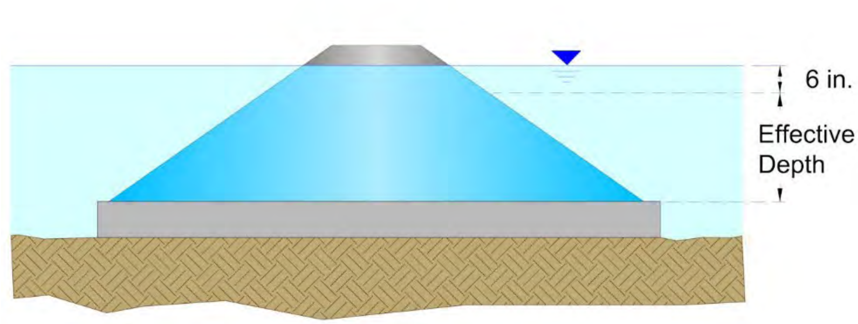


Figure 8-12 Elevation view of a conical fish screen showing the effective depth

8.9.5 Submergence

Conical screens may be operated while partially exposed above water but should be designed such that the screen is sufficiently submerged to maintain adequate effective screen area for the rate of diversion at any given moment.

The definition of effective screen area is provided in Section 8.5.2.

8.10 Project Inspections and Evaluations

8.10.1 General

Inspections and evaluations should be performed at each appropriate phase of a project. This includes during construction, when the project is substantially complete but not yet operating, and after construction.

Inspections of project details and evaluations of project systems are necessary to ensure that a fish screen project functions as intended.

8.10.2 Quality Assurance and Quality Control

An on-site project engineer or inspector should be assigned to every project. The inspector should provide notice to NMFS of key milestones in the construction process and access to the site for inspections.

The inspector is responsible for ensuring construction specifications and tolerances are met and for testing all project systems. NMFS should be allowed to witness testing of project systems.

8.10.3 Inspection

8.10.3.1 During construction

During the course of construction, activities may preclude various facets of screen and bypass construction from being inspected. In instances where these facets of construction may pose a risk of injury or mortality to fish later on during normal operations, the on-site engineer or inspector should inspect these items prior to construction continuing. In some instances, NMFS may require that a NMFS inspector be given the opportunity to inspect these items prior to construction continuing. If this is the case, NMFS will provide the project proponent with a list of screen and bypass elements that will require NMFS inspection during the course of construction. These may include (but are not limited to) the following:

- *Bypass pipe joints, either welded or mechanical*
- *Bypass downwells*
- *Bypass outfalls, if protected during construction by a cofferdam*
- *Any components that convey water that may contain fish*

8.10.3.2 Facilities near completion

Nearly completed fish screen and bypass facilities should be made available to NMFS staff for inspection prior to watering up to verify that the screen is operable in a manner consistent with the design criteria. NMFS staff may inspect construction quality, pipe joints, fit, and finish of components exposed to fish.

8.10.3.3 Evaluations

At some sites, screen and bypass facilities may need to be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved and debris removal systems are effective. At the discretion of NMFS, this may entail a complete biological evaluation, especially if waivers to screen and bypass criteria are granted, or merely a visual inspection of the screen in operation if the screen is relatively simple and designed and constructed to the standard criteria listed throughout the chapters of this document.

8.10.3.4 Mechanical and electrical systems evaluations

Testing of mechanical and electrical systems should be performed before initiating operations.

This should include testing of any alarm systems, including audible alarms, pagers, and other warning systems; data recording equipment, emergency shut-off systems, cleaning systems, actuators, and solenoids; backup systems; and other mechanical and electrical systems. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.5 Automatic cleaning systems evaluations

Cleaning systems and their components should be tested in the dry, when possible, and again when screen facilities are operable, but prior to initiating normal operations.

Using O&M documentation of the cleaning systems provided by the designer or fabricator, all cleaning systems should be tested in automatic and manual operating modes. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.6 Biological evaluations

Depending on the size of a project, any variances from established criteria, and the complexity and uniqueness of the project design, NMFS may require that biological evaluations be conducted on a fish screen facility. The biological evaluations may involve monitoring fish that naturally inhabit the site or releasing test fish obtained from another source such as a hatchery. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations must be performed by qualified personnel using established methods.

The biological evaluations could include monitoring to assess the number of fish being injured or delayed, entrained behind the fish screen, impinged on the fish screen and evidence of fish predation associated with the water intake structure. The biological evaluation study plans should describe the source of fish, test equipment, and methods that will be used; the statistical analysis that will be conducted and associated precision of any tests; and the proposed frequency, timing, and duration of any monitoring and testing.

8.10.3.7 Juvenile fish bypass systems

Hydraulic testing of juvenile fish bypass systems is required to create rating curves for gate openings needed to achieve prescribed flow rates, and to ensure that the bypass system hydraulics conform to hydraulic design criteria.

Biological testing of juvenile bypass systems may be required to ensure that juvenile fish are being returned safely to the main river channel. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations should be performed by qualified personnel using established methods.

The study plan should consider the complexity of the bypass system and the size and number of juvenile fish likely to be present during water diversion operations.

8.10.3.8 Fish screen hydraulic evaluations

The hydraulic evaluations described in this section are required for fish screen facilities. Appendix E (Performing Hydraulic Evaluations) provides information on how to conduct hydraulic evaluations.

Hydraulic evaluations are required on all screens equipped with adjustable flow tuning baffles designed to distribute flow evenly over all wetted screen areas, and where confirmation of hydraulic conditions at a fish screen is necessary. The applicant should submit a hydraulic evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. The final hydraulic evaluation should be conducted under the high design (diversion) flow unless otherwise agreed to by NMFS.

Hydraulic evaluations involve taking water velocity measurements at locations that are oriented both perpendicular (i.e., the approach velocity) and parallel (i.e., the sweeping velocity) to the screen face. Hydraulic evaluations are used on screen facilities with flow-balancing baffles to adjust the baffles to achieve uniform approach velocities across all wetted screen surfaces. Baffle systems should be adjusted in this manner prior to initiating normal water diversion operations. The hydraulic evaluation plan should include the proposed equipment, methods, and time schedule that will be used when conducting the hydraulic evaluations.

In the event that hydraulic conditions are found by NMFS to be unacceptable and the existing baffle system is incapable of adjusting flows to meet the hydraulic criteria, physical modifications to the facility may be required along with follow-up hydraulic evaluations of the modified hydraulic conditions.

Hydraulic evaluations should be carried out as soon as practical to ensure the facility is operating as near to design criteria as practical using the guidelines described in Appendix E. If the facility cannot be operated at an optimal diversion rate for the hydraulic evaluation within the first year of operation, the facility owner should seek to extend the deadline for carrying out the hydraulic evaluation from NMFS.

Hydraulic evaluations should be performed by qualified personnel using established methods.

A final hydraulic evaluation report should be provided to NMFS that includes the following:

- *A description of site and environmental conditions at the time of testing*
- *A list of technicians performing tests*
- *The materials and methods employed in the test, including locations of all velocity measurements in the final iteration of baffle adjustments, including justification of the number of points at which velocity measurements were taken*
- *A description of the final baffle settings*
- *The approach and sweep velocity data for all measured points in the final iteration of baffle adjustments presented in a table format*
- *The approach and sweeping velocity values for all measured points in the final iteration of baffle adjustments presented in a graphical format*

- *An objective evaluation of hydraulics at the site and anticipated screen performance*

8.11 Operations and Maintenance Plans

8.11.1 General

All fish screen projects should have an approved O&M plan. The plan should include procedures deemed acceptable by NMFS for operating the screen facility under a variety of environmental conditions, the full range of water diversion operations, and the procedures for periodic inspections and maintenance required to achieve fish screening effectiveness over the design life of the facility.

The purpose of an O&M plan is to ensure that the facility performs as designed and is providing effective fish screening over the life of the project. The O&M plan is the manual that describes exactly how the fish screen facility will be operated and maintained as well as procedures and personnel to contact in the event of emergencies. The following guidelines provide a template that can be used to prepare an O&M plan.

8.11.2 Operations

The O&M plan should include procedures that will ensure the fish screen meets all previously agreed to criteria. In addition to normal operation conditions, the plan should include information, procedures (including fish salvage plans), and personnel contact information in case of emergencies.

The O&M plan should include the seasonal maximum diversion rates agreed to in the design process, other criteria identified in the project description, project mitigation measures, and any applicable permit conditions or ESA Biological Opinion requirements. Additionally, the plan should address specific criteria on pump use at pumped diversions and gate use at gravity diversions that are required to achieve uniform approach velocities across screen surfaces.

8.11.2.1 Posting

A list of operating procedures that is easy to follow should be posted in a highly visible location at the water diversion site.

The list should include specific operating procedures needed to achieve uniform approach velocities across the screen face at various diversion rates. Emergency power cut-off switches, pressure relief valves, instructions for operating any auxiliary equipment, and emergency shutdown procedures should also be placed in locations that are easily found.

8.11.3 Maintenance

The diversion owner should incorporate maintenance procedures recommended by the designers, contractors, and suppliers into the O&M plan.

The maintenance section of the O&M plan should specify the frequency and interval for performing each maintenance procedure. The project owner is responsible for obtaining documentation (including specifications and maintenance requirements) from suppliers of off-the-shelf and custom systems and equipment and ensuring that all necessary maintenance equipment, tools, and component parts are readily available and on-hand for the maintenance. The O&M manual should identify activities that need to be carried out on a periodic basis (e.g., daily, weekly, monthly, quarterly, annually, or another periodic schedule).

8.11.4 Maintenance Records

The facility owner should maintain a log of O&M activities, which should be made available upon request of appropriate federal and state agencies. The logbook should include the following:

- *One copy of the operating procedures list discussed above (Section 8.11.2)*
- *One copy of the periodic maintenance schedule discussed above (Section 8.11.3)*
- *Records of regularly scheduled and unscheduled maintenance procedures performed*

8.11.5 Periodic Visual Inspections

The project owner, or their agent, should perform visual inspections of the screens on an annual basis or more frequently if required to ensure design criteria are being met. Inspectors should examine cleaning system performance, structural integrity of the screen area, fish-exclusion integrity of seals and transition areas, and other factors affecting screen facility performance. Inspectors should determine if the current maintenance procedures are sufficient to ensure that screen performance will continue to meet the facility's design criteria into the future.

Guidelines for conducting periodic inspections are as follows:

- Auditing maintenance records:
  - Review the O&M logbook to identify any recurring problems.
  - Compare logged records with the O&M plan to ensure the plan is under compliance and note any areas that need troubleshooting.
- Inspecting underwater components:
  - Check for gaps at joints and seams that could compromise screen efficiency.
  - Note any accumulation of debris.
  - Inspect screen material for damage and material integrity.
  - Check screens and structural members for corrosion, wear, or other deterioration.
  - Check sacrificial anodes and replace if necessary.
  - Check screen hold-down plates and other protrusions from the screen face for damage and debris accumulation.
- Witness cleaning system operations:
  - Intentionally foul the fish screen with locally available materials if possible and view the efficiency of the screen cleaning system.
  - Inspect spray orifices for fouling and erosion and whether the water or air spray systems need to be enlarged.

  - Inspect screen faces for undulations in the screen material that may reduce cleaning efficiency (i.e., for traveling brush systems).
  - Inspect screen cleaning brushes for wear and deterioration (e.g., for traveling brush systems).
  - Inspect seals for wear and deterioration.
  - Assess the overall efficiency of the cleaning system and identify any recommended solutions in the inspection report.
  - Inspect underwater moving parts for corrosion and damage.
- Inspect the morphology of the stream channel in the immediate vicinity of the project for debris, erosion, and sedimentation that may potentially damage screens and their supporting structures or adversely affect screen operation and effectiveness.
- If warranted, measure water velocities perpendicular to the screen face to determine flow uniformity over all screen surfaces. Above normal debris accumulation in small areas may indicate approach velocities exceed the design criteria in those locations. Excessively high approach velocities can result in debris accumulation. If the accumulation is not addressed in a timely manner it may result in less efficient water withdrawal and eventual damage to the screen material or its structure.
- Test backup systems and alarms that could include the following:
  - Pump shut-off controls
  - Blow out panels
  - Mechanical brush shut-off system controls
  - Screen cleaning system failure alarms

9 Operations and Maintenance

9.1 Introduction

The design criteria and guidance provided in this document were developed to produce a high level of effectiveness and reliability at installed fish passage and protection facilities. Achieving this requires that these facilities be operated and maintained properly to optimize their performance in accordance with the design objectives of the facility. Failure to do so is a key concern of NMFS. This is because insufficient attention to the operational and maintenance aspects of a facility can compromise its fish passage effectiveness and result in fish injury and mortality.

This chapter addresses O&M issues in general and describes the components needed in a facility O&M plan. Where necessary, other chapters of this document will also address O&M issues that apply specifically to the topics covered in those chapters (e.g., Chapters 5 and 8).

9.2 General Criteria

Passage and screening facilities at barriers, diversions, water intakes, traps, and collection facilities should be operated and maintained in accordance with the O&M plan over the entire life of the project. This is needed to meet the mechanical design and biological objectives of the facility and the goal of providing optimal conditions for fish that result in successful passage (i.e., no mortality and minimal injury and delay).

NMFS requires that facility owners and operators commit to accepting responsibility for installing and properly operating, maintaining, and repairing the fish passage facilities described in the Guidelines. This is to ensure that: 1) fish affected by the facility are protected in a manner that is consistent with the intended performance of the facility based on its design; and 2) fish protection is provided on a sustained basis. For example, the proper function and operation of a fish passage facility would need to be restored immediately after damage from flooding and prior to the arrival of migratory fish, including repairing damaged structures and removing accumulated gravel and sediment.

Where facilities are inadequately operated or maintained, and the injury or mortality of listed fish can be documented, the responsible party is liable to enforcement measures as described in Section 9 of the ESA.

9.3 Specific Criteria – Staff Gages

Staff gages should be installed and maintained at critical locations throughout the facility.

Staff gages allow personnel to quickly determine if the facility is being operated within the established design criteria. Staff gage locations will be identified in the O&M plan.

9.4 The Operations and Maintenance Plan

This section describes how O&M plans are developed and approved and their contents.

9.4.1 O&M Plan Development and Approval

The O&M plan for a facility should be submitted to and accepted by NMFS prior to initiating project construction. The design of facilities should be made in consideration of O&M requirements and vice versa. Therefore, O&M plans need to be developed during the planning and design processes and must be reviewed and approved by NMFS at this time, along with project design documents.

For new facilities, it is recommended that a description of intended operations be obtained from the designer and then incorporated into the O&M plan. Such a description is often referred to as the "designer's intent."

The complexity of the O&M plan should reflect the complexity of the facility it addresses. For example, a facility with complex components, narrow operating requirements, and sophisticated water control systems will require a detailed plan that addresses all of the components, systems, and operational scenarios. This should include potential emergency scenarios, including the identification of spare parts for essential components that need to be on hand in case of failure.

9.4.2 Group O&M Plans

Comprehensive O&M plans for a group of projects will satisfy the requirement for an O&M plan for each project in the group as long as NMFS is in agreement with the O&M of the passage facilities.

Examples of group projects include road maintenance plans for culverts and small screen facilities within a network of water diversions.

9.4.3 General

The O&M plan should include the following criteria, procedures, and staffing requirements.

9.4.3.1 Facility operating criteria

The O&M plan should list the facility operating criteria. This includes (but is not limited to) criteria for water levels at critical locations, gate operations, gate settings, how the system is adjusted to accommodate changes in forebay and tailwater levels, and inspection procedures and frequency (e.g., daily, monthly, and annually).

9.4.3.2 Procedures

The O&M plan should include a description of routine O&M procedures. In addition, the O&M plan should include procedures for dewatering the facility, salvaging fish during a dewatering event, sediment and debris removal, and emergency operations.

Procedures, such as dewatering plans, fish salvage plans, and emergency operations, can have a direct impact on the survival of fish in the facility. It is important that these procedures be incorporated into O&M plans and operators are familiar with them in order to minimize any adverse impacts.

9.4.3.3 Staffing requirements

The O&M plan should discuss the staffing requirements needed to support the O&M plan, including the hours staff are required to be on site to monitor and operate the facility. The staffing requirement component of the plan should incorporate automatic controls and telemetry into the O&M plan and facility that notify operators of problems to increase overall reliability of the facility.

9.4.4 Posting the O&M Plan

The O&M plan should be posted at the facility or otherwise made available to the facility operator. Operators should be familiar with and understand the O&M plan and operate the facility accordingly.

It is important that the O&M plan be available and easily accessed by the facility operator should questions or emergency situations arise.

9.4.5 Periodic Review of O&M Plans by NMFS

Operations and maintenance documents should be reviewed and revised (with NMFS involvement) annually for the first 3 years of operation and then periodically after that as conditions and operations dictate.

NMFS intends that O&M plans be “living” documents. O&M documents should be revised periodically as the owner and operator develop more experience with a new facility. This is important because over time, experience will be gained as to how the facility performs under various hydrologic and environmental conditions, and ideas on how to improve the O&M of the facility will develop. For example, it is important that facility owners and operators note areas in the O&M plan that are deficient or need revision.

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Article

Stream Restoration Is Influenced by Details of Engineered Habitats at a Headwater Mine Site

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Abstract: A lack of information regarding which ecological factors influence restoration success or failure has hindered scientifically based restoration decision-making. We focus on one headwater site to examine factors influencing divergent ecological outcomes of two post-mining stream restoration projects designed to improve instream conditions following 70 years of mining impacts. One project was designed to simulate natural stream conditions by creating a morphologically complex channel with high habitat heterogeneity (HH-reach). A second project was designed to reduce contaminants and sediment using a sand filter along a straight, armored channel, which resulted in different habitat characteristics and comparatively low habitat heterogeneity (LH-reach). Within 2 years of completion, stream habitat parameters and community composition within the HH-reach were similar to those of reference reaches. In contrast, habitat and community composition within the LH-reach differed substantially from reference reaches, even 7–8 years after project completion. We found that an interaction between low gradient and high light availability, created by the LH-reach design, facilitated a Chironomid-*Nostoc* mutualism. These symbionts dominated the epilithic surface of rocks and there was little habitat for tailed frog larvae, bioavailable macroinvertebrates, and fish. After controlling for habitat quantity, potential colonizing species' traits, and biogeographic factors, we found that habitat characteristics combined to facilitate different ecological outcomes, whereas time since treatment implementation was less influential. We demonstrate that stream communities can respond quickly to restoration of physical characteristics and increased heterogeneity, but "details matter" because interactions between the habitats we create and between the species that occupy them can be complex, unpredictable, and can influence restoration effectiveness.

Keywords: Chironomid-*Nostoc* mutualism; community composition; habitat interaction; interspecific interaction; macroinvertebrate; periphyton; Rocky Mountain tailed frog; salmonid fish

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1. Introduction

Each year resource managers and agencies spend over one billion dollars on >5000 stream or river restoration projects in the United States alone [1]. Around the world, the rate of project implementation has increased dramatically since these figures were compiled [2]. Determining the common features of restoration projects deemed ecologically successful, however, has been thwarted by a lack of post-treatment assessments. For example, the National River Restoration Science Synthesis summary database shows that in the U.S., only 10% of stream restoration projects report any form of monitoring data [1,3]. Research-oriented stream restoration studies, particularly comparative or before-after studies, are needed to help guide design and implementation of stream restoration projects [3,4].

Answering the question "what works?" in stream restoration is critical to advancing restoration science and improving the degraded state of streams and rivers worldwide [5]. However, in stream restoration, as with restoration in general, many factors can contribute to ecological success or failure (e.g., [6–8]). Even the term "restoration success" is subjective and difficult to quantify. For our purposes, we define it as the degree of similarity to reference sites or pre-disturbance community composition. Restoration practitioners typically seek to achieve restoration success by altering degraded areas, commonly through improvements to habitat quality and quantity, as these factors are often the most readily manipulated means of improving conditions for target species or communities [9]. Many stream restoration projects, in particular, also seek to improve conditions through increasing habitat heterogeneity [10]. This is partly because many streams in need of restoration were simplified (i.e., channelized, armored, or regulated) for human purposes [11,12], but also because studies of intact ecosystems have shown positive relationships between particular species, or species diversity as a whole, and habitat complexity or heterogeneity [13]. The ecological effectiveness of intentionally increasing habitat heterogeneity has been mixed in stream restoration studies [10] and increasing habitat heterogeneity does not guarantee use by a particular target species or establishment of desired (pre-disturbance) community composition.

The ecological success of restoration actions can be further influenced by often overlooked factors such as species' traits (e.g., dispersal ability, generation time, response to disturbance, specializations), biogeography (e.g., distance and connectivity to source populations), successional processes (e.g., time since project completion), and complex interspecific interactions such as facilitation, predation, or competition [14]. Since these factors are largely context specific, comparative- or case-studies of restoration projects situated in similar ecological contexts may provide a valuable means of elucidating how these potential drivers combine to influence restoration outcomes [15]. Although broad-scale, replicated studies can provide inference for quantifying success rates of certain restoration approaches and for determining "what works" and "where" (e.g., [16]), drawing more detailed mechanistic conclusions about drivers of restoration success or failure is challenging for such studies [17,18]. Thus, restoration case studies fill an important role in enhancing understanding of the ecological complexities of restoration outcomes.

Here, we provide a multi-year, multi-trophic level, comparative study of two post-mining restoration projects implemented on the same headwater stream. Differences in the designs of these projects allowed us to investigate the relative importance of habitat characteristics and time since treatment implementation, while controlling (to the extent possible in a natural experiment) for habitat quantity, species' traits (i.e., equivalent colonizing species pool), and biogeographic factors. To this end, we compared habitat conditions and biotic communities in two stream restoration reaches to an undisturbed reference reach upstream from any mining activities and to an unrestored downstream reach. Our goals were to determine the initial ecological effects of the two stream restoration strategies and to elucidate potential mechanisms contributing to different ecological outcomes. We hypothesized that habitat characteristics would ultimately have the greatest direct influence on the biotic communities in these stream reaches, whereas time since restoration completion would be relatively unimportant if quality habitat was lacking.

2. Materials and Methods

2.1. Study Area

The Stibnite Mine is located at 2034 m elevation in the Salmon River Mountains, Idaho, U.S.A. (Figure 1). Surrounding forests are dominated by various fir species and lodgepole pines. Summers are warm and dry, with most annual precipitation falling as winter snow. Meadow Creek, a third order stream with a moderate (11 m/km) gradient, runs through the site and has been heavily altered by mining activities since the 1930′s [19,20]. In addition to being proposed by the U.S. Environmental Protection Agency as a "Superfund" site, Meadow Creek is designated critical habitat for three salmonid fish species listed as Threatened under the Endangered Species Act. As a headwater stream, contaminant inputs are transported downstream into the Salmon River, the longest free-flowing river system in the contiguous U.S. (Figure 1 inset).

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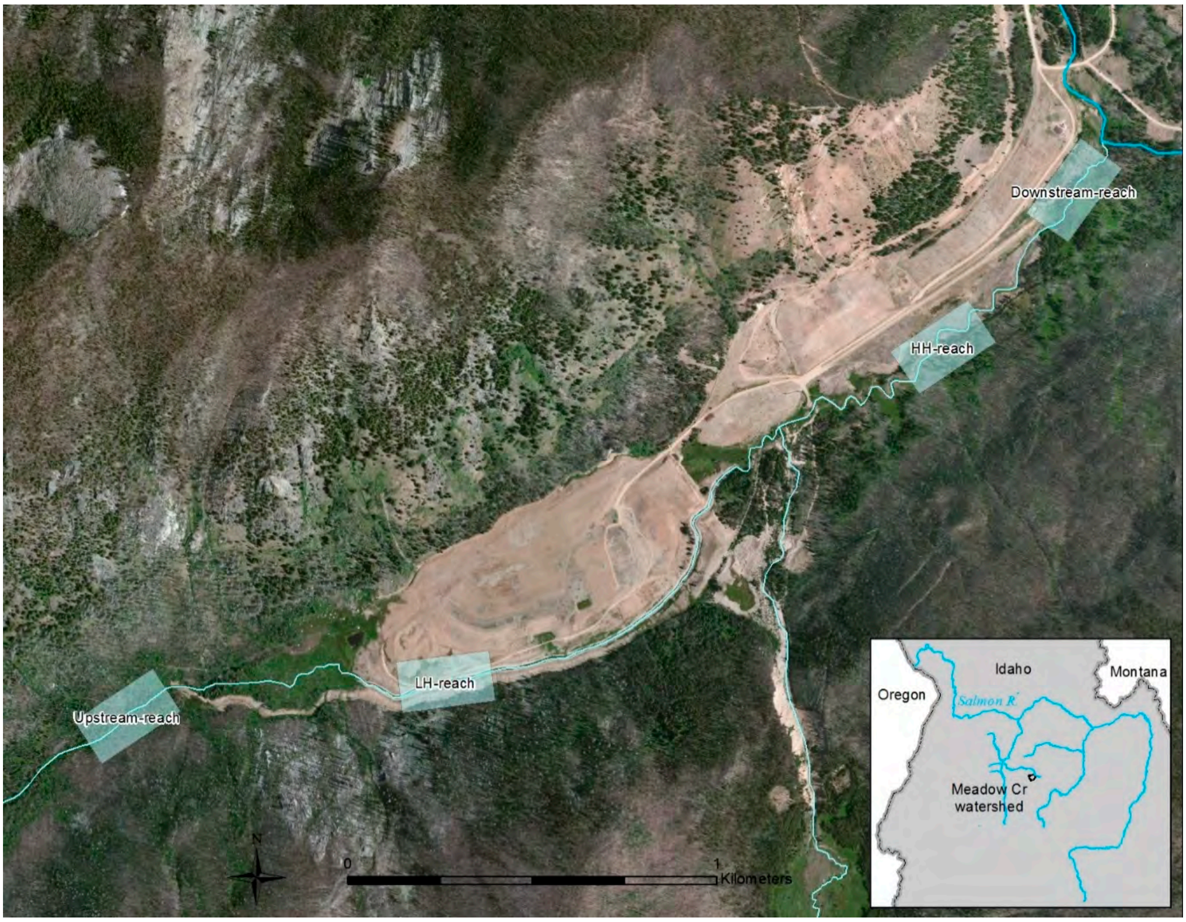


Figure 1. Stibnite Mine site, with Meadow Creek flowing northeast into the East Fork of the South Fork Salmon River (at top right). Over 3.2 km of mine tailings extend from the low habitat heterogeneity (LH-reach) through the high habitat heterogeneity (HH-reach). Boxes indicate 250 m study reaches. Inset shows the Meadow Creek watershed and its location in the headwaters of the Salmon River system in central Idaho, an area designated as critical habitat for three salmonid fish species listed as Threatened under the Endangered Species Act.

To improve in-stream habitat conditions and reduce heavy metal and sediment contaminants derived from mine tailings [19], two stream restoration projects were implemented. One project, implemented in 2005, was designed to closely resemble nearby stream habitats and to achieve high heterogeneity (HH-reach). This involved excavating a new channel adjacent to mine tailings, creating meanders, and restoring historic gradients, substrates, microhabitats, and riparian plants (Appendix A, Figure A1). Another project, implemented in 1999, consisted of excavating a straight flowing, armored, low-gradient stream channel through mine tailings and installing a sand filter (Figure A2). This resulted in a stream reach with somewhat unique habitat characters and relatively low heterogeneity in most variables examined (LH-reach; Table 1). The reaches are the same length (1.4 km) and are separated by 1.7 km. Each reach is approximately 450 m downstream, and 500 m upstream, from tributaries that provide potential colonizing species (Figure 1). See Appendix A for additional study area and restoration details.

Table 1. Habitat results by year of sampling and reach. For quantitative variables, values reported are mean ± S.E. Groups with the same letter (i.e., a–e) are not significantly different (α = 0.05) according to Duncan's Multiple Range Test. For categorical variables, the proportion of transects in each categorical level is reported by group. Variable names are capitalized.

Variable	2006				2007			
	Downstream	HH-Reach	LH-Reach	Upstream	Downstream	HH-Reach	LH-Reach	Upstream
Proportion HIGHGRAD habitat	0.3	0	0	0.1	0.2	0	0	0.1
Proportion LOWGRAD habitat	0.6	0.9	0.2	0.6	0.6	1.0	0.1	0.8
Proportion GLIDE habitat	0.1	0.1	0.8	0.3	0.2	0	0.9	0.1
CURRENT (cm/s)	75.6 ± 3.7 (a)	81.6 ± 4.9 (a)	42.1 ± 4.0 (e)	72.8 ± 4.6 (a,b)	61.6 ± 4.0 (b,c)	56.7 ± 5.1 (c,d)	31.7 ± 4.3 (e)	49.0 ± 3.1 (d)
UNDERCUT (% shoreline)	0.75 ± 0.7 (c)	0.00 (c)	0.00 (c)	29.0 ± 8.4 (a)	11.0 ± 5.5 (b,c)	0.00 (c)	0.00 (c)	23.5 ± 9.3 (a)
Substrate size (mm)	100 ± 7.5 (b,c)	67.4 ± 7.4 (d)	97.3 ± 6.3 (c)	70.1 ± 5.7 (d)	124 ± 6.8 (a,b)	129 ± 12 (a)	109 ± 6.2 (a,b,c)	70.9 ± 6.9 (d)
Sediment (% transect covered)	-	-	-	-	3.3 ± 0.9 (b,c)	2.5 ± 1.1 (c)	9.5 ± 1.2 (a)	7.5 ± 1.7 (a,b)
Substrate embeddedness (% buried)	21.4 ± 2.4 (a,b)	12.6 ± 1.7 (d)	24.7 ± 1.9 (a)	14.5 ± 1.3 (c,d)	18.8 ± 1.7 (b,c)	5.0 ± 0.7 (e)	12.8 ± 1.7 (d)	16.3 ± 0.9 (c,d)
Proportion SOLID substrate	0.3	0	0.2	0.1	0.6	0	0	0.1
Proportion RESISTANT substrate	0.7	0	0.7	0.1	0.4	0.2	0.9	0.3
Proportion LOOSE substrate	0	1.0	0.1	0.8	0	0.8	0.1	0.6
LWD (% coverage)	0.50 ± 0.33 (b)	0.00 (b)	0.00 (b)	5.25 ± 1.5 (a)	1.50 ± 0.4 (b)	0.25 ± 0.25 (b)	0.75 ± 0.4 (b)	6.0 ± 1.8 (a)
ORGANIC ($L \cdot m^{-2}$)	0.12 ± 0.02 (c)	0.21 ± 0.04 (b,c)	0.55 ± 0.1 (a)	0.64 ± 0.2 (a)	0.18 ± 0.1 (b,c)	0.26 ± 0.1 (b,c)	0.55 ± 0.1 (a)	0.32 ± 0.13 (a)
COVER (%)	7.00 ± 2.1 (b)	0.50 ± 0.3 (c)	0.00 (c)	28.0 ± 3.0 (a)	5.75 ± 1.4 (b)	0.50 ± 0.3 (c)	0.00 (c)	34.2 ± 7.8 (a)
LIGHT ($kW \cdot m^{-2} \cdot h^{-1}$)	4.72 ± 0.2 (b)	6.61 ± 0.1 (a)	6.98 ± 0.1 (a)	3.14 ± 0.3 (c)	4.76 ± 0.3 (b)	6.65 ± 0.1 (a)	6.96 ± 0.1 (a)	3.16 ± 0.29 (c)
Temperature > 16 °C (h/yr)	78	-	-	0	171	-	-	0
Temperature maximum (°C)	18.5	-	-	13.5	20.25	-	-	14.5

2.2. Study Design

In addition to the HH- and LH-reaches, we sampled an unrestored reference reach downstream of the restoration projects (Downstream-reach, Figure A3) and an undisturbed upstream reference reach (Upstream-reach; Figure A4). Due to the directional flow, the three lower reaches are not independent and could be influenced by conditions in higher reaches of the stream. However, these reaches have different tributaries downstream and upstream from them and we focus on structural habitat conditions (rather than water chemistry and contaminants) that are less likely to have cross-reach independence issues. In late July 2006 and 2007, we sampled 10 belt-transects in 250 m sections of each study reach. Belt-transects were placed at 25 m intervals in each section, with random off-sets of ±2 m. Each belt-transect extended across the wetted width of the stream and upstream for 1 m. Pre-restoration data on habitat and communities were not available except for fish in two reaches. Therefore, we did make opportunistic use of these data since they were available. Pre- and post-restoration water chemistry and site contaminant data are provided in Dovick et al., 2016 and 2020 [19,20], and were thus not presented here. We do note, however, that metalloid contaminant levels in sediment, water, and biotic samples generally increased with current direction (i.e., greatest in Downstream-reach, next greatest in HH-reach, followed by LH-reach, and Upstream-reach), both before- and after restoration in 2005.

We sampled in two different years due to the dynamic nature of streams in this disturbance-prone landscape. Wildfires, debris flows, and high interannual variability in peak spring runoff levels are common. Thus, results obtained from streams sampled in 1 year can differ substantially from those obtained in a subsequent year [21,22]. We sampled and compared data across two years to provide a means of reducing the chances of spurious conclusions being drawn from a single year's data.

2.3. Stream Habitat Sampling

At each belt-transect, we recorded wetted width, average depth, current velocity (CURRENT), percent of transect covered by sediment (SEDIMENT), substrate size (SUBSTRATE), and substrate embeddedness (EMBEDDEDNESS) as in [21]. We measured the percent of each belt-transect covered by large woody debris (LWD; >5 cm diameter) and the volume of organic debris dislodged during kick sampling (ORGANIC; wood < 5 cm diameter and leaf litter). We also recorded the percent of each belt-transect covered by riparian vegetation (COVER) and the percent of the shoreline with undercut bank morphology (UNDERCUT). The microhabitat type of each belt-transect was classified as having no surface agitation (GLIDE), agitation but no whitewater (LOWGRAD), or whitewater (HIGHGRAD). The substrate mobility within each belt-transect was rated, relative to the effort required to dislodge benthic rocks, as: immovable when kicked (SOLID), kicking effort required (RESISTANT), and movement when stepped on (LOOSE).

We used Solar Pathfinder equipment and digital photography to provide year-round, transect-specific solar data (Solar Pathfinder Assistant version 1.1.5, 2006). June–August average light availability ($kW \cdot m^2 \cdot hr^{-1}$; LIGHT) was used in analyses.

Water temperature was recorded hourly (HOBO data loggers, Onset Computer Corp., Bourne, MA, USA) in two locations: where water entered the LH-reach and where it exited the HH-reach. For each location, we determined the number of hours each summer, where water temperatures were ≥16 °C (WATERTEMP) [21].

2.4. Stream Community Sampling

We collected, dried, and weighed all autochthonous primary production (PERIPHYTON) that was dislodged while taking each Surber sample (see below). We recorded whether the dominant epilithic macro- or microphyte in each belt-transect was biofilm, filamentous algae, moss, or cyanobacteria colonies (*Nostoc* sp.).

Surber samples (0.10 m^2, 500 μm mesh) were collected in the thalweg of alternate belt-transects (50-m apart) for a total of 5 samples per reach per year. Benthic macroinvertebrates were keyed to genus (family for Chironomidae and order for Oligochaeta) using Merritt and Cummins (1996) [23]. We calculated macroinvertebrate summary metrics including total density (DENSITY), density of each genus, taxonomic richness (RICHNESS), and evenness (EVENNESS; inverse of dominance) for each sample.

In each belt-transect, we kick-sampled for Rocky Mountain tailed frog larvae (*Ascaphus montanus*), which were captured in D-frame nets at the downstream edge of the belt-transect [21]. For each reach and year, we calculated the proportion of belt-transects occupied by larvae. We also recorded incidental observations of adult tailed frogs.

Snorkeling surveys were conducted by the Payette National Forest in the Downstream-reach and in the HH-reach prior to relocation of the stream channel in 2005, and again after restoration in 2006 and 2007. Fish counts were made by species and life stage. We used these data to calculate the number of fish per meter surveyed and report the species composition for each reach in each year. We supplemented snorkeling data with observational data at all 10 belt-transects per reach in both years and we report the proportion of transects where fish were detected by reach and year. We report naïve occupancy rates rather than rates adjusted for detection probability.

2.5. Data Analysis

We tested for significant differences in response variables among combinations of four reaches and two years, which resulted in comparisons among eight groups (GROUP). This approach allowed us to quantify differences between reaches and changes through time in a manner that was consistent with the approach required for multivariate analyses discussed below. Untransformed univariate quantitative response variables were analyzed using general linear modeling (GLM) and a post-hoc, Duncan's Multiple Range Test after checking for compliance with model assumptions. Categorical habitat variables were analyzed using chi-square tests (SAS 9.0.1, SAS Institute Inc., Cary, NC, USA). To assess habitat heterogeneity differences between GROUPs, we examined relative standard error (RSE = standard error/mean) values for each individual quantitative variable measured by GROUP. RSE provides an index of heterogeneity by relativizing the within GROUP variability for a given habitat variable by the mean value of that variable for all transects, with values > 0.20 being considered relatively high in ecological studies [24]. We further compared the mean RSE of all nine quantitative habitat variables for each GROUP to provide an overall score of each reaches' relative heterogeneity.

To test for community-level differences between GROUPs, macroinvertebrate samples were analyzed using Multi-Response Permutation Procedure (MRPP) in PC-ORD [25]. See Appendix B for details on this and subsequent multivariate analyses. We performed indicator species analyses (ISA) to determine which macroinvertebrate genera were significantly associated with, or indicative of, a particular GROUP [25]. Relationships between macroinvertebrate community composition and habitat or treatment variables were analyzed using nonmetric multidimensional scaling (NMS) ordination performed on genera density data.

To determine which habitat variables influence the prevalence of the dominant macroinvertebrate taxon, we used nonparametric multiplicative regression (NPMR) in HyperNiche 2.11 software [26]. This approach allowed us to model the density of the dominant taxon as a function of non-linear, multiplicatively interacting combinations of habitat variables [27].

3. Results

3.1. Stream Habitat

Habitat conditions varied predominantly among reaches, with fewer changes between years. There was a significant difference between reaches in the amount of microhabitat types (Table 1; χ^2 = 17.3, n = 80, d.f. = 6, p = 0.008). The HH-reach contained mostly LOWGRAD, whereas the LH-reach contained largely GLIDE habitat. The reference reaches contained mostly LOWGRAD but had comparatively higher proportions of HIGHGRAD and GLIDE habitats. CURRENT differed significantly across both reach and sampling year.

Within each year, the LH-reach had significantly slower CURRENT than the other three reaches (approximately half that of the Downstream- and HH-reaches; Table 1). Within each year, the HH-reach had more variable CURRENT than the Downstream- and LH-reaches.

Substrate characteristics varied among reaches and sampling year (Table 1). Average SUBSTRATE was smallest in the HH- and Upstream-reaches. SUBSTRATE did not change significantly from year to year within any reach except in the HH-reach, where the average size increased. SEDIMENT was higher in the LH-reach than in the other three reaches. The HH-reach had the least embedded substrate in both years, whereas the LH-reach had the most embedded substrate in 2006 (Table 1). Substrate mobility differed significantly among reaches (Table 1; χ^2 = 34.8, n = 80, d.f. = 6, p = 0.0001). The HH- and Upstream-reaches had substrate that was LOOSE or RESISTANT, whereas the LH-reach substrate was more often RESISTANT. In both years, the HH-reach had higher between-transect variability than the LH-reach for most of the substrate variables examined (Table 1).

The amount of in-stream vegetative material (LWD, ORGANIC), riparian vegetation (COVER), and undercut banks (UNDERCUT) were greater in the Upstream-reach than in the other three reaches. The Downstream-reach had significantly more COVER than the HH- and LH-reaches, but did not have significantly more LWD, ORGANIC, or UNDERCUT than either of the restoration reaches. The LH-reach generally lacked each of these habitat elements (Table 1). LIGHT differed significantly among reaches, but not years. The HH- and LH-reaches each received around 7 $kW \cdot m^2 \cdot hr^{-1}$. The Downstream-reach received 65% less- and the Upstream-reach received 43% less LIGHT than the two restoration reaches because of riparian shading (Table 1). Water temperatures increased as water flowed through the two restoration reaches (Table 1).

Based on RSE analysis of quantitative habitat variables, the HH-reach had greater heterogeneity than the LH-reach in both years (Appendix C Table A1, Figure A5). In 2006, substrate size, substrate embeddedness, and riparian cover were the primary drivers in this difference in heterogeneity. Whereas, by 2007, variability in substrate embeddedness was similar among the two reaches and sediment load variability was found to be greater in the HH-reach, as were substrate size, LWD, ORGANIC, and COVER (Table A1). Across all quantitative habitat variables, the average RSE was 57–61% greater in the HH-reach than in the LH-reach, depending on year of sampling. Average RSE values increased between 2006–2007 in all reaches (except the Downstream-reach), likely due to higher peak stream flows that spring. By 2007, average RSE values in the HH-reach were significantly greater than those of the other three reaches (Appendix C Figure A5), mainly because of increases in the diversity of CURRENT, LWD, and ORGANIC, as these habitat elements began to appear in this reach.

3.2. *Periphyton*

PERIPHYTON differed significantly by reach, but not by year (Table 2). PERIPHYTON was approximately three times greater in the LH-reach than in the Upstream-reach, which in turn, had significantly more PERIPHYTON than the Downstream- and HH-reaches. Similar to PERIPHYTON, the dominant epilithic macro- or microphyte differed substantially by reach (χ^2 = 127.8, n = 80, d.f. = 9, p < 0.0001 (Table 2). In the Downstream- and HH-reaches, diatom/microalgae (FILM) was the dominant epilith in all belt-transects in both years. Cyanobacteria colonies (NOSTOC), and to a lesser extent filamentous ALGAE, dominated in the LH-reach, whereas FILM dominated in the Upstream-reach and MOSS was subdominant (Table 2).

Table 2. Biotic results by year of sampling and reach. For quantitative variables, values reported are mean ± S.E. Groups with the same letter (i.e., a–d) are not significantly different (α = 0.05) according to Duncan's Multiple Range Test. For categorical variables, the proportion of transects in each categorical level is reported by group. Variable names are capitalized.

Variable	2006				2007			
	Downstream	HH-Reach	LH-Reach	Upstream	Downstream	HH-Reach	LH-Reach	Upstream
PERIPHYTON (g 0.1 m^{-2})	0.03 ± 0.01 (c)	0.03 ± 0.01 (c)	5.15 ± 1.2 (a)	1.83 ± 0.63 (b)	0.01 ± 0.001 (c)	0.02 ± 0.009 (c)	7.15 ± 1.6 (a)	2.74 ± 0.6 (b)
Proportion FILM dominant	1	1	0.1	0.3	1	1	0	0.3
Proportion ALGAE dominant	0	0	0	0	0	0	0.1	0
Proportion MOSS dominant	0	0	0	0.7	0	0	0	0.7
Proportion NOSTOC dominant	0	0	0.9	0	0	0	0.9	0
Prop. FILM, ALGAE, MOSS, NOSTOC dominated	1/0/0/0	1/0/0/0	0.1/0/0/0.9	0.3/0/0.7/0	1/0/0/0	1/0/0/0	0/0.1/0/0.9	0.3/0/0.7/0
Macroinvertebrate DENSITY (ind 0.1 m^{-2})	83.4 ± 13 (c)	85.2 ± 14 (c)	1094 ± 268 (a)	37.8 ± 10 (d)	204 ± 32 (b)	252 ± 51 (b)	1373 ± 91 (a)	24.2 ± 5.8 (d)
Non-Chironomid density (ind 0.1 m^{-2})	67.2 ± 11 (b,c)	72.4 ± 12 (b)	34.2 ± 10 (d)	35.4 ± 8 (c,d)	184 ± 32 (a)	240 ± 51 (a)	75.2 ± 15 (b)	22.4 ± 5.8 (d)
Macroinvertebrate RICHNESS	11.6 ± 0.9 (a,b)	9.4 ± 0.7 (a,b)	10.0 ± 1.9 (a,b)	9.8 ± 1.4 (a,b)	11.8 ± 1.3 (a,b)	12.8 ± 1.0 (a)	10.4 ± 1.1 (a,b)	8.0 ± 0.9 (b)
Macroinvertebrate EVENNESS (E)	0.77 ± 0.01 (a,b)	0.66 ± 0.01 (b)	0.21 ± 0.15 (c)	0.88 ± 0.01 (a)	0.66 ± 0.04 (b)	0.67 ± 0.03 (b)	0.12 ± 0.01 (c)	0.87 ± 0.03 (a)

3.3. Macroinvertebrates

Benthic macroinvertebrate communities in the HH- and Downstream-reaches each changed significantly between years of sampling ($T < -1.6$; $A > 0.05$; $p < 0.05$). The LH-reach reach did not change significantly between years ($T = -1.54$; $A = 0.04$; $p = 0.08$), nor did the Upstream-reach ($T = -1.34$; $A = 0.02$; $p = 0.09$).

NMS ordination produced a two-axis solution (instability = 0.00000, 54 iterations, stress = 10.3, $p = 0.004$), representing 66.6% of the variance in the original data. Samples fell into two clusters, one cluster containing samples from the LH-reach (both years) and the other cluster containing samples from the other three reaches, except for one outlier from the LH-reach (discussed below). Within the larger cluster, the Downstream- and HH-reaches were similar in both years (Figure 2). These reaches were positively correlated with high WATERTEMP and LIGHT and negatively correlated with COVER, small substrate, and PERIPHYTON. The Upstream-reach did not change from 2006 to 2007 and was associated with high COVER, small substrate, and low LIGHT. CURRENT was positively correlated with samples from these three reaches. Samples from the LH-reach were distinct and did not vary between years (Figure 2). Low CURRENT, high LIGHT, and high PERIPHYTON were associated with this reach. One outlying point from the LH-reach (in 2006) clustered with samples from the other reaches. This sample was collected in a transect that had a current velocity of 74 cm/s, which was 50% greater than the average current velocity in that reach and equal to the average current velocity in the HH-reach.

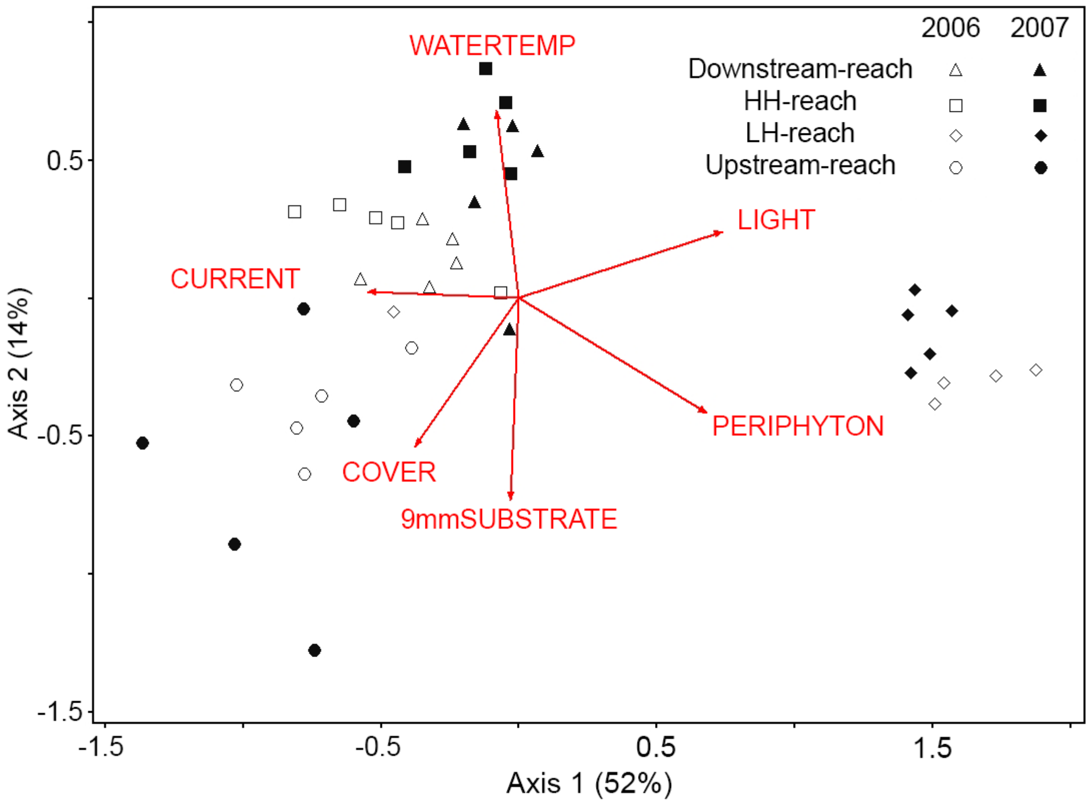


Figure 2. Nonmetric multidimensional scaling (NMS) biplot of five Surber samples per reach per year ($n = 40$) in two-dimensional genera space. Samples plotted closer together have more similar macroinvertebrate communities. Percent variance represented by each axis is given in parentheses. Current velocity (CURRENT) is most strongly correlated with Axis 1 ($r^2 = 0.32$). Water temperature (WATERTEMP) is positively related ($r^2 = 0.41$) and small substrate size (9 mmSUBSTRATE) is negatively related ($r^2 = 0.41$) to Axis 2. Riparian canopy cover (COVER), periphyton biomass (PERIPHYTON), and solar availability (LIGHT) are related to both axes ($r^2 > 0.23$ for both axes).

Macroinvertebrate density (DENSITY) was significantly different among reaches and years. Chironomid taxa had a strong influence on DENSITY (Figure 3). Including

lated (r^2 = 0.41) to Axis 2. Riparian canopy cover (COVER), periphyton biomass (PERIPHYTON), and solar availability (LIGHT) are related to both axes (r^2 > 0.23 for both axes).

Chironomids, DENSITY in the LH-reach was an order of magnitude greater than that of any other reach. The thousands of Chironomids found in the LH-reach were found exclusively living encased within *Nostoc parmelioides* cyanobacteria colonies (Appendix D). Excluding Chironomids from density calculations results in a different pattern. Non-Chironomid DENSITY in the HH-reach was 3.3-fold greater than in the LH-reach in 2007 (Figure 3; Table 2). Non-Chironomid DENSITY was significantly lower in the LH-reach than in the Downstream- and HH-reaches.

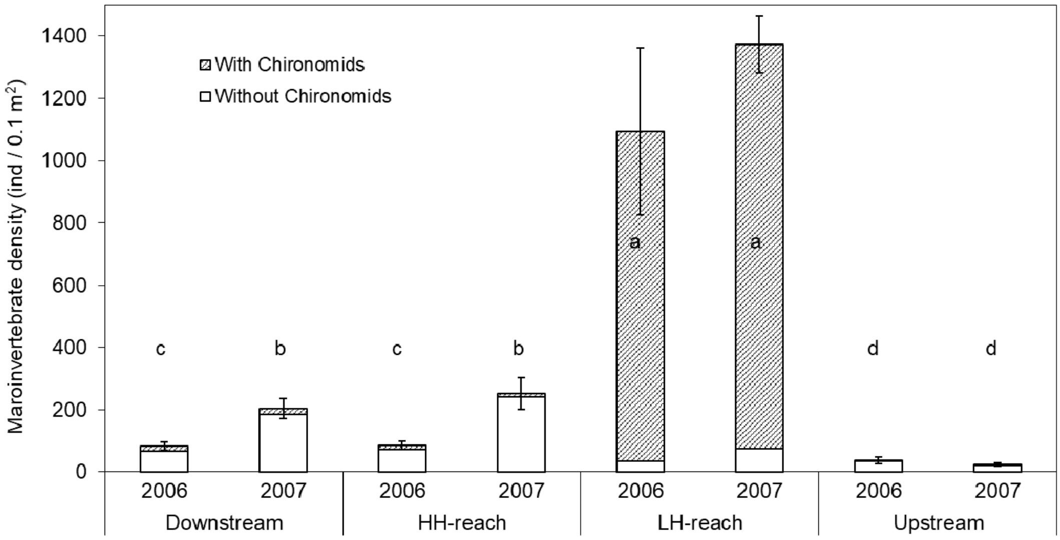


Figure 3. Average macroinvertebrate density (DENSITY) including and excluding Chironomids, from five Surber samples per reach per year. Error bars show ±1 SE for total DENSITY only. Groups with the same letter (i.e., a–d) are not significantly different (based on total DENSITY; α = 0.05) according to Duncan's Multiple Range Test.

Taxonomic RICHNESS ranged from 12.8 in the HH-reach to 8.0 in the Upstream-reach (both in 2007). These were the only two GROUPs that differed significantly (Table 2). EVENNESS however, differed significantly across reaches and was greater in the Upstream-reach than in than the two restoration reaches. The Downstream- and HH-reaches did not differ in EVENNESS, but had significantly greater EVENNESS than the LH-reach (Table 2).

Indicator Species Analysis identified 10 taxa with significant indicator values for at least one reach in at least one year (Table 3). In total, three taxa, the mayfly *Drunella*, the stonefly *Yoroperla*, and Chironomids, were characteristic of a particular reach in both years. In general, taxa that are periphyton scrapers were indicative of the Downstream- and HH-reaches, whereas a *Nostoc* colony miner/macroalgae chewer was associated with the LH-reach. A shredder/scraper was associated with the Upstream-reach. Mobile and unprotected (i.e., by a rock or plant material casing) taxa were associated with the Downstream-, HH-, and Upstream-reaches.

The density of Chironomid *Nostoc* mutualists (Figure A5) across transects in all reaches was best explained by the interaction between CURRENT and LIGHT, which explained 92% of the variation in mutualist density (Figure 4; n = 20, N* = 4.04, xR^2 = 0.92, p = 0.024). Mutualist density was high in transects where CURRENT was low and LIGHT was high, conditions found in the LH-reach. However, mutualist density was low where both CURRENT and LIGHT were high (conditions found in Downstream- and HH-reaches). High CURRENT and low LIGHT, as was observed in the Upstream-reach, resulted in intermediate densities. For CURRENT and LIGHT respectively, tolerance was 0.106 and 0.886 (both 20% of the range of the variable) and sensitivity was 0.804 and 0.838.

Table 3. Indicator Species values (percentage of a perfect indication) for macroinvertebrate taxa. Taxa shown have an indicator value significantly greater (α = 0.05) than values generated by 1999 Monte Carlo simulations, in at least 1 year of sampling.

Taxon	Grp. [1]	Mobile and Not Incased	2006 Down-Stream	2006 HH-Reach	2006 LH-Reach	2006 Up-Stream	2007 Down-Stream	2007 HH-Reach	2007 LH-Reach	2007 Up-Stream
Cinygmula	Sc	y	54 **	10	7	6	16	70 ***	7	1
Drunella	Sc, P	y	22	54 *	8	2	9	65 **	22	0
Epeorus	Sc, CG	y	52 *	28	1	12	33	65 *	0	0
Skwala	P	y	20	0	0	0	5	68 **	0	0
Yoroperla	Sh, Sc	y	0	0	28	52*	0	3	3	53 *
Chironomidae	M	n	1	1	97 ***	0	2	1	97 ***	0
Simulium	CF	n	7	0	18	29	68 *	3	0	5
Anagapetus	Sc	n	15	7	2	20	80 ***	10	0	1
Brachycentrus	CF, Sc	n	-	-	-	-	0	60 *	0	0
Rhyacophila	Ch	n	14	7	26	45	20	9	48 *	20

[1] Functional groups based on Merritt and Cummins (1996) and field observations. Sh = Shredder CF = Collector-filterer, CG = Collector-gatherer, Sc = Scraper, P = Predator, M = miner of *Nostoc* sp. * Indicator values significant at $p < 0.05$, ** Indicator values significant at $p < 0.01$, *** Indicator values significant at $p < 0.001$ based on Monte Carlo test of significance on observed maximum indicator value for each taxon (1999 permutations).

Diversity **2021**, *13*, x FOR PEER REVIEW 13 of 26

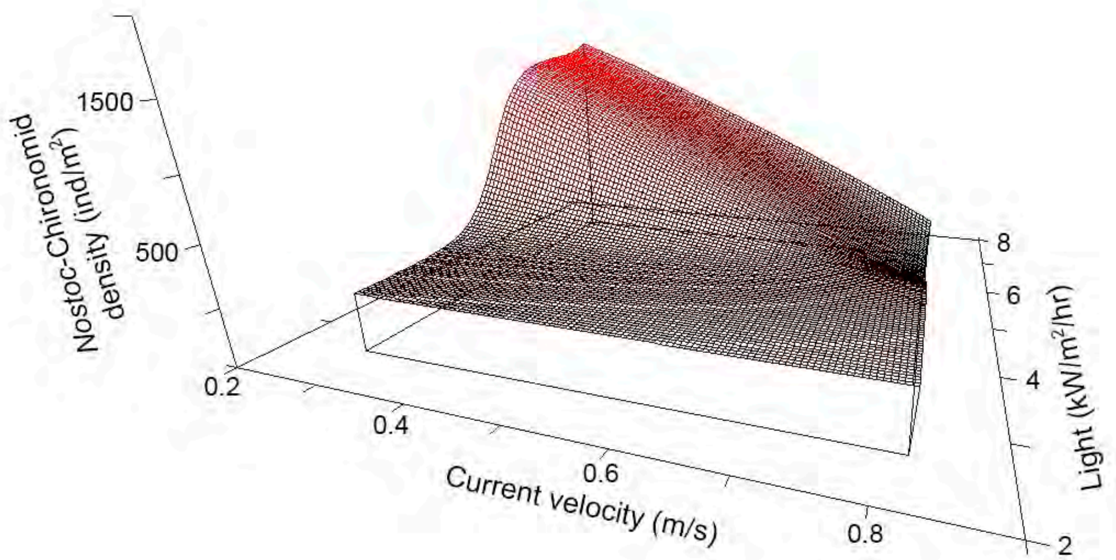


Figure 4. Nonparametric multiplicative regression (NPMR) modeled Chironomid-*Nostoc* mutualist density versus current velocity and light availability. Model is based on density data from 20 Surber samples collected in 2006 and explains 92% of the variation in the empirical data.

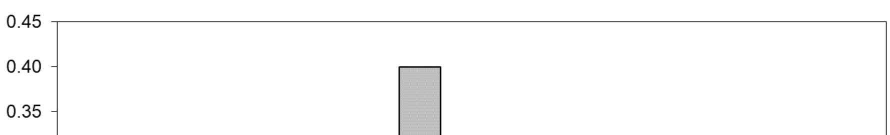
Figure 4. Nonparametric multiplicative regression (NPMR) modeled Chironomid-*Nostoc* mutualist density versus current velocity and light availability. Model is based on density data from 20 Surber samples collected in 2006 and explains 92% of the variation in the empirical data.

3.4. Amphibians

In 2006, tailed frog larvae occupied 10% of transects in the HH-reach and no transects in the LH-reach (Figure 5). Occupancy rates were at least twice as high in the Downstream- and Upstream-reaches compared with the HH-reach. In 2007 however, the HH-reach had the highest larval occupancy rate, which was > 30% higher than that of the Downstream- and Upstream-reaches. Occupancy in the Downstream- and Upstream-reaches decreased by about 50% from the previous year and again, no tailed frog larvae were detected in the LH-reach. Adult tailed frogs were observed only in the Upstream- and Downstream-reaches (not shown).

3.4. Amphibians

In 2006, tailed frog larvae occupied 10% of transects in the HH-reach and no transects in the LH-reach (Figure 5). Occupancy rates were at least twice as high in the Downstream- and Upstream-reaches compared with the HH-reach. In 2007 however, the HH-reach had the highest larval occupancy rate, which was > 30% higher than that of the Downstream- and Upstream-reaches. Occupancy in the Downstream- and Upstream-reaches decreased by about 50% from the previous year and again, no tailed frog larvae were detected in the LH-reach. Adult tailed frogs were observed only in the Upstream- and Downstream-reaches (not shown).



compared with the HH-reach. In 2007 however, the HH reach had the highest larval occupancy rate, which was > 30% higher than that of the Downstream- and Upstream-reaches. Occupancy in the Downstream- and Upstream-reaches decreased by about 50% from the previous year and again, no tailed frog larvae were detected in the LH-reach. Adult tailed frogs were observed only in the Upstream- and Downstream-reaches (not shown).

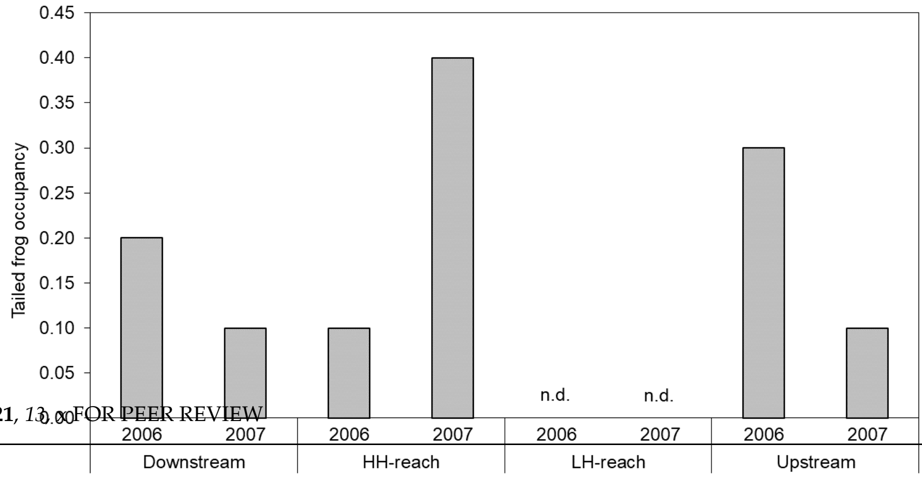


Figure 5. Proportion of belt-transects occupied by tailed frog larva in each reach and year. No larvae were detected in the LH-reach (n.d.).

3.5. Fish

The number of fish per meter surveyed more than doubled in the HH-reach from pre-restoration levels, whereas numbers remained relatively constant in the Downstream-reach over the same years (Figure 6). Prior to restoration, westslope cutthroat trout (*Oncorhychus clarki*) and steelhead (*O. mykiss*) were observed in the Downstream-reach, but only westslope cutthroat trout were observed in the former channel flowing through the HH-reach area. After 1- and 2-years post-restoration, westslope cutthroat trout, steelhead, and bull trout (*Salvelinus confluentus*) were observed in the HH-reach, whereas only westslope cutthroat trout were observed in the Downstream-reach. The Upstream- and LH-reaches were not surveyed by Payette National Forest crews.

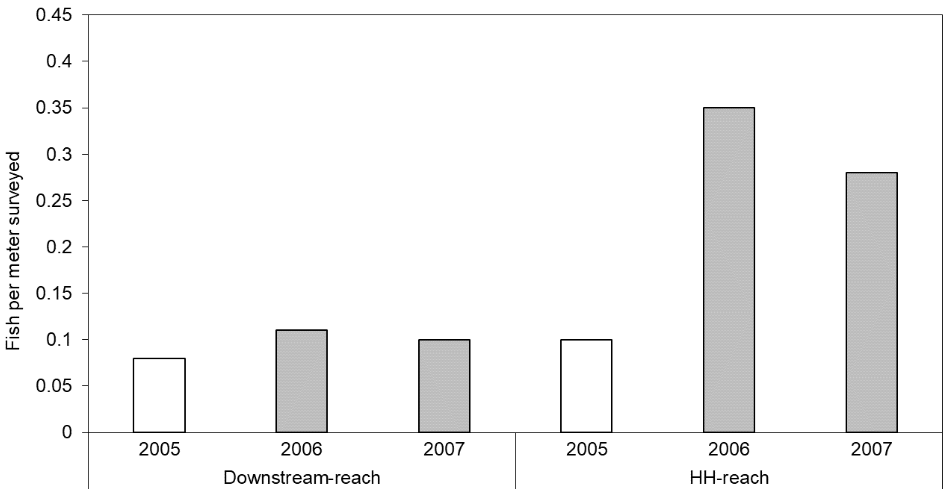


Figure 6. Number of fish (all species and size classes) per meter counted during snorkeling surveys. Data from 2005 (unshaded bars) were collected prior to initiation of restoration actions on the HH-reach.

During belt-transect sampling of all four reaches, the naïve fish occupancy rate in 2006 was 0.30 in the HH-reach (i.e., fish detected in 30% of transects) and 0.10 in the LH-reach. Downstream- and Upstream-reaches had occupancy rates of 0.10 and 0.30, respectively. In 2007, occupancy rates declined slightly to 0.20 in the HH-reach and to 0.10 and 0.20 in the Downstream- and Upstream-reaches, respectively. The LH-reach was the only area with no fish detected in 2007 (naïve occupancy rate = 0.00).

4. Discussion

4.1. Effects of Restoration Strategy on Stream Habitat

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A companion study at this site found that these restoration actions were effective in reducing arsenic and antimony contamination, especially where sand filters were installed for ground water filtration, although contaminant levels remained elevated and there was evidence of substantial bioaccumulation [19]. However, we found that the two restoration strategies resulted in pronounced differences in stream habitat conditions. The more holistic restoration approach used in the HH-reach resulted in greater habitat heterogeneity and in overall habitat conditions that were more similar to reference reach conditions within 2 years of project completion, despite having substantially greater metalloid concentrations in sediment, water, and biotic samples than concentrations observed in the LH-reach [19]. With a restoration emphasis on contaminant and sediment reduction, habitat conditions in the LH-reach were dissimilar to reference conditions even after 8 years since project completion. The proportion of different microhabitat types, substrate characteristics, and perhaps most importantly, current velocity were key differences between HH- and LH reaches. However, other habitat components such as large wood, riparian cover, and undercut bank morphology were generally lacking in each restoration reach when compared to reference conditions, similar to findings from other stream restoration studies (e.g., [16]). Similar to what Bernhardt and others [3] found, there was not a substantial cost difference between the successful and less successful habitat restoration projects (Payette National Forest unpublished data), but the habitat differences we observed resulted in considerably different conditions for in-stream communities.

4.2. Effects of Stream Restoration Strategy on Stream Community

Periphyton community composition and biomass in the two restoration reaches were dramatically different despite equal solar energy availability. Periphyton, including epilithic moss, has been shown to provide important post-restoration refugia and habitat as macroinvertebrates colonize new benthic surfaces [28,29]. The dominant periphyton community in the HH-reach (diatom/microalgae) was similar to that of reference reaches and it supported an abundant assemblage of predominantly scraper macroinvertebrates. In contrast, benthic substrates in the LH-reach were almost completely covered by *Nostoc parmelioides*, a colonial cyanobacteria that was far less abundant in the other study reaches and in 13 other streams in the vicinity [21,22]. Our habitat model shows that the cause of this dominance was likely an interaction between light availability and current velocity, conditions resulting from restoration actions (discussed further below). Past studies have implicated these two factors separately in influencing *Nostoc* sp. performance by controlling photosynthetic rate [29] and the rate of gas exchange [30], respectively. As the autochthonous base of the stream food web and as a structural habitat component, this difference in periphyton community may explain the observed differences in higher trophic-level organisms in these reaches [31,32].

Despite a lack of riparian cover, large woody debris, and complex bank morphology, the macroinvertebrate community in the HH-reach was similar to communities of reference reaches, likely because of similar substrate and current conditions. This is in contrast to some studies which have found that restoring structural features does not necessarily translate into improvements in macroinvertebrate community composition (e.g., [33]). In the LH-reach, however, low current velocity from the grading done during the restoration process and high light availability from a lack of riparian canopy cover resulted in dominance of the LH-reach by Chironomid larvae of the *Cricotopus* genus. These specialists live within colonies of the cyanobacteria *Nostoc parmelioides*, which provide the Chironomid larvae with food, oxygen, and protection from predation by other macroinvertebrates and fish [34,35]. The macroinvertebrates associated with the HH-reach, on the other hand, tended to be unprotected by *Nostoc* refugia or by rock casings. Others have shown that, in California streams, "unprotected" macroinvertebrates were more bioavailable to secondary consumers than macroinvertebrates which were protected by casings [36]. Therefore, habitat conditions in the LH-reach may ultimately result in lower autochthonous energy for predatory macroinvertebrates and fish, at least until Chironomid larva pupate and emerge from their hosts. These differences could potentially lead to alternative stable states in these two restoration reaches, with long-term consequences to restoration outcomes.

We were surprised that tailed frog larvae colonized the HH-reach within a year of channel relocation and that their occupancy rate surpassed that of reference sites within 2 years because tailed frogs are generally considered to be sensitive to disturbance and warm temperatures [37]. We cannot differentiate between tadpoles that immigrated from connected source habitats and those that hatched within the HH-reach, but the availability of biofilm periphyton (preferred food source) and interstitial spaces (cover from predators) within the unconsolidated substrate may explain the rapid colonization and high occupancy rate in the HH-reach [37]. No tailed frog larvae were observed in the LH-reach, probably because of the low gradient and slow current [38,39] created by the restoration project. The abundance of epilithic *Nostoc* colonies likely also limited tailed frog use in the LH-reach (an indirect effect of restoration approach), because *Nostoc* are unpalatable to most stream herbivores [40,41] and because tailed frog larvae have evolved a specialized feeding mechanism for stream-living, whereby they attach to rocks using suction and feed via scraping periphyton from rock surfaces [42].

Predatory fish density and richness (Family Salmonidae) both increased in the HH-reach following restoration, perhaps due to high densities of bioavailable macroinvertebrates and increased habitat quality. We found that four genera of bioavailable macroinvertebrates (three scraper mayflies and a predatory stonefly) were significantly associated with riffle habitats of the HH-reach. Compared with other reaches, the benthic substrate in the HH-reach was less embedded and more loosely anchored, while the stream was wider and shallower, creating a greater diversity of current velocities, microhabitats, and macrohabitats (i.e., pools, riffles). In contrast, the LH-reach had the lowest abundance of bioavailable macroinvertebrates and the lowest variability in habitat parameters (i.e., heterogeneity), probably resulting in low fish diversity and occupancy rates, as heterogeneity is important for fish species during different seasons and life history stages [43,44].

4.3. Mechanisms Contributing to Different Ecological Outcomes

Our analyses suggest that the primary differences in biotic community responses to these restoration projects are related, either directly or indirectly, to stream gradient, substrate, and light availability. The low gradient of the LH-reach resulted in low current velocities which likely caused sediment to settle and embed the rock substrate. We found that these conditions, along with high light availability, favored the mutualistic interaction between *Nostoc parmelioides* and Chironomid larva. The mutualists dominated the benthic community, resulting in poor habitat conditions for tailed frog larvae, most macroinvertebrate genera, and reduced available prey resources for salmonids. These findings suggest that a combination of habitat qualities was the main, direct determinant of differences in ecological outcome of the two restoration projects.

While the more heterogeneous project was more ecologically successful, and thus at a minimum, increasing heterogeneity did not hinder restoration effectiveness, we found inconclusive evidence that habitat heterogeneity itself was the primary driver, as habitat heterogeneity is scale-dependent and varies across space, time, and species. For example, where habitat characteristics in the LH-reach *did* resemble those of other reaches, as was the case in one outlying transect, periphyton and macroinvertebrate community composition was indistinguishable from that of the other reaches. Ostensibly, increasing the number of these microhabitats within the LH-reach would have increased habitat heterogeneity, and perhaps the entire community would have shifted to resemble the HH-reach, but it would still be difficult to determine whether habitat characteristics or heterogeneity itself was responsible. This may be one reason why past restoration studies have found varying effects of increasing habitat heterogeneity on fish [45–47] or macroinvertebrate biodiversity [33]. Time since completion of these projects also did not appear to be important in determining restoration success, as the more recent project was more ecologically successful. The concept of habitat restoration is predicated around the notion that, through successional processes, restored habitats will become more similar to natural conditions with time [9], otherwise restoration actions would need to be continually applied to maintain desired conditions. Likewise, biogeography, the traits of potential colonizers, and elevated contaminant levels were also relatively unimportant in determining ecological success of these two projects since the restoration reaches had similar potential colonizing species, similar connectivity and distance to sources of these species, and the reach with greater post-restoration metalloid concentrations [19] was more ecologically successful.

5. Conclusions

Determining which factors influence the outcome of management actions aimed at improving habitat or maintaining populations is a central question in restoration ecology. Despite the importance of this question, it is rarely answered empirically following project implementation [18], especially in stream or river habitats [3,48]. We found that habitats and communities in restoration sites can quickly (within 1–2 years) resemble reference conditions when holistic restoration techniques are used, when colonizing species are nearby, and when those species are adapted to dynamic environments. However, our findings suggest that "details matter" and in stream restoration, restoring physical characteristics such as historic gradients, may provide a foundation for an ecologically successful project. Interactions between the habitats that we create and between the species that occupy them can be complex, unpredictable, and can influence restoration effectiveness. Understanding and planning for this uncertainty will help guide restoration decisions.

Author Contributions: Conceptualization, R.S.A. and D.S.P.; methodology, R.S.A. and D.S.P.; formal analysis, R.S.A.; investigation, R.S.A. and D.S.P.; data curation, R.S.A.; Writing—Original draft preparation, R.S.A.; Writing—Review and editing, R.S.A. and D.S.P.; funding acquisition, D.S.P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Boise State University (Institutional Animal Care and Use Committee (IACUC) Permit #692-AC11–013).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study can be found at https://www.sciencebase.gov/catalog/ by searching for the article title information.

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Conflicts of Interest: The authors declare no conflict of interest. The funding agency provided fish data and information on the two restoration projects, but had no role in the design of the study; in the collection, analyses, or interpretation of other data; or in the writing of the manuscript, or in the decision to publish the results.

Appendix A

The Stibnite Mine has been a source of sediment, heavy metal (arsenic, antimony, cadmium, lead, mercury, selenium) and cyanide contamination in Meadow Creek and the South Fork Salmon River system for decades. This central Idaho mine produced antimony, tungsten, and gold beginning in the 1930s. Runoff and leaching of contaminants has been a chronic problem for resource managers, as Meadow Creek flows through approximately 3.2 km of mine tailings (Figure 1 of article). Water samples collected by Idaho Department of Environmental Quality on a semi-annual basis from the 1980s to 2000, showed concentrations of arsenic and cyanide that consistently exceeded the Environmental Protection Agency's (EPA) aquatic chronic level, and often exceeded the aquatic acute level for stream-dwelling organisms (Woodward-Clyde 1998). In addition to contaminants, data collected by the Payette National Forest Fisheries Program indicate that Meadow Creek was a primary source of sediment affecting downstream aquatic habitats (M. Faurot, Payette National Forest, unpublished data). In 2001, the EPA proposed to add the Stibnite/Yellow Pine Mining Area to its National Priorities List of the nation's most contaminated hazardous waste sites; "Superfund" sites that are targeted for investigation and cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CIRCLA).

The U.S. Department of Agriculture Forest Service, in cooperation with the EPA and the responsible mining company, initiated two stream restoration projects to reduce human exposure to contaminants in water and fish, and to improve in-stream habitat. The first project (LH-reach), completed in 1998, involved excavating a straight flowing, low gradient stream channel to a depth below the level of the mine tailings, installing a sand filter between the tailings and stream, and armoring the channel bottom and streamside with rock substrate (Woodward-Clyde 1998). This low gradient portion of the channel extends for 1.4 km and then flows into an extremely high gradient section of channel that extends for 0.2 km. The second restoration project (HH-reach) was completed in 2005 in a 1.4 km reach downstream from the first project. The stream channel in this second reach was excavated adjacent to the mine tailings and was constructed with meanders, a moderate gradient, alternating pools and riffles, large wood debris, intermediate benthic substrate sizes, and a riparian zone enriched with transplanted topsoil and planted with approximately 38,000 tree cuttings and seedlings. Just downstream of this restoration project, the newly constructed stream rejoins the original stream channel (Downstream-reach).

The South Fork of the Salmon River and its tributaries, including Meadow Creek, are designated critical habitat for three species listed as threatened under Endangered Species Act: Snake River chinook salmon (*Oncorhynchus tshawytscha*), Snake River steelhead (*Oncorhynchus mykiss*), and Columbia River bull trout (*Salvelinus confluentus*). Westslope cutthroat trout (*Oncorhynchus clarki*), a special status species, also occurs in the drainage. Rocky Mountain tailed frogs (*Ascaphus montanus*) occur in most streams in the area.

Woodward-Clyde. (1998) Stibnite area site characterization report. Unpublished report prepared for The Stibnite Area Site Characterization Voluntary Consent Order Respondents.

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Figure A1. HH-reach in summer 2007. Photo by David Pilliod.

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Figure A2. LH-reach in summer 2007. Photo by Robert Arkle.

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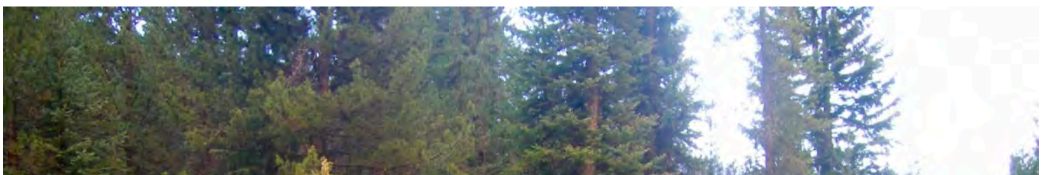

Figure A2. LH-reach in summer 2007. Photo by Robert Arkle.

Figure A3. Downstream-reach in summer 2007. Photo by Robert Arkle.

Figure A3. Downstream-reach in summer 2007. Photo by Robert Arkle.

Figure A4. Upstream-reach in summer 2012. This area burned in 2007 after field sampling was completed. Photo by Robert Arkle.

Figure A4. Upstream-reach in summer 2012. This area burned in 2007 after field sampling was completed. Photo by Robert Arkle.

Appendix B

For MRPP analysis, we report a test statistic (*T*), with increasingly negative values indicating greater multivariate differences between GROUPS, an effect size statistic, *A* (0 to 1), with values of one indicating perfect homogeneity within GROUPS and 0 indicating that within-GROUP homogeneity is no stronger than expected by chance, and a *p*-value indicating whether the mean within-GROUP distance is smaller than the distance expected from chance alone (McCune and Grace 2002).

ISA analysis generates an Indicator Value for each genus by comparing the faithfulness and exclusiveness of genera in the predefined GROUPS (Dufrêne and Legendre 1997;

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ISA analysis generates an Indicator Value for each genus by comparing the faithfulness and exclusiveness of genera in the predefined GROUPS (Dufrêne and Legendre 1997; McCune and Grace 2002). Indicator values were calculated separately for 2006 and 2007 and the statistical significance of these values was examined using a Monte Carlo

McCune and Grace 2002). Indicator values were calculated separately for 2006 and 2007 and the statistical significance of these values was examined using a Monte Carlo randomization technique with 1999 iterations.

Using NMS, macroinvertebrate samples from all eight GROUPS were analyzed and plotted to illustrate the similarity between samples from each reach, to show how communities in each GROUP changed between years of sampling, and to indicate how habitat variables are related to macroinvertebrate community composition. Sorenson (Bray-Curtis) distance was used to measure dissimilarity between sample units (Surber samples). In total, 250 runs of real data and 250 runs of randomized data were used to provide a Monte Carlo test of the statistical significance of each axis generated through the NMS procedure. The proportion of variance represented by each of the final dimensions was evaluated based on the correlation coefficient (r2) between Sorenson distance in ordination space and original space. Linear relationships between community composition and GROUP/habitat variables were examined by correlations between these variables and ordination axes. Genera present in <5 percent of samples were excluded, as rare species can have undue influence on ordination results (McCune and Grace 2002).

In our NPMR analysis, we used the local linear model with Gaussian weighting functions and conducted a free search for the best combinations of predictor variables and their tolerances. Model fit was assessed using a cross-validated R2 value (xR^2), which evaluates the ratio of the residual sum of squares (RSS) to the total sum of squares (TSS) using a "leave-one-out" approach. The xR^2 also controls against over-fitting because no data point contributes to the estimate of its own fitted value. This penalizes model fit as additional variables are added, resulting in a plateau or a decrease in fit with an increasing number of predictors. We applied an additional control against over-fitting by selecting the best-fitting model with a given number of predictor variables only when it resulted in a $\geq$10% increase in xR^2 over the competing model with one fewer predictor variable (i.e., a 10% improvement criterion for adding a predictor variable).

For the best-fitting model, we report the average neighborhood size (N* = average number of sample units contributing of the estimate of density at each point), xR^2, and a *p*-value obtained from Monte Carlo randomizations. This randomization procedure tests the null hypothesis that the fit of the best-fitting model is no better than could be obtained by chance alone using the same number of predictor variables in 100 free search iterations with randomly shuffled density data. We also report tolerance and sensitivity values for each quantitative predictor variable in this model. Tolerance (S.D. of the Gaussian weighting function for each predictor; we also report tolerance as a percentage of the range of each predictor variable) gives an indication of how restricted a species is within the gradient of a give predictor. Higher tolerance values indicate a wider environmental niche with respect to that predictor variable and also that data points with a greater distance from the target point contribute to the estimation of density at the target point, with the weights diminishing with increasing distance from the target point. Sensitivity indicates the relative importance of the predictor variable in the model. A sensitivity of 1 indicates that, on average, changing the value of the predictor by $\pm$5% of its range results in a 5% change in the response variable.

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Appendix C

Table A1. Relative standard error (RSE = standard error/mean) values for each quantitative variable in each sampling reach and year. Higher values reflect greater variability, or heterogeneity, between the 10 transects sampled in each reach and year relative to the mean value. Average RSE values across all habitat variables are provided for each reach and year, as are similar values calculated excluding variables with mean = 0 in a given reach and year (e.g., UNDERCUT, LWD, and COVER in the HH- or LH-reach in 2006 or 2007). The latter calculation removes the effects of a given habitat element being absent from the stream reach. Sediment was not quantified in 2006 and thus, was not included in average calculations for that year.

Variable	2006				2007			
	Downstream	HH-Reach	LH-Reach	Upstream	Downstream	HH-Reach	LH-Reach	Upstream
CURRENT (cm/s)	0.049	0.060	0.095	0.063	0.065	0.090	0.136	0.063
UNDERCUT (% shoreline)	0.933	0.000	0.000	0.290	0.500	0.000	0.000	0.396
Substrate size (mm)	0.075	0.110	0.065	0.081	0.055	0.093	0.057	0.097
Sediment (% transect covered)	-	-	-	-	0.273	0.440	0.126	0.227
Substrate embeddedness (% buried)	0.112	0.135	0.077	0.090	0.090	0.140	0.133	0.055
LWD (% coverage)	0.660	0.000	0.000	0.286	0.267	1.000	0.533	0.300
ORGANIC ($L \cdot m^{-2}$)	0.167	0.190	0.182	0.313	0.556	0.385	0.182	0.406
COVER (%)	0.300	0.600	0.000	0.107	0.243	0.600	0.000	0.228
LIGHT ($kW \cdot m^{-2} \cdot h^{-1}$)	0.042	0.015	0.014	0.096	0.063	0.015	0.014	0.092
Average	**0.292**	**0.139**	**0.054**	**0.166**	**0.235**	**0.307**	**0.131**	**0.207**
Average (excluding variables with mean = 0)	**0.292**	**0.185**	**0.087**	**0.166**	**0.235**	**0.345**	**0.169**	**0.207**

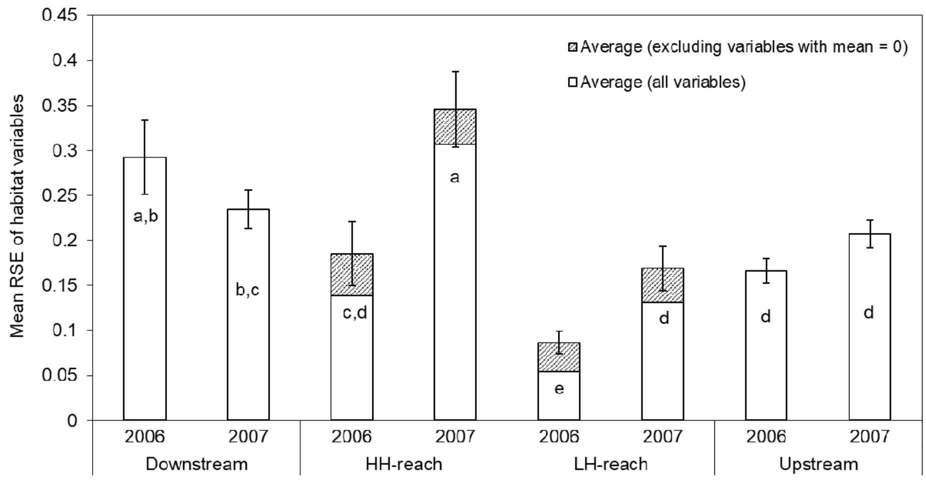
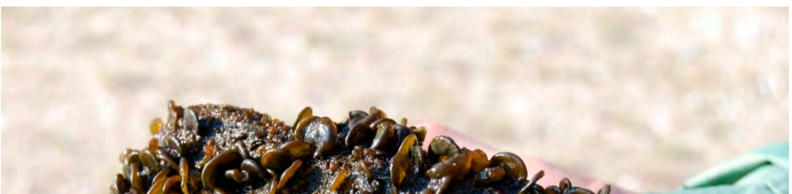


Figure A5. Mean relative standard error (RSE = standard error/mean) values across all quantitative variables measured in each sampling reach and year. Higher values reflect greater variability, or heterogeneity, between the 10 transects sampled in each reach and year relative to the mean value measured in those transects. Included variables are shown in Table A1. Error bars show ± 1 SE for crosshatched bars. Groups with the same letter (i.e., a–e) are not significantly different (α = 0.05) according to Duncan's Multiple Range Test.

Figure C1. Mean relative standard error (RSE = standard error/mean) values across all quantitative variables measured in each sampling reach and year. Higher values reflect greater variability, or heterogeneity, between the 10 transects sampled in each reach and year relative to the mean value measured in those transects. Included variables are shown in Table C1. Error bars show ± 1 SE for crosshatched bars. Groups with the same letter (i.e., a–e) are not significantly different (α = 0.05) according to Duncan's Multiple Range Test.

Appendix D



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Appendix D

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Figure A5. Cyanobacteria colonies (*Nostoc parmelioides*), each containing a Chironomid larva, growing on the surface of a cobble from the LH-reach. The upper surface of the rock was exposed to the current, whereas the lower half was embedded in other cobbles and sediment. Each disk-shaped colony is approximately 1 cm diameter. No other macroinvertebrates were removed prior to the photograph being taken, yet few if any, are visible. Photo by David Pilliod.

Figure A6. Cyanobacteria colonies (*Nostoc parmelioides*), each containing a Chironomid larva, growing on the surface of a cobble from the LH-reach. The upper surface of the rock was exposed to the current, whereas the lower half was embedded in other cobbles and sediment. Each disk-shaped colony is approximately 1 cm diameter. No other macroinvertebrates were removed prior to the photograph being taken, yet few if any, are visible. Photo by David Pilliod.

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