The Track Record of Environmental Impacts Resulting from Pipeline Spills, Accidental Releases and Failure to Capture and Treat Mine Impacted Water

U.S. Gold Mines
Spills & Failures Report

EARTHWORKS

Great Basin Resource Watch

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Report available at earthworksaction.org/USgoldminefailures

COVER PHOTOS, TOP - DOWN:
Pit lake at Lone Tree Mine, Nevada. Photo by Bruce Gordon.
Acid mine drainage at Kensington Mine, Alaska. Photo by U.S. Forest Service.
Cyanide warning sign at Hycroft Mine, Nevada (formerly Crofoot Lewis).

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Earthworks is dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions.

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Great Basin Resource Watch is a regional environmental justice organization dedicated to protecting the health and well being of the land, air, water, wildlife, and human communities of the Great Basin from the adverse effects of resource extraction and use.

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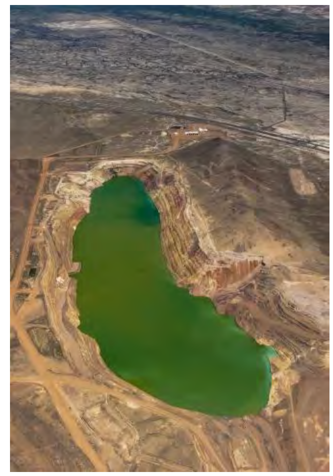
Introduction

Gold mining is a significant source of toxic releases in the U.S. – including releases of cyanide, arsenic, mercury, cadmium and other hazardous substances to the air, water and land.[1]

The most common method for processing gold from mining is cyanide leaching, which uses cyanide to extract gold and other metals from ore. Cyanide leaching facilitates the mining of low-grade ores, generating large volumes of mine waste that become a permanent feature on the landscape.

This mine waste, as well as the processing chemicals used to extract the gold, can be a source of pollution to surface and groundwater. Because virtually everything that is mined becomes waste, and this waste is disposed of on the mine site, the toxic materials contained in the waste are permanent as well.



Lone Tree Mine pit lake.
Photo by Bruce Gordon.

This report compiles the record of spills and seepage control failures at operating gold mines in the United States and documents associated water quality impacts.

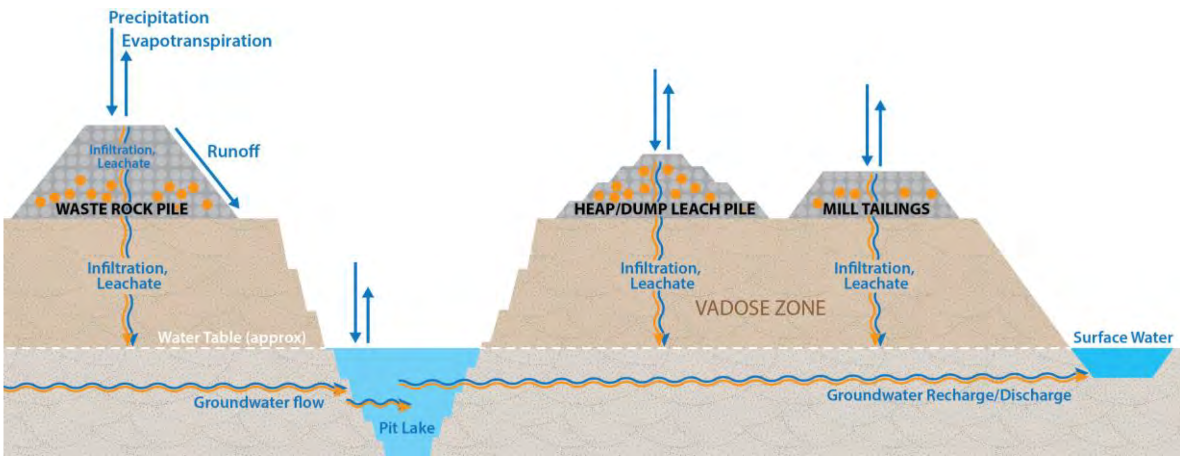
The mine facilities where releases of hazardous materials can occur include heap leach pads, tailings impoundments, pipelines, process water ponds, waste rock piles and pit lakes.

- **Heap leach pads:** Heap leach pads are used to process lower grade ore using surface irrigation with a sodium cyanide solution, which picks up gold and other metals as it infiltrates through the ore. Leach pads often have one containment liner that serves as the primary capture for the gold and cyanide-laden (pregnant) solution. Some mines incorporate two liners. The second liner is used to monitor for leakage of the primary liner. Despite the existence of these liners, leakage still occurs when the liner is compromised or degrades over time.
- **Tailings:** Higher grade ore is crushed and combined with processing chemicals in large vats. The waste product, called tailings, are usually stored as a fine textured slurry behind an earthen dam. In most cases these tailings impoundments are not lined.
- **Process ponds** are lined, of much smaller size and are typically completely removed as part of the reclamation process.
- **Heap leach pads, tailings impoundments and process solution ponds** generally contain high levels of metals and cyanide, so containment is vital to avoid contamination. These facilities can be a long-term source of pollution if reclamation and long-term maintenance are inadequate.

Acid mine drainage, Kensington Mine, Alaska. Photo by U.S. Forest Service.

Acid mine drainage can develop at gold mines where sulfide minerals are present. When sulfide minerals are exposed to air and water, they react to form sulfuric acid, which can leach minerals from the surrounding rock to form acid mine drainage. If the acid mine drainage is not contained, it becomes a long-term source of contaminants.

When mining occurs below the water table, dewatering is required to keep the mine dry. Once mining operations cease, ground water seeps back into the underground mine workings, or back into the pit to create a pit lake. For open pit mines, since most gold mines occur in areas of high evaporation, the flow of water is typically into the open pit. However, if outflow occurs, groundwater can be degraded since pit lake water and water from underground mine workings is typically of poorer quality than the surrounding groundwater.



This diagram illustrates the various mine components that can become a source of contaminants to surface and/or groundwater.

Methods

This report is based on information gathered from an extensive review of state and federal documents, news reports, and a federal database. It provides data for 27 operating U.S. gold mine operations, representing 93% of U.S. gold production in 2013 – the most current data on U.S. gold production available from the U.S. Geological Survey.[2] The report focuses on documenting two failure modes:

1) pipeline spills and/or other accidental releases of hazardous materials[3] and
2) seepage collection and treatment failures.[4]

Although the report focuses on water quality impacts, soil impacts may also occur from a hazardous release. This report does not catalog soil impacts.

Most of the mines in this report are primarily gold producers. However, gold can be produced as a by-product at other metal mines (e.g., copper, zinc/lead operations). This report includes data from the Bingham Canyon, Robinson and Greens Creek mines because gold is a significant by-product as identified in the 2013 U.S.G.S. gold report. The report did not evaluate the Cresson (Cripple Creek and Victor Mine), an operating gold mine in Colorado, due to the difficulty in obtaining comprehensive information on the site.

Results

Our research determined that 100% of the mine operations reviewed in this report experienced at least one failure, with most mines experiencing multiple failures.

- **27 of the 27 mining operations (100%) have experienced at least one pipeline spill or other accidental release**, such as spills of cyanide solution, mine tailings, diesel fuel, and ore concentrate.
- **20 of the 27 mining operations (74%), have failed to capture or control contaminated mine seepage**. The seepage of cyanide solution was one of the more common impacts. The development of acid mine drainage was associated with some of the most lasting impacts.
- **Water quality impacts to surface and/or groundwater were identified at 20 of the 27 mining operations (74%)**, including impacts to drinking water supplies for residential homes and businesses, loss of fish and wildlife habitat, and fish kills.
- **Water quality impacts were not identified at 7 out of 27 mining operations**. At 6 of those 7 mines (86%), no perennial streams were present in the project area and groundwater was generally deep.

Research shows that mines with high acid generating potential and in close proximity to surface and groundwater are at highest risk for water quality impacts.[5] Availability of water is key to the development of acid drainage and the extent of containment. Many of the currently operating gold mines are located in the arid southwest, where precipitation is low (often less than 10 inches per year). Thus, the potential for surface precipitation to carry contaminants to the groundwater is significantly limited. Acid mine drainage will require water treatment and capture in perpetuity at the Bingham Canyon Mine, Golden Sunlight Mine, and Phoenix Mines, among others.

At 6 of the 7 gold mines where water quality impacts were not identified (e.g., Bald Mountain, Ruby Hill, Mineral Ridge, Mesquite, Denton/Rawhide, Turquoise Ridge) no perennial streams are present in the project area and groundwater is generally deep (>250 feet). For example, at the Denton Rawhide mine in Nevada, groundwater is so deep that it has not been located and there is no surface water within five miles of the mine. Impacts to ephemeral streams, where water flows only briefly after rainfall events, are more difficult to assess. Monitoring opportunities are limited, and in some cases ephemeral streams are not protected by the provisions of the Clean Water Act.[6] For example, at the Mineral Ridge Mine, the ephemeral streams in the mine area were determined to be non-navigable, and therefore, not subject to the water quality protections and monitoring requirements provided by the Clean Water Act.[7]

The ability to fully realize the extent of impacts is hampered by the limitations of monitoring. Often seepage from tailings or other mine facilities are recognized by a visual inspection of the containment dam. However, seepage can and has occurred from portions of a facility that are not monitored or difficult to monitor. In many cases, documentation of the failure does not occur until contamination reaches the nearest down gradient water monitoring point. As stated above, the depth to groundwater can be great and there is the potential that a containment failure could occur and not be noticed until after the mine is closed. Despite the incorporation of leak detention systems, which are applied at most new mines, (regulations vary from state to state) many failures of containment occur beyond detection.

TABLE 1 - 2013 gold production amounts for mines reviewed in this report			
Mine	**Location**	**Company**	**2013 Gold Production (Kilograms)**
Newmont Operations	NV	Newmont	53,200
• Carlin Operations			
• Phoenix			
• Twin Creeks			
Cortez and Pipeline Mines	NV	Barrick	41,600
Goldstrike	NV	Barrick	27,700
Fort Knox/True North	AK	Kinross	13,100
Pogo	AK	Sumitomo (50%); Barrick (50%)	10,400
Smoky Valley	NV	Kinross (50%); Barrick (50%)	9,700
Turquoise Ridge	NV	Barrick	6,970
Bingham Canyon	UT	Kennecott	6,430
Hycroft	NV	Allied Nevada	5,940
Marigold	NV	Goldcorp	5,080
Kettle River - Buckhorn	WA	Kinross	4,670
Jerritt Canyon	NV	Veris Gold	4,340
Kensington	AK	Coeur Mining	3,570
Mesquite	CA	New Gold	3,330
Bald Mountain	NV	Barrick	2,920
Golden Sunlight	MT	Barrick	2,860
Ruby Hill	NV	Barrick	2,830
Greens Creek	AK	Hecla	1,790
Wharf	SD	Goldcorp	1,750
Robinson	NV	KGHM International	1,480
Florida Canyon	NV	Jipangu	1,440
Mineral Ridge	NV	Scorpio	1,220
Briggs	CA	Atna Resources	990
Rochester	NV	Coeur Mining	960
Denton Rawhide	NV	Rawhide	743
Total production of listed mines			215,013
Total U.S. production[8]			230,000
Percent of total U.S. production			93%

TABLE 2 - Synopsis of pipeline spills and other accidental releases, and mine water capture and treatment failures (e.g. seepage) for U.S. gold mines				
Mine Operations	**Pipeline spills and/or other accidental releases***	**# of pipeline spills and/or other releases**	**Mine water collection and treatment failures**	**Water quality Impacts to surface water and/or groundwater**
Carlin Operations	YES	11	YES	Cyanide has exceeded water quality standards in Maggie Creek and James Creek. Groundwater has also been degraded by cyanide.
Phoenix	YES	4	YES	Springs and seeps have exceeded drinking water standards for antimony, arsenic, beryllium, cadmium, copper, chromium, fluoride, iron, magnesium, manganese, mercury, nickel, nitrate, pH, sulfate, total dissolved solids, and zinc. Surface water has been adversely affected by acid mine drainage. Groundwater has exceeded water quality standards for many pollutants.
Twin Creeks	YES	38	YES	Groundwater has been degraded with cyanide, arsenic, total dissolved solids, and there have been water quality violations for arsenic in Rabbit Creek. Cyanide solution has also reached Kelley Creek.
Cortez and Pipeline Mines	YES	31	YES	Groundwater has been degraded with arsenic, sulfates, total dissolved solids and cyanide.
Goldstrike North Operations	YES	12	YES	Springs in Antelope Creek drainage have been adversely affected by acidic seepage (low pH).
Fort Knox/ True North	YES	2	None identified	None identified.
Pogo	YES	1	YES	Groundwater has been degraded and there have been violations of surface water quality standards for manganese, pH, cyanide and iron for discharges to the Goodpaster River.
Smoky Valley (Round Mountain)	YES	49	YES	Groundwater has been degraded with cyanide.
Turquoise Ridge	YES	36	None identified	None identified. There are no perennial streams in the project area.
Bingham Canyon	YES	28	YES	Waste water from the mine has escaped the site's collection system, contaminating groundwater with metals, pH and sulfates. The groundwater plume covers more than 72 square miles – rendering water for thousands of Salt Lake City residents undrinkable.[9] Water treatment in perpetuity will be required at this mine to treat acid mine drainage. The release of hazardous pollutants has harmed natural resources, including migratory birds and their support ecosystems, which includes wetlands, marshes, freshwater wildlife habitats, playas and riparian areas and freshwater ponds.
Hycroft	YES	16	YES	Water quality standards for cyanide, mercury selenium and nitrates have exceeded water quality standards in groundwater.
Marigold	YES	14	YES	Groundwater has been degraded with chloride, total dissolved solids and cyanide.
Kettle River (Buckhorn)	YES	1	YES	The mine has degraded water quality in Gold Bowl Creek, Nicholson Creek, Upper South Fork Bolster Creek and Marias Creek, as well as groundwater, seeps, and springs. Water quality violations occurred for exceedances of total dissolved solids (TDS), total suspended solids (TSS), ammonia, arsenic, chloride, copper, lead, mercury and zinc.[10]

Mine Operations	Pipeline spills and/or other accidental releases*	# of pipeline spills and/or other releases	Mine water collection and treatment failures	Water quality Impacts to surface water and/or groundwater
Jerritt Canyon	YES	40	YES	Water quality standards in groundwater have been exceeded for chloride, arsenic, sulfates, total dissolved solids and trichloroethane, and groundwater has been degraded by cyanide, and in some cases antimony, cadmium, magnesium, mercury, nitrates and selenium. Surface water has been impaired in Sheep Creek, North Fork Humboldt River and South Fork Owyhee.
Kensington	YES	2	YES	Acid mine drainage has degraded water quality in Lower Slate Lake and mine discharges have caused water quality violations for manganese, zinc, aluminum and cadmium in East Fork Slate Creek. Water treatment in perpetuity will be required due to acid mine drainage.
Mesquite	YES	15	None identified	None identified. No perennial streams. The closest perennial surface water is approximately 15 miles southwest of the site.
Bald Mountain	YES	12	None identified	None identified. There are no perennial streams in the project area.
Golden Sunlight	YES	10	YES	The mine has violated water quality standards for cyanide in groundwater, and adversely affected groundwater in four domestic wells and a veterinary clinic. Water treatment in perpetuity will be necessary to capture and treat acid mine drainage.
Ruby Hill	YES	3	None identified	None identified. No perennial streams exist in the permit area and ephemeral drainages were to be eliminated with the construction of the East Archimedes pit.
Greens Creek	YES	8	YES	Surface water in Further Creek, Further Seep and Duck Blind Drain has been degraded with sulfates, lower pH and zinc. Surface water quality standards for zinc and lead have been violated as a result of discharges into Greens Creek, and violations have occurred as a result of discharges of diesel oil and drilling mud to Zinc Creek. Contaminated sediments in Hawk Inlet have occurred as a result of a spill of ore concentrate. Groundwater has been degraded with sulfates.
Wharf	YES	11	YES	Exceedances of water quality standards for nitrates, arsenic and cyanide in groundwater. Annie Creek has been polluted with selenium, ammonia, cyanide, arsenic above water quality standards. Adverse impacts to surface water in Annie Creek resulted in a fish kill, and adverse impacts to the fish population.
Robinson	YES	15	YES	The mine has caused groundwater degradation, and a consent decree was executed in response to a major release of mine tailings process water that harmed 2.3 miles of stream bed.
Florida Canyon	YES	25	YES	Water quality standards for cyanide, mercury and nitrates have been exceeded in groundwater.
Mineral Ridge	YES	3	None identified	None identified. No springs or seeps are located within the Project Area and only ephemeral drainages are present.
Briggs	YES	2	YES	Water quality standards for cyanide have been exceeded in groundwater.
Rochester	YES	12	YES	Groundwater has been degraded with arsenic, mercury, manganese, nitrate/nitrite, total dissolved solids and cyanide. American Canyon (an intermittent drainage) has been adversely affected by process solution. Exceedances of water quality standards for nitrate and arsenic have occurred in American Canyon springs.
Denton Rawhide	YES	10	None identified	None identified. Groundwater was not located, and there is no surface water within 5 miles of the mine.

*Limitations in the data for pipeline spills and other accidental releases make it difficult to determine, in some cases, whether water quality impacts resulted from the spill.

Mine Operations Data

Carlin Operations, NV[11]	
The Carlin Operations are located in Eureka County, Nevada, between 6 and 21 miles north of the town of Carlin and 35 to 40 miles west of Elko. The Carlin Operations include the North and South Area Operations. The South Area Operations site is located in Eureka County, Nevada and consists of the Gold Quarry open pit mine. The North Area Operations site is located in Eureka and Elko Counties, Nevada. The operation consists of: 1) The Carlin, Genesis/Blue Star, Post, Bootstrap/Capstone, Tara, Beast, Sold, North Star, Payraise, Bob Star, Bobcat, Pete, Castle Reef, and Crow open pits; 2) Carlin, Deep Star, Deep Post, and Leeville underground mines.	
Reports of pipeline spills and other accidental releases[12]	According to the 2014 NPDES Fact Sheet, mill tailings, and sewage from the Carlin North and South area facilities are pumped to the Mill 5/6 Tailings Storage Facility Booster Pump House. Over the years, failures of pipelines, pumps, and valves have resulted in excursions of tailings slurry and associated process solution outside the original limited containment of the Mill 5/6 Tailings Storage Facility Booster Pump House and onto unlined areas.[13] **July 9, 2014:** At Gold Quarry, 6,400 gallons of process solution (.33 mg/L WAD cyanide) was spilled due to a damaged pipeline from construction activity. April 29, 2008: A report of a release from the slurry tank of 110,632 gallons of cyanide solution.[14] The release affected soil and a roadway. **December 21, 2000:** A report of 69,000 gallons of pregnant solution released from pregnant pond leak detectors in North Area leach facility due to unknown causes.[15] **June 16, 1997:** A news report of 245, 000 gallons of cyanide solution released as the result of a heap leach pad failure and discharged into James Creek. About 18,000 gallons then flowed into Maggie Creek.[16] Cyanide levels were well above drinking water standards when the spill reached Maggie Creek. The spill was caused when material on the leach pad slid, breaking a cyanide solution line. The company reported fish fatalities. **August 17, 1993:** A report of a release of 1.58 pounds of mercury from sump pump leak due to a broken shaft.[17] **April 16, 1990:** A report of 13 pounds of cyanide spilled due to failure of drainage valve in storage tank.[18]
Seepage collection and treatment failures	In 2012, acid mine drainage was observed seeping from the south wall of the Pete Pit and forming a small pit lake in the spring of 2011 after a small pit wall failure.[19] A makeshift HDPE-lined sump was constructed to collect the drainage and transport it via water truck to the Leeville De-Sedimentation Project. In the summer/fall of 2012 an additional splay of the Pete Pit stormwater diversion ditch was constructed to collect and divert stormwater from an area below the existing diversion ditch but above the rim of the Pete Pit. It is hoped that this additional diversion will dry up the acid mine drainage seep in the Pete Pit. In 1990, it was determined, based on the presence of cyanide and elevated Total Dissolved Solids (TDS) in downgradient monitoring wells, that the James Creek Tailings Storage Facility at Gold Quarry was leaking process solution into groundwater.[20] Pumpback wells were installed to achieve compliance by 1996.
Impacts to water resources	Cyanide has exceeded water quality standards in Maggie Creek and James Creek. Groundwater has also been degraded by cyanide.

Phoenix Mine, NV The Phoenix Mine is located in north-central Nevada in Lander County, 12 miles southwest of Battle Mountain. The mine is located on public BLM lands and private lands. The mine was originally permitted in 2003.	
Reports of pipeline spills and other accidental releases	**June 3, 2014:** Cyanide solution release occurred as a result of leaks in the leach pad. The holding pond for the leach pad leaked fluid, which were released into the soil. Soil contamination near the leach pad is possible. Dead ducks were found in the holding pond. Some contaminated items – acid, copper and lead – taken to the local landfill within 3 weeks.[21] **Feb 10, 2014:** 1,404 gallons of tailings seepage leaked as a result of overflow from the seepage tank. The seepage was collected from the North Fortitude Waste Rock Facility.[22]Dec 12, 2013: 200 gallons of 93% sulfuric acid were released to pavement and ground during offloading from delivery tanker to storage tank due to a hose coupling failure during the transfer. Affected soils were to be removed and placed on the copper heap leach pad. The contaminated soil was replaced with clean fill.[23] **February 26, 2008:** A failure of the tailings pipeline resulted in the release of approximately 49,000 gallons of tailings slurry. The pipeline was quickly repaired however further investigation revealed the presence of HDPE liner fragments within the Tite- Liner® pipe, indicating that the internal liner surface has started to shear (peel) off.[24]
Seepage collection and treatment failures	**2006:** Seepage of a small quantity of low pH and poor quality water was discovered at the toe of the historic Box Canyon Waste Rock Facility (BCWRF) in early 2006, following an intense precipitation event. Flow was estimated at approximately 2 gallons per minute. An EDC was approved 11 September 2006, to construct a solution collection, conveyance, and storage system at the toe of the Box Canyon Waste Rock Facility, similar in design to that constructed for the North Fortitude Waste Rock Facility seeps.[25] **2005:** Seepage of low pH and poor quality solution emanating from a portion of the southern toe of the North Fortitude Waste Rock Facility (NFWRF) was noted in June 2005 and formally inspected during a 30 August 2005 compliance inspection. Flow emanates from two locations along a 300-foot width of the toe and ultimately migrates to a natural drainage and into the Fortitude Pit along the north pit wall. The seepage rate averages approximately 2 gpm except during storm events when the solution volume is significantly increased by meteoric contributions reporting to the waste rock facility and the natural drainage watershed area. Solution at the seep exhibits an average pH of 3 and the Fortitude Pit Lake exhibits an average pH of 4 or less. Solution at both locations also reports exceedances for numerous Profile I constituents.[26] **2002:** Ground water from the Gold Tailings Facility (monitoring wells CVM-1, CM-22, CM-24, PW-1, PW-4), contains elevated concentrations of chloride, sodium, and sulfate, which is the result of a solute plume originating from the Gold Tailings Facility. This plume is the result of an unlined disposal area that was used for copper and gold tailings intermittently from 1965 to 1993. The chloride plume is currently being managed under the State of Nevada Water Pollution Control Permit.[27] **2002:** According the 2002 Final Environmental Impact Statement, iron concentrations were highest in the ground water samples from the Copper Leach Area and the Midas Pit, reaching 1,500 and 100 milligrams per liter, respectively. However, ground water samples throughout the study area had iron concentrations that exceeded the secondary drinking water standard of 0.6 milligrams per liter, including the Copper Leach Area, Fortitude Pit, Galena Canyon, Iron Canyon, Midas Pit, Philadelphia Canyon, proposed Phoenix Pit, proposed Reona Pit, and the West Copper pit.

	PHOENIX MINE, NV - CONTINUED Manganese concentrations show a pattern similar to iron, reaching their highest level of 190 milligrams per liter at the Copper Leach Area and showing widespread exceedances of the secondary drinking water standard of 0.1 milligram per liter over the entire study area, including Buffalo Valley, Copper leach Area, Fortitude Pit, Fortitude Waste Rock Facility, Galena Canyon, Iron Canyon, Midas Pit, Philadelphia Canyon, proposed Phoenix Pit, proposed Reona Pit, and East Copper Pit. Aluminum concentrations exceeded the secondary drinking water standard of 0.2 milligrams per liter in ground water samples from the Midas Pit and the proposed Phoenix Pit, although aluminum was not determined for all samples.[28] "The most acidic surface waters occurred adjacent to historic mining facilities and mineralized areas (e.g., Iron Canyon and Butte Canyon). The total dissolved solids concentrations in samples from these surface waters often exceeded the drinking water standard of 500 milligrams per liter and had pH values less than the drinking water standard of 6.5 (Figure 3.2-6). These surface waters also had the highest metal concentrations. In general, the metal concentrations in these springs and seeps exceed drinking water standards for antimony, arsenic, beryllium, cadmium, copper, chromium, fluoride, iron, magnesium, manganese, mercury, nickel, nitrate, pH, sulfate, total dissolved solids, and zinc. "The combination of low pH and high dissolved metal and sulfate concentrations reported for surface waters, found near historic mining facilities and mineralized areas, indicates that acid rock drainage exists. Acid rock drainage is caused by water and air interacting with sulfide minerals commonly present in ore deposits. This result has been observed in surface water from Iron and Butte Canyons."[29] Groundwater at the site has been affected by the numerous leaks and seepages from mine facilities. "The oxidation of sulfide minerals is the primary cause of acid rock drainage observed in the surface and ground water monitoring locations adjacent to existing mines and excavated areas."[30] The Fortitude Pit Lake water is of poor quality. Based on the 2005 analysis of the treated water, Nevada Profile I maximum contaminate level (MCL) exceedances were reported for sulfate, lead, nickel, manganese, cadmium, and total dissolved solids.[31] The pit lake is being dewatered currently for water use at the mill. **1998:** Low quality stormwater drainage was noted in the Iron and Butte Canyons. Battle Mountain Gold began collecting and treating acidic surface water from Iron Canyon and Butte Canyon in April 1998 (Brown and Caldwell 1998c).[32] Acid mine drainage continues from these areas. As of the end of 2015, acidic water (pH 2.81 – 3.21) was collected from the Iron Canyon drainage.[33] Dead ducks were found in the leach fluid leak holding pond.
Impacts to water resources	Springs and seeps exceeded drinking water standards for antimony, arsenic, beryllium, cadmium, copper, chromium, fluoride, iron, magnesium, manganese, mercury, nickel, nitrate, pH, sulfate, total dissolved solids, and zinc. Surface water has been adversely affected by acid mine drainage. Waterfowl fatalities have occurred. Water quality exceedances have also occurred in groundwater.

Twin Creeks Mine, NV

The Twin Creeks Mine (Rabbit Creek and Chimney Creek Mines) is located on private and public land approximately 26 miles northeast of Golconda, NV. The open pit mine was permitted in 1997.

Reports of pipeline failures and other accidental releases[34]	**July 26, 2016:** 4,000 gallons of process solution (no cyanide content) was spilled due to a drain valve failure. **July 15, 2015:** 24,000 gallons of process water containing 0.006 lbs. of cyanide was spilled when a process line split. **June 30, 2013:** Approximately 191,000 gallons of tails slurry was released due to a disconnect elbow joint in the line. **September, 5 2012:** 2,984 gallons of process solution of unknown concentration was spilled when a mill line failed. **February 20, 2013:** 9,200 gallons of tails slurry containing 0.52 lbs. of cyanide was released due to a separated flange on the CIL-Tails discharge line. **September 17, 2012:** 1,253 pounds of carbon containing 1.74 lbs. of mercury was released in a landfill from a baghouse sock malfunction. **February 1, 2008:** 800 gallons of barren cyanide solution with a concentration of 18 mg/L was spilled due to a pump failure resulting in an overflow. **September 11, 2007:** Approximately 45,000 gallons of barren solution containing about 68.93 lbs. of cyanide was spilled when a pipeline was ruptured by a large rock dislodged during road/ramp widening. **January 6, 2007:** 200 gallons of ammonium nitrate solution was spilled when a trailer rolled over and down a ditch. **2007:** A report of a release of cyanide solution onto the ground from a process pipe. Report incident 848526. **October 11, 2005:** 1,500 gallons of tails slurry containing 51 mg/L cyanide was released as a result of a pipe failure. **June 16, 2005:** 24,000 gallons of process solution containing .89 pounds of sodium cyanide spilled when construction damaged a pipeline. **May 23, 2005:** 67,500 gallons of 11.8 WAD cyanide solution (tails underdrain) spilled when a bulldozer ruptured double HDPE line. **January 2, 2005:** About 2,000 gallons of tails solution containing cyanide spilled. **January 8, 2004:** 37,500 gallons of process solution containing 0.6 pounds of sodium cyanide seeped through six locations along the tailings embankment. **May 21, 2004:** About 200 pounds of ore containing arsenic trisulfate was assumed to be released during hauling. **October 31, 2003:** About 1,200 pounds of ore containing arsenic spilled during the cleaning of trailers. **October 28, 2003:** 300 pounds of Getchell containing 3.5 of arsenic compounds spilled. **July 17, 2003:** An estimated 60,000 gallons of water containing 56 micrograms per liter of arsenic were discharged into Rabbit Creek as a result of a leak in the main supply valve. TWIN CREEKS MINE, NV - CONTINUED

Reports of pipeline failures and other accidental releases	**May 9, 2003:** 1.4 million gallons of water containing arsenic at 260 ug/L of arsenic were released as a result of pipeline break. Newmont was able to pump about 444,600 gallons back into containment. **January 21, 2003:** 500 gallons of lime with mill water solution of unknown cyanide concentration spilled due to a failed fitting on a pump. **2003:** Process columns in the mill overflowed, releasing approximately 34 pounds of cyanide.[35] **August 13, 2002:** 1,500 gallons of process solution containing 1.30 pounds of cyanide spilled when a slurry line coupler failed. **August 12, 2002:** 900 gallons of mill water with a cyanide concentration of 0.003 mg/L escaped when a hose was left unattended. **May 13, 2002:** 24,000 gallons of process solution containing 34 pounds of cyanide was released when process columns overflowed. Some of the solution made its way to Rabbit Creek and then to Kelley Creek. **April 8, 2002:** 3,500 gallons of mill water containing 0.0134 pounds of cyanide spilled when a hose was left unattended. **2002:** 24,000 gallons of cyanide solution spilled at a mining facility, as a result of an overflow of process solution from the Pinion Mill at the Twin Creeks Mine, owned by Newmont Mining Company. A Nevada official said 5,000 gallons entered Rabbit creek.[36] **January 30, 2002:** 4,000 and 30,000 lbs. of Getchell gold ore containing 8.7 and 65 lbs. of arsenic sulfide in the matrix spilled from failures in the hydraulic systems in dumping trucks. **January 8, 2002:** 1,200 lbs. of Getchell ore containing 2.6 lbs. of arsenic sulfide spilled by the roadside and discovered later. **October 24, 2001:** 3,000 gallons of barren solution containing 2.32 lbs. of cyanide spilled due to a pipeline failure. **2001:** A report of a release of an estimated 75 pounds of cyanide after the line was flushed and left open for 30 hours causing a release. The spill reached Rabbit Creek.[37] **2001:** When flushing a heap leach line the valve on the line was left open for 36 hours, releasing cyanide solution.[38] **December 8. 2000:** 1.5 tons of gold ore containing arsenic trisulfide (5%) spilled from the transport trunk from operator error, and was recovered. **November 13, 2000:** 3,000 gallons of water containing 0.27 pounds of cyanide spilled due to a frozen line. **November 1, 2000:** 1,000 gallons of reclaimed water containing 0.39 pounds of cyanide spilled due to a frozen line. **March 3, 2000:** 16 lbs. of mercury spilled when a bucket was tipped over a scissors lift. **December 28, 1999:** 500 gallons of solution containing 0.0104 lbs. of WAD cyanide spilled due to a malfunction in the filter plant. **1997:** On May 2, thousands of gallons of cyanide solution used to leach gold from crushed rocks were flushed into the desert. The mine reported 8,100 gallons.[39]

Seepage collection and treatment failures	**TWIN CREEKS MINE, NV - CONTINUED** The Pinon tailings impoundment formed a leak which caused a perched zone with poor water quality including high concentrations of WAD cyanide, arsenic, TDS and other constituents.[40] Water discharged to Rabbit Creek has shown occasional exceedances (by 1-10 times) of total dissolved solids and arsenic (over 10 times).[41]
Impacts to water resources	Groundwater has been degraded with cyanide, arsenic, total dissolved solids, and there have been water quality violations for arsenic in Rabbit Creek. Cyanide solution has also reached Kelley Creek.

Cortez Hills and Pipeline Mines, NV The Cortez operations, owned by the Cortez Joint Venture, are located on a combination of public (BLM) and private land in Lander County. The operations are a mix of inactive and active open pit and underground mine facilities.	
Reports of pipeline spills and other accidental releases[42]	**October 4, 2016:** 5,000 gallons of contact water were spilled due a broken valve. **August 31, 2016:** 24,000-gallon spill of infiltration water form Pipeline mine. Possible elevated arsenic levels in infiltration water. **February 24, 2015:** Barren solution release of about 2,000 gallons due to a failure of a pressure relief valve. A total of about 1.2 pounds of cyanide were released. **October 29, 2014:** About 61,172 gallons of contact water were released from a pressure relief valve that froze and cracked. Estimated amount of arsenic discharged to the environment is 0.5 lbs. **1992-1994:** Twenty-seven spills involving cyanide-containing process solution occurred between July 1992 and December 1994 at Cortez. The majority of the spills were caused by equipment failures or operator error.[43] For example, in July 1992 a ruptured line to the leach pad resulted in 50,000 gallons of barren solution being sprayed across a road and collected in a 100' x 40' gully. Twenty pounds of cyanide were released. In November 1994, a grader hit and ruptured a hose at an inactive impoundment area releasing 140,000 gal of process solution and 50 lbs. of sodium cyanide. Other noteworthy spills occurring during the period include 330,912 lbs. of slurry with a concentration of 2.8 mg/l WAD CN at the #2 thickener in February, 1994 and 256,192 gallons of toe seepage solution with a concentration of 0.042 mg/l WAD CN at tailings impoundment 6 in October, 1994. The remaining spills involved a total of between 225 and 100,000 gallons of roaster calcines, barren solution, pregnant solution, tailings material, reclaim solution and cyanide containing groundwater.[44]
Seepage collection and treatment failures	At the Cortez Mine, six monitoring wells were installed around the perimeter of Tailings Impoundments 1,2,3 and 4 in 1969.[45] These monitor wells were sampled occasionally, revealing cyanide. In 1980 an area of degraded shallow groundwater was identified downgradient of tailings impoundment 5. In the 1980's multiple monitor wells were installed, and then converted to pumpback wells to pump out the degraded water. According to the Nevada Department of Environmental Protection (NDEP) Fact Sheet, "Solution from Tailings Impoundments 1, 2, 3 through Tailings Impoundment 6 and the East and West heap leach pads is the likely cause of contamination in the shallow groundwater aquifer. Arsenic, sulfate, total dissolved solids (TDS), and cyanide are the remaining constituents of concern."[46] The fact sheet also reports that poor water quality and Profile 1 reference value exceedances were reported from Monitoring Well-09A in a 2008 report (chloride at 3000 mg/l; nitrate as N at +130 mg/l: total dissolved solids at 10,500 mg/l; sulfate at +3,400 mg/L). Final permanent closure of Pregnant Pond 2 was approved, which included the removal and appropriate disposal of all pipelines, pumps, tanks, and associated infrastructure. The site was backfilled and recontoured to promote free drainage from the site. Water quality in MW-09A has not improved since the closure.
Impacts to water resources	Groundwater degradation with arsenic, sulfate, cyanide and total dissolved solids (TDS).

Barrick Goldstrike – North Block, NV The North Block operations consist of the Betze open pit and Meikle and Rodeo underground operations. The operations are located on BLM lands and private lands north of Carlin, Nevada.	
Reports of pipeline failures and other accidental releases[47]	**July 16, 2016:** 559 gallons of process solution containing thiosulfate was spilled due to a hose failure on a sump pump. **January 2, 2016:** 3,000 gallons of "Milk of Line" was released with unknown constituents due to a level indicator malfunction on the pH control line. **August 27, 2015:** 3,000 gallons of calcium thiosulfate solution was spilled due to a hose failure on a pump. After cleanup composite soil samples still indicated "significant thiosulfate concentrations were present." **May 28, 2015:** 9,700 gallons of process water was released containing thiosulfate and possibly metals. **April 28, 2015:** About 1,700 gallons of autoclaved ore slurry containing metals was released due to a failure of a valve on a reclaim water tank **April 28, 2015:** About 11,000 gallons of tailing reclaim solution containing heavy metals was released due to operator error. **August 16, 2012:** 2,805 gallons of caron-in-leach slurry was released due to operator error. **August 18, 1996:** 4,250 gallons of reclaim water was released from Mill #2 during an unscheduled shutdown of Mill #1. The valves on top of Mill #1's reclaim water tanks failed to close causing the sumps at Mill #2 to become overwhelmed, resulting in a loss of containment.[48] **August 9, 1996:** Approximately 1,500 pounds of ammonia vapor was released from the refrigeration building through the building's ventilation system. The release was caused by the failure of a Bi-Lok type fitting on an oil tube at one of the refrigeration machines. **February 27, 1996:** 2,000 gallons of diluted cyanide (86.4% cyanide) solution was released due to a pump failure at the mill site. **February 22, 1996:** 1,000 gallons of Bio-Leach water (pH of 2.61) overflowed due to a transfer line failure. **January 15, 1991:** Approximately 200 gallons of concentrated sodium cyanide solution was released when a weld on a one-inch diameter HDPE pipeline failed. This pipeline is part of a system which delivers a concentrated sodium cyanide solution from the storage tank to the ADR facility. It was estimated that 394 pounds of sodium cyanide was released.
Seepage collection and treatment failures	**2012:** Seepage that contained cyanide at 0.018 mg/L from the North Block Tailings Facility was observed. At the time the area was trenched and the solution was pumped back into the tailings impoundment.[49] **2006:** A seep was detected downgradient of the Goldbug Refractory Ore Stockpile. The stockpile was excavated, and a flaw was discovered in the soil liner due to settling of the foundation material below. The source of the low pH seep was removed and disposed of in a contained process facility.[50]
Impacts to water resources	There is some evidence of contamination of surface water as mentioned in the Betze Pit Expansion EIS, "Two springs in the upper Antelope Creek located below old mine workings had pH values between 3.0 and 4.0 standard units."[51]

Fort Knox Mine, AK Fort Knox, originally permitted for construction and operation in 1994, is an open-pit heap leach gold mine located approximately 26 miles northeast of Fairbanks. True North is a satellite deposit. It is located primarily on State of Alaska lands and private land.	
Reports of pipeline failures and other accidental releases	**2012:** Fairbanks Gold Mining, Inc. estimates that approximately 45,000 gallons of cyanide solution were released onto the mine roadway of the heap leach operation. A heavy-equipment operator working in the area of a buried cyanide solution pipeline inadvertently damaged a 12-inch supply line with a bulldozer ripper blade.[52] **2010:** Fort Knox estimates 305,300 gallons of process water spilled. Approximately 270,000 to 275,000 gallons remained within the building, while the remaining 30,000 to 35,000 gallons spilled onto the gravel roadway and parking area.[53]
Seepage collection & treatment failure	**2012:** There was uncertainty about whether seepage from the True North waste rock dump was affecting surface water. According to a 2012 audit, "it appears that pit runoff as well as non-contact stormwater is collecting behind a portion of the reclaimed Zeppelin/Hindenburg dump in the upper Spruce Creek drainage. As a result of reclamation grading activities in that area, the upper reach of Spruce Creek has been blocked by waste material. Water, containing elevated total dissolved solids and sulfate concentrations, is ponding on the up-gradient side of the waste dump. The exact nature of this water is currently unknown, but could be water infiltrating/flowing from the pits. According to site records, a pit lake existed in the Central Pit in 2005 and 2006, but suddenly disappeared in 2007. Coincidentally, a new spring appeared in the upper reaches of Spruce Creek; a spring which ADNR believes did not exist prior to mining. It is this spring that is currently feeding the aforementioned pond. The probability is high that this water is permeating through the waste rock dump, exiting at the toe, and may be contributing to ambient water quality impacts in Spruce Creek. However, upon review of the water quality in Spruce Creek by ADEC, the agency concluded (in their findings letter dated February 5, 2010) that a correlation between the water quality in Spruce Creek and water quality effects from FGMI's mining and reclamation activities could not be established at this time."[54] Subsequent monitoring in 2012 found no correlation.
Impacts to water resources	None identified.

Pogo Mine, AK The Pogo Mine is an underground gold mine located 38 miles northeast of Delta Junction, Alaska near the Goodpaster River. The mine was permitted in 2003, and it is located primarily on lands owned by the State of Alaska.	
Reports of pipeline failures and other accidental releases	**2015:** A spill of 90,000 gallons of paste backfill occurred, releasing a mix of mine tailings and cement containing three parts per million cyanide. The spill occurred as a result of a ruptured line.[55]
Seepage collection and treatment failures	**2011:** Pogo Mine exceeded its surface water discharge limits for pH, iron, manganese and cyanide.[56] On December 11, 2011 the State of Alaska issued a notice of violation for these exceedances. The company paid a penalty for the violations, and was required to increase the capacity of the waste water treatment plant in response.[57] Investigations also found that the recycled tailings pond (RTP) was experiencing seepage. Three wells located below the RTP Dam (MW12-500, MW12-501, and MW12-502) monitor groundwater downstream of the RTP seepage collection system. Chloride, nitrate, selenium, sodium, and potassium levels in groundwater were measured above the trigger limits in 2012.[58] The company was required to conduct additional grouting in 2012 to control seepage, but excess precipitation delayed the mitigation.[59] Samples for these wells were collected monthly throughout 2013. Eight sampling events occurred in 2013 for MW12-500 when water was present in the well. Chloride and sodium were detected above the trigger limits on all sampling events and nitrate was detected above the trigger limits during 7 sampling events. Two sampling events occurred in 2013 for MW12-501 when water was present in the well. Chloride and sodium were detected above the trigger limits on all sampling events. Nitrate was detected above the trigger limits during one sampling event. Other parameters were also analyzed and compared to the Water Quality Standards. In March and June higher than normal levels of several parameters were indicated. MW11-001A and MW11-001B provide information on water quality trends down-gradient from the Dry Stack Tailings Facility (DSTF) and up-gradient of the RTP. MW11-001A is an alluvial well and MW11- 001B is a bedrock well. Samples were taken MW11-001B on March 13, May 7, June 23, September 4, and October 20, 2013. The copper and nitrate values for both wells are fluctuating over time with no apparent trend. However, the fluctuations exceed the standard.
Impacts to water resources	The mine has degraded groundwater and resulted in water quality standard violations for manganese, cyanide, iron and pH for discharges into the Goodpaster River.

Smoky Valley/Round Mountain Mine, NV The Round Mountain Mine is an open pit heap leach mine located in Nye County, Nevada approximately 55 miles north of Tonopah. It is located on private land and BLM land.	
Reports of pipeline failures and other accidental releases[60]	**April 19, 2015:** 1,077 gallons of tailings slurry spilled due to a plugged grit screen. **April 10. 2015:** An unknown amount of hydrated lime was released into the potable water system. Cause and amount are not reported. **March 17, 2015:** 9,000 gallons of tailings slurry spilled due to an air/relief valve malfunction. **January 8, 2015:** 5,925 gallons of process solution released due to a split in a pipeline. A soil sample from the spill site was analyzed at 0.021 mg/L for WAD cyanide. **September 15, 2014:** 935 gallons of cyanide solution at a concentration of 0.35 lbs./ton spilled off the R-pad containment. **September 23, 2013:** 48,510 gallons of process solution overflowed the tailings dam containment ditch and ran to the toe of the previous ramp. The cause was the removal of the barge pump and restriction of tailings discharge both necessary for new construction. **January, 28, 2013:** Approximately 300,000 gallons of mill reclaim solution was released. The solution was above standards in sulfate, total dissolved solids, WAD cyanide, manganese and arsenic at 850, 1500, 010, 0.28, and 0.14 mg/L. **December 4, 2013:** About 9,214 gallons of tailings slurry was released due to the failure of a two vacuum breaker valves under extreme cold temperatures. **June 26, 2013**: From 1,000 to 1,600 gallons of tailings reclaim process solution spilled due to a break in a pipeline during relocation. Titrated samples showed no cyanide and pH of 7.9 to 8.1. **June 22, 2013:** 2,887 gallons of process solution with a cyanide concentration of 0.04 lb./ton spilled as a result of a pipe rupture. **June 1, 2013:** 3,70 gallons of process solution containing 6.38 lbs. of cyanide spilled due to a temporary pump outage. **March 18, 2013:** 1,556 gallons of reclaim water spilled due to a failure in a pipeline. **January 27, 2013:** An estimated 202,000 gallons of tailings/mill reclaim water released from an overtopping of a small event pond. **August 20, 2012:** About 538 gallons of process solution with a cyanide concentration of 0.5 lbs./ton spilled due to a valve failure. **April 17, 2012:** 1,403 gallons of process solution containing 4.09 lbs. of cyanide spilled from a burst pipe. **December 28, 2011:** Approximately 18,200 gallons of process solution containing 8.34 lbs. of cyanide spilled due to a valve failure. **July 12, 2011:** About 1,400 gallons of a blend of fresh and reclaim water released as a result of an accidental pump shut off. **April 10, 2011:** 3,070 to 6,900 gallons of process solution containing 3.45 to 7.77 lbs. of cyanide spilled due to high flows in the process solution return ditch. **November 21, 2009:** 787 gallons of reclaim water spilled due to an air valve relief valve failure. **December 18, 2008:** 13,000 gallons of tailings thickening overflow water containing no detectable cyanide spilled due to a failure of the bypass valve.

October 5, 2008: 592 gallons of tailings slurry at pH 7.93 spilled from a pump failure.

April 18, 2008: 748 gallons of mill tails slurry containing no cyanide spilled when a flange on a pipe blew out.

April7, 2008: About 90,000 gallons of decant water that was non-detect for cyanide spilled due to an overflow in a filter causeway.

December 30, 2007: Approximately 6,000 gallons of tailings slurry spilled when a vacuum breaker froze and broke.

November 2, 2007: 3,150 gallons of mill tailings slurry and solution containing no cyanide breached containment.

June 14, 2007: 577 gallons of reusable pregnant cyanide solution containing a total of 0.36 lbs. of cyanide spilled when line maintenance occurred.

May 19, 2007: About 5,600 gallons of solution containing 8.19 lbs. of cyanide spilled due to a blown plug on a process line.

February of 2012: Seepage that contained cyanide at 0.018 mg/L from the North Block Tailings Facility was observed. At the time the area was trenched and the solution was pumped back into the tailings impoundment.[61]

2006: A seep was detected downgradient of the Goldbug Refractory Ore Stockpile. The stockpile was excavated, and a flaw was discovered in the soil liner due to settling of the foundation material below. The source of the low pH seep was removed and disposed of in a contained process facility.[62] 37,398 gallons of mill tailings slurry with no detectable cyanide spilled due to a line rupture.

December 20, 2006: Approximately 30,000 gallons of 50/50 mill tailings and water that contained no cyanide spilled when the tails slurry line broke.

June 9, 2006: 3,727 gallons of mill tailings slurry were released due to a pipe failing from internal wear.

November 17, 2005: 5,500 gallons of tails slurry with no detectable cyanide spilled due to a broken flange.

November 3, 2005: About 16,429 gallons of sodium cyanide solution containing about 3.43 lbs. of cyanide overflowed the collection ditch.

March 7, 2005: About 10,000 gallons of cyanide solution containing about 6.61 lbs. of cyanide spilled due to a coupler failure at a leach pad.

December 5, 2004: 33,000 gallons of solution containing 43 lbs. of cyanide leaked when the lime slaker system failed from cold weather.

September 25, 2004: 7,154 gallons of pregnant carbon solution containing 0.9 lbs. of cyanide spilled when the carbon screen plugged resulting in overfilling.

August 27, 2003: 64,731 gallons of barren solution containing 60.7 lbs. of cyanide spilled as the solution breached containment from an operator error.

August 27, 2003: Greater than 500 gallons of process solution spilled due to a faulty process line.

July 19, 2003: 943 gallons of solution containing 0.16 lbs. of cyanide spilled when a fresh water line within a K5 valve box broke.

	SMOKY VALLEY/ROUND MOUNTAIN MINE, NV - CONTINUED **June 10, 2003:** 37,000 lbs. of nitric acid (70% solution) was accidentally filled into the wrong truck at Battle Mountain. The acid dissolved the welds of the tank trunk and leaked acid at the mine. **May 23, 2003:** 707 gallons of solution containing 0.003 lbs. of cyanide spilled when a tailings pump seal failed. **March 17, 2003 (date uncertain):** 1,226 gallons of solution containing about 0.92 lbs. of cyanide was spilled due to a power spike. **December 26, 2002:** 1,254 gallons of solution containing 2.23 lbs. of cyanide spilled when a ditch overflowed. **July 2, 2002:** 2,198 gallons of barren solution containing 0.13 lbs. of cyanide spilled when power was accidentally turned off. **March 11, 2002:** 620 gallons of process solution containing 0.09 lbs. of cyanide spilled due to an improper shutdown during a planned power outage. **December 12, 2001:** 748 gallons of mill tailings slurry with no detectable cyanide spilled from a failed flange on a pipeline from temperature changes. **July 28, 2000:** 6,829 gallons of barren solution containing 0.3 lbs. of sodium cyanide seeped out of primary containment due to a leaking valve on a dedicated heap leach pad. Three spills involving between 4,515 and 7,015 gallons of cyanide solution occurred at the Round Mountain mine in the period of 1992-94. Two of the spills resulted from problems with either the operation of a leach pad or flawed repairs to the leach pad. The third spill was a result of an equipment failure and operator error. See these details below.[63] **1992:** On March 18, inadequate percolation in a section of the leach pad caused ponding of leaching solution on top of the pad. A portion of the ponded solution overflowed into the collection ditch where a plug subsequently formed. As a result of the plug the ditch overflowed releasing 2,000 gallons of cyanide solution in a run 200 feet south of the pad. **1992:** On March 24, between 2,500 and 5,000 gallons of process solution containing between 11.5 and 22.9 pounds of sodium cyanide spilled - contaminating soil and a road bed. The solution leaked through the leach pad berms following operator and management error in repairs to reshape the leach lines. **1994:** In October, a spill occurred of 15 gallons of liquid cyanide solution containing 45 pounds of dry cyanide. The spill resulted when a gasket on an overfilled delivery truck burst.
Water collection and treatment failures	Monitoring wells are located along the downgradient side of the process facilities and in various other locations around the property. Analytical results are reported to NDEP quarterly and annually. For the period 2007 to the first quarter 2010, WAD cyanide concentrations ranged between 0.0124 mg/L and less than the detection limit of 0.002 mg/l – indicating groundwater impacts from cyanide.[64]
Impacts to air and water resources	Groundwater degraded by cyanide.

Turquoise Ridge, NV The operation consists of several inactive open pits and two underground mines (Turquoise Ridge and Getchell) operated by Turquoise Ridge Joint Venture. Turquoise Ridge now sends all of its ore to the Twin Creeks Mine for processing. It is located about 70 miles north of Winnemucca, NV on private lands and on public lands owned by BLM.	
Reports of pipeline failures and other accidental releases[65]	**November 23, 2013:** 7,500 gallons of dewatering water with an arsenic concentration of 0.98 mg/L spilled when a pipe repair failed. **January 10, 2011:** About 3,000 gallons of untreated mine water with an arsenic concentration of 2.5 mg/L spilled as a result of a frozen line. **April 3, 2008:** Less than 3,000 gallons of underdrain solution with an arsenic concentration of 20 mg/L spilled when an indicator failed causing a tank to overflow. **November 19, 2005:** 7,180 gallons of mine water containing arsenic spilled when an air bubble caused a dewatering line rupture. **August 4, 2005:** 5,000 to 6,000 gallons of mine dewatering water containing 2 mg/L arsenic spilled due to a leaking pipe. **May 20, 2005:** About 6,000 gallons of mine sediments sludge containing 150 lbs. of arsenic spilled when a pipeline ruptured. **December 10, 2004:** 2,500 gallons of mine water high in arsenic spilled due to an air vac failure. **October 12, 2004:** 1,000 gallons of dewatering water high in arsenic spilled from a failed AIRVAC. **October 1, 2004:** An estimated 15,000 gallons of dewatering water spilled due to a break in an HDPE pipe. The water may have contained arsenic at a concentration of 1.4 mg/L. **September 30, 2004:** 10,000 to 15,000 gallons of high arsenic mine water spilled as a result of a failed coupler. **April 5, 2004:** Less than 5,000 gallons of magnesium chloride solution spilled when the bladder containing the solution ripped. **February 23, 2004:** 4,000 gallons of treated process water spilled as a result of a line rupture. **November 5, 2002:** 750 gallons of pit water with an arsenic concentration of 0.2 mg/L spilled as a result of a cracked valve. **May 20, 2002:** Approximately 3,000 gallons of tailings underdrain solution spilled from a pump failure as a result of a wind storm. The maximum soils contamination was 0.013 mg/L for WAD cyanide. **April 2, 2002:** About 3,000 gallons of tails water with a 0.5 mg/L and 30 mg/L concentration of cyanide and arsenic respectively spilled due to a pump failure during a power outage. **March 6, 2002:** 2,000 gallons of heap leach water spilled due to a blockage in the piping. **February 20, 2001:** 1,000 gallons of heap leach pad runoff and rain water containing 0.05 mg/L WAD cyanide spilled from a broken pipeline. **February 18, 2001:** 1,000 gallons of pregnant pond water spilled. **December 20, 2000:** About 20,000 gallons of treated water containing arsenic at 10 to 15 ug/L spilled due to a factory welded lateral failure.

	TURQUOISE RIDGE, NV - CONTINUED **December 19, 2000:** 30,500 gallons of treated water containing arsenic at < 5 ug/L was released; caused unknown. **December 5, 2000:** 22,600 gallons of treated water containing arsenic at 8.5 ug/L spilled due to a split pipe. **August 16, 2000:** 900 gallons of mine water containing 1.5 mg/L arsenic spilled when a fusion coupling broke. **March 6, 1998:** 10,000 gallons of cyanide solution were released due to a power outage. **May 16, 1996:** About 480 cubic feet (100 tons) of ore slurry spilled when a tank overflowed. **March 25, 1996:** 500 gallons of solution containing 4.17 lbs. of cyanide spilled as a result of a broken plastic fitting. **May 25, 1995:** 3,000 gallons or ore slurry spilled due to a broken line. **May 16, 1995:** 6,400 gallons of process solution containing 0.3 lbs. of cyanide spilled due to a break in a pipeline as a result of construction. **May 5, 1995:** About 3,000 gallons of tailings slurry spilled when a truck ran over a pipeline. **February 2, 1995:** 4,070 gallons of slurry/cyanide mix solution containing 1.4 lbs. of cyanide spilled as a result of operator error. **January 31, 1995:** 61 tons of cyanide slurry spilled. **May 11, 1994:** Underdrain tailings solution containing 3.5 lbs. of cyanide spilled from a broken pipeline as a result of a storm event. **February 22, 1994:** 25 tons of overflow slurry/cyanide solution with a cyanide concentration of 0.11 lbs./ton spilled from a neutralizer tank. **February 1, 1994:** Approximately 20,000 gallons of barren solution spilled when the pipeline came apart. **October 27, 1993:** 25,500 gallons of process solution containing 0.855 lbs. of cyanide spilled as a result of an overload of ore in the circulating part of the grinding circuit. **August 3, 1993:** 22,800 gallons of 18.3 mg/L cyanide solution spilled due to a faulty subdrain. **July 17, 1993:** 36,000 gallons of pregnant solution containing 6.4 lbs. of cyanide spilled when a perimeter ditch became plugged.
Seepage collection and treatment failures	None documented.
Impacts to water resources	None documented. There are no perennial streams in the project area.

Bingham Canyon Mine, UT	
The Bingham Canyon mine is an open pit, copper, gold, silver and molybdenum mine located 28 miles southwest of Salt Lake City, Utah. It is the largest open pit mine in North America.	
Reports of pipeline failures and other accidental releases	**2011:** Report of malfunction of equipment that allowed the release of approximately 145,424 gallons of copper tailings.[66] **2011:** Report of pipeline overflow onto soil with estimated 100,000 – 290,000 gallons of copper tailings material released from pipeline.[67] **2011:** Report of tailings slurry released from tailings slurry hot box. 160,000 gallons of tailings released.[68] **2010:** Report of a release of process water due to broken pipeline. **2010:** Report of a discharge of sulfuric acid from a pipeline in the precious metal plant released between 4,000-5,000 gallons.[69] **2007:** Report of a release of 35,000 gallons of hydromet tails containing arsenic due to pipeline break.[70] **2007:** Report of 1,240,000 gallons of process water containing arsenic from pipeline break due to cold temperatures. [71] **2006:** Report of 270,000 gallons of process water released because of pump failure, which resulted in overflow of containment area.[72] **2006:** Report of 660,000 gallons of process water containing arsenic released due to cracked pipe.[73] **2006:** Report of 1,000,000 gallons of process water released from the Magna Reservoir due to a failed level indicator.[74] **2004:** Report of 4,000,000 gallons of process water with arsenic from pipeline.[75] **2004:** Report of 2,000,000 gallons of process water with arsenic from broken process water line.[76] **2004:** Report of 202,000 gallons of process water released due to pipeline failure.[77] **2003:** Report of 70,000 gallons of process water with arsenic released due to pipeline failure.[78] **2003:** Report of 70 tons of copper concentrate released from pipeline.[79] **2003:** Release of copper concentrate, containing 340 pounds of arsenic, 20,000 pounds of copper, and 200 pounds of lead.[80] **2003:** Copper concentrate pipeline ruptured, releasing 240,000 tons of copper, 428 tons of arsenic, 253 tons of lead.[81] **2002:** Report of 5,800 gallons of process water from slag pot cooling area due to plugged drain line.[82] **2001:** Report of tailings pipeline failure, releasing 4 pounds of arsenic, 14 pounds of chromium and 1 pound of lead.[83] **2000:** Report of 110 tons of ore slurry released due to a leak in ore line.[84] **2000:** Report of 18,000 tons of sulfuric acid released from pipe due to flange failure.[85] **1999:** The process water pipeline sprung a series of leaks in 1989 and 1999. It has been estimated that 100 million gallons of process water with high arsenic levels spilled before the leak was discovered.[86]

	BINGHAM CANYON MINE, UT - CONTINUED **1998:** Report of copper sulfate released into a canal. **1998:** Report of clogged piping system causing pipe to back up and overflow releasing acid rock drainage into water. **1997:** Report of settling pond overflow due to clogged outlet valve. Release of copper sulfate into water. **1997:** Report of pipeline rupture releasing process water (pH 2.5-4.0) into water. **1993:** Report of 45,000 gallons of wastewater spilled due to a rupture of the transfer line.[87] **1991:** Report of 30,000 gallons of industrial wastewater spilled at the wastewater treatment plant due to line break.[88]
Seepage collection and treatment failures	**2011:** Noncompliance in April-June 2011 for discharges of copper, zinc and total suspended solids at copper smelter.[89] Wastewater from the mine has escaped the site's collection system, contaminating groundwater with acid, metals and sulfates. The groundwater plume extends towards the nearby Jordan River and covers more than 72 square miles – rendering water for thousands of Salt Lake City residents undrinkable.[90] There have been multiple tailings spills.[91] Drainage from the waste rock piles will require water treatment in perpetuity to prevent additional groundwater pollution.[92] In February 2008, the United States Fish and Wildlife Service took legal action against Kennecott for the release of hazardous substances from the mine's facilities, including selenium, copper, arsenic, lead, zinc and cadmium.[93] Groundwater contaminated by mine operations has been released from the mine site through artesian springs into areas that serve as fish and wildlife habitats. According to the federal biologists, the release of these hazardous pollutants has harmed natural resources, including migratory birds and their support ecosystems, which includes wetlands, marshes, freshwater wildlife habitats, playas and riparian areas and freshwater ponds.[94] Soils and sludge are contaminated, as are surface water and groundwater, which affect wetlands between the site and the shore of Great Salt Lake.[95]
Impacts to water resources	Wastewater from the mine has escaped the site's collection system, contaminating groundwater with acid, metals and sulfates. The groundwater plume extends towards the nearby Jordan River and covers more than 72 square miles – rendering water for thousands of Salt Lake City residents undrinkable.[96] Groundwater contaminated by mine operations has been released from the mine site through artesian springs into areas that harm natural resources. This includes fish and wildlife habitats, including migratory birds and their support ecosystems, which includes wetlands, marshes, freshwater wildlife habitats, playas and riparian areas and freshwater ponds.

Hycroft Mine, NV (Crowfoot-Lewis) The Hycroft Mine is an open pit heap leach gold and silver mine located within a 14,753 – acre mine boundary on public land administered by the BLM and private land. Hycroft was formerly known as the Crofoot-Lewis open pit mine, which was a small heap leaching operation that commenced in 1983.	
Reports of pipeline failures and other accidental releases[97]	**July 27, 2016:** 3,117 gallons of pregnant solution, containing 0.39 lbs. of cyanide, spilled due to a pump failure. **April 8, 2016:** 2,500 gallons of process solution spilled when a pipeline broke. **February 11, 2016:** About 1,000 gallons of process solution, with a cyanide concentration of 0.17 mg/L, spilled when a hose gasket on a pump failed. **January 14, 2016:** 600 gallons of process solution, containing 0.67 lbs. of cyanide, spilled as a result of a broken vacuum breaker on a pump. **January 11, 2016:** 16,830 gallons of process solution spilled as a result of a broken line. **January 10, 2016:** An estimated 1,200 gallons of process solution, with a cyanide concentration of 0.29 lbs./ton, spilled due to an insecure 8-inch HDPE pipe at the North Event Pond. **January 5, 2016:** Approximately 6,000 gallons of process solution, containing 3.12 lbs. of cyanide, spilled when a closed valve created excessive internal pressure causing a weld to fail. **October 20, 2015:** Mining impacted storm water was released. The water had a pH of 2.9 to 3.1. **March 30, 2015:** Process water was released. There is no additional information on this event. **July 8, 2015:** An estimated 1,402 gallons of process water, containing 4 lbs. of cyanide, spilled when an 8-inch HDPE pipe pulled loose. **January 16, 2015:** About 2,400 gallons of process solution, with a cyanide concentration of 0.03 lbs./ton, spilled from an uncapped abandoned pipe. **January 10, 2015:** An estimated 2,000 gallons of process solution containing 0.834 lbs. of cyanide spilled from a failed feed line hose. **November 18, 2014:** 596 gallons of process solution containing cyanide at 0.13 lbs./ton spilled when a power pump caused the B side pump to trip, hence losing power. **November 6, 2014:** 7.5 gallons of 30% sodium cyanide solution containing 21.7 lbs. of sodium cyanide spilled from a broken line. **1994:** On December 4, the facility reported a spill of approximately 30 gallons (or 100 pounds) of liquid sodium cyanide with a concentration of approximately 30 percent cyanide. The spill was the result of a mechanical failure on a delivery truck.[98] **1990:** The facility experienced problems associated with electrical power interruptions compounded by record sub-zero temperatures. During the hours of 6 p.m. to midnight on December 20, 1990, sub-zero temperatures (near -20 F), combined with two separate power interruptions by Sierra Pacific Power, resulted in several frozen lines on the leach pads. As a result, four header system failures on Pad 1 and one header system failure on Pad 2 occurred. The blow-out on Pad 2 discharged 1.7 pounds of sodium cyanide contained in 5,000 gallons of solution into a man-made 100-year storm drainage ditch between Pad 1 and Pad 2. The freezing leach lines discussed in Incident No. 2 resulted in a gradual raising of solution storage pond levels to the extent that an estimated total of 300,000 gallons containing 100-150 pounds of sodium cyanide flowed from the low-pregnant pond to an earth lined containment dike. Two separate flows occurred - one on December 24, 1990 (estimated 228,000 gallons) and the other on December 27-28, 1990 (estimated 72,000 gallons). These flows contained 76 pounds and 24 pounds of cyanide, respectively.

	HYCROFT MINE, NV (CROWFOOT-LEWIS) - CONTINUED
Water collection and treatment failures	In April 2004, it was noted that in the shallow perched aquifer that underlies the Crofoot Heap Leach pad various constituents of concern exceeded Nevada Division Profile I RVs at various sampling points [e.g., selenium (SP-27 and SP-30), WAD cyanide (SP-18 and SP-28), mercury (SP-25 and SP-30), and nitrate (SP-30)]. Although SP-30 showed exceedances for selenium (1.9 mg/L), mercury (0.017 mg/L), and nitrate (18 mg/L), cyanide was at less than detectable levels (<0.005 mg/L). As of the fourth quarter of 2016, the influence of process solution is still evident in shallow investigation wells SP-25 and SP-30. Well SP-25 shows concentrations of mercury at 0.04 mg/L and nitrate at 13 mg/L, and well SP-30 has mercury concentrations of 0.012 mg/L.[99]
Impacts to water resources	Water quality standards for cyanide, mercury selenium and nitrates have exceeded water quality standards in groundwater. The only perennial surface water occurrence that exists within the area is approximately 2 miles to the west of the project, consisting of shallow duck ponds.[100]

Marigold Mine, NV The Marigold Mine is an open pit gold mine, which was initially authorized in 1998. It is located 3 miles south of Valmy, NV on private land and public BLM land.	
Reports of pipeline failures and other accidental releases[101]	**May 23, 2013:** 58,000 gallons of process solution containing 48 lbs. of sodium cyanide was released due a weld failure in a 10-inch HDPE pipe. **February 8, 2012:** 5,000 gallons of barren solution containing 6.9 lbs. of cyanide was released when header feeding line broke. **May 28, 2005:** 400 gallons of process solution was spilled due to a defect in a flange connecting two HDPE pipes. **May 19, 2005:** 30 gallons of process solution was spilled as a result of the failure of two HDPE pipes. **December 8, 2004:** Solution from a carbon-in-leach area breached containment. The final report does not indicate the volume of the spill. However, given the effort involved in developing the final cleanup report the volume is likely to be have been very large. **November 17, 2004:** About 1,100 gallons of barren solution containing 0.413 lbs of cyanide was released due to a leaking buried line. **June 24, 2004:** Approximately 3,000 gallons of barren solution with a sodium cyanide concentration of 0.1 lbs./ton was spilled when an excavation struck a process pipeline. **April 14, 2004:** 5.940 gallons of heap leach pregnant solution containing 0.743 lbs of cyanide was spilled as a result of line damage from an excavation. **March 22, 2004:** 3,191 gallons of process solution containing 0.065 lbs. of cyanide was spilled as a result of a rupture in a process line from an excavation. **July 26, 2002:** 5,000 gallons of cyanide solution containing 7.39 lbs. of cyanide was released from a pipeline failure. **June 20, 2002:** 800 gallons of heap leach barren solution containing 0.67 lbs. of cyanide was released due to a burst feed line. **April 16, 2002:** 2,712 gallons of barren solution containing 0.34 lbs. of cyanide was spilled due to a failed screen. **January 17, 1993:** 10,000 to 20,000 gallons of containing 1.9 lbs. of sodium cyanide was released due to a frozen pipeline. **April 3, 1991:** About 3,00 gallons of tailings solution containing 4.9 lbs. of cyanide was released when a tailing line broke.
Seepage collection and treatment failures	**2000:** According to 2000 DEIS for the Marigold Mine expansion, the current tailings impoundment is leaking water at a rate of about 34 gpm at the north end, down from the 1991 seepage of 110 gpm. The seepage is elevated in TDS and chloride relative to Nevada drinking water standards and is elevated in background levels of these constituents in groundwater.[102]

Seepage collection and treatment failures	**MARIGOLD MINE, NV - CONTINUED** **1992:** It was discovered that the tailings impoundment was seeping tailings fluid into the vadose zone near the decant tower on the northern side of the facility. Monitor wells were installed in the vadose zone and the alluvial aquifer north of the tailings to determine the extent of the seepage plume, and monitor its impact on the aquifer. The pH of the seepage plume ranges from 6.2 to 7.5 and is somewhat more acidic than the alluvial groundwater. TDS is elevated in the seepage plume with values in the range of 500 to 1,000 mg/l. Chloride is also elevated. WAD cyanide ranges from 0.01 to 0.15 mg/l staying with the Nevada water quality standard of 0.2 mg/l. Although the seepage plume has reached alluvial groundwater at monitor well TDOH-12U, the water quality in that well is within drinking water standards. Leakage initially observed in 1991 was estimated 190 gpm. In 1992, monitoring indicated that the rate was 110 gpm.[103]
Impacts to water resources	The mine has degraded the groundwater aquifer with total dissolved solids (TDS), chloride and cyanide.

Buckhorn Mine, WA The Buckhorn Mine is an underground gold mine located in northeastern Washington. It began operations in 2008. Ore is processed off-site at the Kettle River Mill in Republic Washington.	
Reports of pipeline failures and other accidental releases	2012: A truck carrying concentrated wastewater from the Buckhorn Mine crashed and spilled about 4,200 gallons into Marias Creek.[104] The wastewater contained nitrates and sulfates.
Seepage collection and treatment failure	Concentrations of mine-related contaminants have increased over time at certain surface water, groundwater, spring, and seep locations since mining was initiated.[105] The three primary reasons for the increases are intended or unintended discharge of inadequately treated wastewater, seepage of mine water from the underground mine, and the possible onset of acid drainage from the weathering of sulfide ore and mined materials, including underground workings, development rock, and ore.[106] **2012:** A $395,000 fine was issued from the Department of Ecology for repeated and continued water quality violations. The groundwater capture zone failed to contain spring rains and snow melt, resulting in contaminated water reaching Gold Bowl Creek.[107] According to a news article, "In the first five years, the state agency issued six notices of violation, two civil penalties and six administrative orders, the hearings board ruling states."[108] Also in 2011, Ecology determined that discharges of treated mine water created slope instability and triggered a landslide that impacted a small stream below the mine.[109] **2010:** In September 2010, Kinross reported that misconduct by treatment plant staff had resulted in unreported discharges that exceeded permit limits for ammonia, nitrate, TDS, arsenic, zinc, and pH between May 2009 and August 2009.[110] **2009:** Washington Department of Ecology issued a $40,000 fine for a violation of its water quality permit for failing to adequately capture and treat water from the mine operation.[111] Notice of Violation 6965 was issued for exceeding Total Dissolved Solids effluent and stormwater limits. Notice of Violation 7031 was issued for 7 water quality exceedances in outfalls in April, May and June 2009. Notice of Violation 7080 was issued for 57 water quality exceedances for zinc, copper, lead and TRC effluent limits.[112] **2007:** Washington Department of Ecology issued a $62,000 penalty over issues including stormwater discharges and slope failures during mine construction. Administrative Orders were related to failure of the treatment plant to properly remove contaminants and failure to adequately capture water potentially affected by the mine.
Impacts to water resources	The mining operations have degraded water quality in Gold Bowl Creek, Marias Creek, South Fork Nicholson Creek and Upper South Fork Bolster Creek as well as groundwater, seeps and springs downstream and downgradient of the mine.[113] The Washington State Department of Ecology (Ecology) has issued numerous Notices of Violation (NOVs) and Administrative Orders (AOs) to Kinross. The water quality violations were for exceedences of TDS, TSS, ammonia, arsenic, chloride, copper, lead, mercury, and zinc, as well as pH values that were higher than the permit limit of 8.5.[114]

Jerritt Canyon Mine, NV The Jerritt Canyon Mine has been in operation since 1980. The primary commodities mined are gold and silver from underground and open pit mining and heap and vat leach processing operations. It is located approximately 46 miles north of Elko in the Independence Mountain Range on federal lands managed by the Forest Service and BLM, and private lands.	
Reports of pipeline failures and other accidental releases[115]	**December 6, 2015**: About 5,000 gallons of tailing facility seepage for the East Lined Pond spilled as a result of failed transformers. **September 1, 2015:** Approximately 18,000 gallons of seepage water escaped from the East Line Pond when a pump failed resulting in an overflow. The seepage was very high in total dissolved solids and chloride, and elevated in antimony, arsenic, magnesium, manganese, mercury, and total nitrogen. **April 29, 2015:** 1,000 gallons of reclaim water of was spilled as a result of a corroded pipe. The water was very high in total dissolved solids and chloride, and elevated in lead, manganese, magnesium, mercury, and sulfate. **February 14, 2015:** 4,000 gallons of process solution was released when a transfer line to one of the heap leach carbon column blew apart. **January 2, 2015:** 2,000 gallons of process solution was released from a seepage well when a flow check valve froze. The solution was high in total dissolved solids, chloride, arsenic, and manganese. **January 2, 2015:** 6,000 gallons of process solution (unknown concentrations) was released from a failure of a pump in the west seepage system causing overflow in the East lined pond. **January 1, 2015:** 2,000 gallons of process solution was released from a seepage well when a flow check valve froze. **December 12, 2014:** About 500 gallons of process solution was spilled due to a failure of a discharge pump line. **November 28, 2014:** 800 to 1,000 gallons of process solution (unknown concentration) was released from a sump pump failure. **December 8, 2013:** Unknown volume of seepage recovery water from Tailings Facility I was spilled which was high in total dissolved solids and chloride **November 7, 2013:** Approximately 450 gallons of process solution was spilled due to an overwhelmed overflow pump. The solution was high in total dissolved solids, sulfate, chloride, antimony, arsenic, magnesium, mercury, nitrate (total N), and selenium. **August 11, 2013:** An estimated 90,000 gallons of Tailings Storage Facility (TSF-1) seepage water was released due to a weld failure in the seepage return line. The solution was high in total dissolved solids, chloride, antimony, and manganese. **July 28, 2013:** An estimated 1,500 gallons of process slurry with a cyanide concentration of 0.003 mg/L was released when a line on the discharge side of the thickener pump came apart. **July 25, 2013:** About 300 gallons of process slurry with a cyanide concentration of 0.003 mg/L was released when a line on the suction side of the thickener underflow came apart. **July 1, 2013:** 1,000 gallons of carbon-in-leach solution containing 0.009 lbs. of cyanide was spilled due to excessive tank pressures on the concrete floor and access road. **June 20, 2013:** 10 pounds of elemental mercury spilled from scrubber solution lines from operator error.

JERRITT CANYON MINE, NV - CONTINUED

November 21, 2012: About 1 pound of mercury was found 1.5 feet below the ground surface and was considered to be a historical release.

September 18, 2012: A calculated 10,080 gallons of solution from the WSR-W storage reservoirs which have total dissolved solids that average 20,000 mg/L. The cause of the leakage was unknown.

September 18, 2012: Roughly 5 pounds of mercury spilled near the toe of the Tailings Facility I adjacent to the Splitter Box Pond. The release appears to have come from a piping that originally carried mill tailings.

September 28, 2011: Cyanide solution with a concentration of 10 mg/L of an unknown amount spilled and the source was unknown.

December 3, 2010: 43,000 gallons of seepage water at 13,500 mg/L total dissolved solids was released when a pipe separated from a joint.

October 3, 2010: 10,200 gallons of Tailings Facility water containing cyanide and arsenic spilled when a sample port was left open.

July 22, 2010: About 170,000 gallons of seepage water from the mill was released (Spill Report 110923-02) resulted in a Finding of Alleged Violations issued on August 17, 2011.[116] The spill occurred due to a corroded bolt flange failure on a buried pipe located outside of the Wet Mill. The water was extremely high in total dissolved solids (~28,000 mg/L) and chloride (~10,000 mg/L), and above Profile I reference values for antimony, arsenic, cadmium, magnesium, manganese, mercury, selenium, sulfate, and thallium. Analysis indicated that the groundwater in the mill area was degraded by a multiple discrete sources of process solution. Data from groundwater monitoring wells located downgradient of the release showed that this release was a partial contributor to the groundwater degradation with respect to chloride, TDS and other constituents.[117] Elevated cyanide concentrations observed in several wells indicated that a release from a source of cyanide-rich process solution unrelated to tailings seepage solution. Upon further investigation, the source of the cyanide release was determined to be from the secondary containment for the Liquid Cyanide Storage Tank.

May 30, 2010: About 90,000 gallons of seepage reclaim water containing mercury, arsenic, cyanide, and thallium was released as a result of a broken weld at the flange adapter on the south seepage line. The water was extremely high in total dissolved solids (~20,700 mg/L) and chloride (~11,500 mg/L), and above Profile I reference values for antimony, arsenic, cadmium, magnesium, manganese, mercury, selenium, sulfate, and thallium.

November 8, 2009: 2,500 gallons of process solution containing 20.5 mg of cyanide and 0.01 pounds of arsenic spilled from a leaking valve.

August 27, 2009: Approximately 5,000 gallons of cooling pond process solution was released as a result of a leaking valve.

August 26, 2008: Drain down fluid from the Coffee heap leach pad spilled when construction activity pulled a drain line loose. The amount and concentrations were not known.

December 3, 2007: About 30,000 pounds of gold ore containing 1,500 pounds each of arsenic and mercury was spilled due a vehicle accident.

November 28, 2007: About 1,000 gallons of tailings seepage water spilled due to a failed pipe fitting.

September 9, 2007: About 25,000 pounds of Pete ore containing < 5% arsenic and mercury was spilled when a trailer rolled from driver inattention.

	JERRITT CANYON MINE, NV **August 9, 2006:** Approximately 2,000 gallons of seepage water was released when a motor grader punctured a partially buried seepage pipeline. The seepage water exceeded Profile I levels for chloride, sulfate, magnesium, total dissolved solids, manganese, selenium, and thallium. **August 5, 2005:** 71,000 gallons of tailing slurry overflowed the tailing overflow catchment pond due to a weld failure on a discharge pipeline. The water was extremely high in total dissolved solids (~19,000 mg/L) and chloride (~9,300 mg/L), and above Profile I reference values for antimony, arsenic, cadmium, WAD cyanide, magnesium, mercury, nickel, nitrate, selenium, sulfate, and thallium. **February 10, 2005:** 30,000 gallons of Cooling Pond Quench Pond Lime solution was released as a result of a failing weld on a "Y" connection. The solution was high in arsenic. **January 13, 2005:** 5,700 gallons of tailing seepage water containing elevated levels of arsenic, chloride (8,500 mg/L), manganese, mercury, and total dissolved solids (20,000 mg/L) was released when an equipment blade from snow removal struck a pipeline. **2000:** A report of eight pounds of arsenic released from a lined pond and partial out of a cooling tower due to pump failure.[118] **May 26, 1996:** 1,000 gallons of process slurry flowed out of the chlorination building after a tank valve was inadvertently left open during maintenance operations. The slurry flowed out of the east doors and into the milk of lime containment area. The slurry contained approximately 0.03% (3.2 lbs.) of sodium hypochlorite.[119] **January 11, 1996:** Jerritt Canyon experienced a power bump at the mill resulting in the overflow of a heap leach carbon column. The power bump disabled the pump at the end of the heap leach carbon column train, while the feed pump remained operating. Barren solution overflowed the last carbon column in the train and flowed out of the building into the driveway area, and into a ditch that drains to the tailings line drainage pond. Approximately 2,500 gallons of barren solution flowed onto the ground and into the ditch. The solution contained approximately one pound of cyanide. **August 21, 1995:** The south chlorination tank #2 ruptured, resulting in approximately 2,000 gallons of slurry.[120] **1995:** Jerritt Canyon experienced a rupture in the south tailings slurry line. The rupture occurred at a fatigued joint in the pipeline, approximately 100 yards west of the tailings line drainage pond and 50 yards north of the tailings dam. An estimated 2,400 gallons of tailings slurry was discharged to the road and surrounding ground surface. Less than 10 pounds of cyanide was involved in this spill. **1989:** 20,000 gallons of cyanide released.[121]
Seepage collection and treatment failures	The tailings generated from the vat leach operation were responsible for creation of a cyanide plume in groundwater. Exceedances of chloride, TDS, arsenic and sulfate were also observed in wells downgradient of the tailings impoundment. The tailings impoundment was lined and had seepage control features, but these were not adequate to prevent groundwater contamination. In 1991, a cyanide plume was detected from tailings pond. From 1993-2004, groundwater monitoring wells downgradient of the tailing impoundment showed exceedances for Cl and TDS consistently from 1993-2004.[122]

	JERRITT CANYON MINE, NV - CONTINUED According to the mine's recent discharge permit review, contamination from TSF-1 leakage has degraded groundwater with respect to chloride and TDS (and in some cases with antimony, arsenic, cadmium, magnesium, manganese, mercury, nitrate, selenium and WAD cyanide).[123] Four waste rock disposal areas (Marlboro Canyon East, Gracie, Snow Canyon, and DASH East) all exhibited seepage from the toe slope. The quality of the seepage water has been shown to exceed the 500 mg/l total dissolved solids (TDS) standards for the South Fork Owyhee River, due primarily to high sulfate and magnesium concentrations. The State of Nevada has been working with the Permittee to address these seepages since the 1990s.[124] In 2004, routine sampling of the lower Sheep Creek drainage indicated elevated sulfate, TDS, and magnesium concentration as a result of seepage emanating from the DASH East RDA UDS. Drainage from the toe of the East DASH waste rock disposal area into Sheep Creek exceeded the 500 mg/L TDS reference value for the North Fork Humboldt River due to elevated sulfate and magnesium concentrations.[125] Both Sheep Creek and the NF Humboldt have been incorporated into the State of Nevada 303(d) List of Impaired Waters — Sheep Creek for TDS and the NF Humboldt for total phosphorous and dissolved oxygen. Precipitation infiltrating through the angle of repose slope along the lower lift of the East DASH waste rock disposal area was previously believed to be contributing to the elevated sulfate, magnesium and TDS concentrations present in the seepage solution emanating from the toe of the East DASH disposal area. This seepage discharge entered Sheep Creek which flows through an under-dump drain constructed in the bases of both the Northwest DASH RDA and the East DASH RDA. Sheep Creek is a tributary of the NF Humboldt and on occasion, surface flow from the Sheep Creek has reached the NF Humboldt. As a point of reference, flow in Sheep Creek would travel a distance of seven (7) miles from the toe of the DASH waste rock disposal area to its confluence with the NF Humboldt.[126] In June of 2008 groundwater was found to contain volatile organic compounds in four monitoring wells. Four wells contained trichloroethane and three of the wells exceeded the Nevada State action level for trichloroethane. The trichloroethane levels ranged from 2.3 to 1,360 micrograms per liter. Chloroform was found in three of the wells from 68 to 1,320 micrograms per liter.[127]
Impacts to water resources	Water quality standards in groundwater have been exceeded for chloride, arsenic, sulfates, total dissolved solids and trichloroethane, and groundwater has been degraded by cyanide and in some cases antimony, cadmium, magnesium, mercury, nitrates and selenium. Surface water has been degraded in Sheep Creek, North Fork Humboldt River and South Fork Owyhee.

Kensington Mine, AK The Kensington Mine, permitted in 2005, is an underground mine using flotation process to recover gold. It is located in southeast Alaska on private and federal lands in the Tongass National Forest, approximately 45 air miles north of Juneau.	
Reports of pipeline failures and other accidental releases	2005: In October a piece of drilling equipment fell and released drilling fluid into Slate Creek Cover, north of Juneau.[128] **2005:** In August, kerosene spilled at Comet Beach, and about 2 gallons of diesel spilled into Slate Creek Cove in September.[129]
Seepage collection and treatment failures	**2013:** A 2013 inspection report identified acid mine drainage occurring at the north end of Lower Slate Lake.[130] The pH was usually 4 or 5, with one point as low as 2. The mine collected water samples and sent them to the lab for analysis. The acid mine drainage is coming from rock that was excavated during the phase 2 construction of the dam last summer. Some of the acid generating material was mixed with other fill for unknown reasons during last summer's construction of the second stage of the downstream dam raise, and placed into a non-lined area of the tailings facility. Water quality tests showed that the resulting drainage from the area contained high levels of metals and a low pH.[131] Acid drainage was noticed by Coeur staff when the snow cover melted from the tailings facility in late spring 2013. Acid generating material had been accidentally placed as fill at the north end of the tailings facility after being excavated from near the dam while preparing the foundation for the Stage II lift. Attempts to seal the seeping water from cracks and holes in the shotcrete were ineffective. A small water treatment plant was built to treat the water being collected from the seeps, however a September inspection found that water quality was still being degraded in Lower Slate Lake, and speculated that not all the fill material had been removed.[132] **2006-2010:** EPA issued a $140,000 fine for CWA violations over mine discharges. Water quality violations were issued for violating water quality standards for manganese, zinc, aluminum and cadmium. Acid mine drainage was released into East Fork Slate Creek during construction between 2006 and 2010.[133] According to a report in the Juneau Empire in 2008, the mine operator had records of water quality violations dating back to March 2007, but didn't inform the agencies until December of that year.[134]
Impacts to water resources	Acid mine drainage has degraded water quality in Lower Slate Lake, and mine discharges have caused water quality violations for manganese, zinc, aluminum and cadmium in East Fork Slate Creek. Water treatment in perpetuity will be required due to acid mine drainage.

Mesquite Mine, CA The Mesquite Mine is an open pit cyanide heap leach mine located in at the southern end of the Chocolate Mountains on public lands, state lands and private lands approximately 33 miles east of Brawley, CA.	
Reports of pipeline failures and other accidental releases	**February 1, 2017:** An estimated 5 gallons of process solution was released off containment.[135] **April 4, 2015:** 525 gallons of diesel fuel spilled off containment.[136] **August 12, 2015:** 500 gallons of hydraulic oil spilled off containment due to mechanical failure on hydraulic fitting on shovel. **August 14, 2015:** estimated 100 gallons of hydraulic oil were spilled off containment.[137] **August 19, 2015:** 25 gallons of process solution containing .011 lbs. of cyanide were spilled off containment.[138] **June 27, 2014:** 11.13 gallons of cyanide solution escaped containment on the north east side of heap leach pad #6. **August 19, 2014:** 25 gallons of process solution was spilled off containment.[139] **October 14, 2014:** a fueling hose came disconnected from a haul truck and subsequently leaked 100 gallons of diesel fuel off containment. **2014:** 11.13 gallons of cyanide solution escaped containment on the heap leach pad. **2014:** A fueling hose came disconnected and leaked 100 gallons of diesel off containment.[140] **1990:** Leaching solution (770, 50, 2,520, 33, 26 gallons)[141] **1990:** Pregnant solution (52 gallons) **1989:** Pregnant solution (4,000 gallons) **1986:** Goldfields Operating Co., Mesquite CA, Leaching solution (amount unknown)[142]
Seepage collection and treatment failures	None identified.
Impacts to water resources	None identified. The closest perennial surface water feature is the Coachella Canal, approximately 15 miles southwest of the site.[143]

Bald Mountain Mine, NV Bald Mountain Mine is an open pit mine located 65 miles northwest of Ely on private and BLM lands**.**	
Reports of pipeline failures and other accidental releases[144]	**September 15, 2016:** 3500 gallons of (0.029g/ton) of cyanide solution spilled with a total release of 0.435 lbs. The release resulted from a strut off valve failure. **September 27, 2007:** 610 gallons of cyanide at 0.03lb/ton spilled due to an **Inadvertent carbon column overflow.** **March 12, 2005:** 12,000 gallons of magnesium chloride solution of unreported concentration released to soil. **February 8, 2002:** 500 gallons of cyanide solution at 0.08mg/L concentration released due to a frozen pipe. **February 17, 2001:** Approximately 14,000 gallons of heap drain down solution released with a cyanide concentration of about 0.08 mg/L. The cause was a frozen pipe. **December 3, 1998:** 10,000 gallons of cyanide solution at 0.62 mg/L was spilled due to a broken solution line. **September 8, 1998:** Storm water release of 3,000 gallons from a leach pad with trace amounts of cyanide. **February 8, 1998:** 4,000 gallons of cyanide solution (barren solution and heap material) of a total release of 3.3 lbs. released due to a heap pad failure. **June 22, 1997:** Approximately 38,000 gallons of 0.22 lb./tons of cyanide solution was spilled as a result of a 2 inch plug becoming undone from a threaded coupler on a 10 inch header pipe. **January 6, 1991:** 5,000 gallons of sodium cyanide solution containing 4 pounds of cyanide were spilled due to a loose check valve; a maintenance operator had failed to tighten the bolts. The spill affected 50 square yards of soil to a depth of 4-8 inches. About half of the solution was pumped back into the system. The remainder froze in place and was to be removed for placement on the heap. Follow up soil sampling confirmed low cyanide levels.[145] **September 14, 1989:** Process solution release at a 10 mg/kg of unknown quantity **1989:** Barren solution 9,000 gallons.
Seepage collection and treatment failures	None identified.
Impacts to water resources	None identified. There are no perennial streams in the project area.[146]

Golden Sunlight Mine, MT The Golden Sunlight Mine is an open pit, cyanide leach mine operated on BLM and private lands in Montana, approximately five miles northeast of Whitehall, Montana. The BLM issued its plan of operations in 1982.	
Reports of pipeline spills and other accidental releases	2006: A spill of approximately 560 gallons of cyanide solution occurred on January 6, 2006 as a result of a displaced hose at the Slaker Building.[147] **2000:** Golden Sunlight reported two recent cyanide leaks, one occurred as a result of a failed vat leach tank, leading to the release of 390,000 gallons of cyanide solution and another prompting a 2,020-gallon discharge. The spills occurred on Aug. 31 and Oct. 26, respectively.[148] **1998:** Golden Sunlight reported a cyanide spill on Sept. 2 to the Montana Department of Environmental Quality. Mine officials said the leaks, which migrated to several ground-water wells at the mine site, occurred between June 1 and July 21. Cyanide was detected in five of six ground-water wells, with levels of cyanide reaching as high as between 30 and 39 parts of cyanide per million parts of water. The state water-quality standard for cyanide is 0.005 parts per million. The mining company did not notify the agency of the spill until a month after it occurred. The company did not have pumpback wells on site to address the spill[149] **1994:** 48.3 tons of tailings were spilled due to a leak in the spare tailings line. State agencies were not notified for many months. A notice of noncompliance was issued for failure to notify the agency and conduct required cleanup activities.[150] **1991:** 60 pounds of cyanide spilled due to tailings line leak causing soil contamination.[151] **1989:** A pipeline blockage caused acid mine drainage to discharge onto the ground.[152] **1988:** A pipeline leak occurred sometime between March 31 and April 5 before it was discovered by the company. Approximately 15,000 gallons of mine waste flowed from the emergency spillway.[153] **1987:** A cyanide slurry spill occurred. Estimated that the spill included 60 pounds of cyanide. **1986:** A pipe fitting split and discharged approximately 2000 gallons of cyanide solution.[154]

Seepage collection and treatment failures	**GOLDEN SUNLIGHT MINE, MT - CONTINUED** **2013:** Montana Department of Transportation submitted a letter to the Montana Department of Environmental Quality asserting that Golden Sunlight has degraded groundwater quality at the MDT Whitehall facility at least since 1993, a period of 20 years. The agency attributes the source of groundwater quality degradation to the discharge from the nearby mine tailings impoundment.[155] **2004:** According to the 2004 Supplemental Environmental Impact Statement, various reports describe the failure to capture seepage from the tailings impoundment.[156] Despite continual upgrading of the wells, seepage is escaping the south pumpback system. Data suggest slow migration of seepage away from Tailings Impoundment No. 1 (GSM 1998, 1999, and 2000 annual reports). There also is a vertical component to the seepage migration as well (GSM 2000 annual report). Keats (2001) concluded the second and third rows of pumpback wells were not completely capturing the seepage. Keats recommended treatment at the source area rather than adding pumpback wells. Portage Environmental Inc. reviewed the current monitoring well program in 2004. It summarized the level of contamination in all wells in the report. The majority of wells below the pumpback system still show some cyanide, nitrate, or metal contamination. According to the SDEIS, "It is hard to define how much of that is from the 1983 leak or from the continued migration of seepage past the capture systems. The agencies and GSM continue to review sampling results and modify the seepage containment system to prevent violations at the permit boundary." **1993:** In August, a 7 gpm seep was discovered in a drainage area below the tailings impoundment. Cyanide levels in the seep were measured at 0.6 ppm (3 times human health standards). Another seep was found further down the drainage.[157] The water flowed down to a manmade catchment pond in the drainage, which was discharging into an overflow pipe down into an intermittent stream. **1993:** Cyanide solution from tailings impoundment leached into groundwater and surfaced as seeps which flowed into an intermittent drainage below. Cyanide concentrations ranging up to 45 ppm total cyanide (204 times human health standards).[158]
Tailings spills or failures.	**1983:** 19 million gallons of cyanide solution leaked from an unlined tailings impoundment. Cyanide solution leaked down through underground alluvial gravel channels, under a cut-off wall intended to prevent groundwater migration out of the impoundment. Resulting groundwater contamination affected the Jefferson River alluvium. Four domestic wells and a well at the veterinary clinic were contaminated. Placer Dome was sued by neighboring landowners. In 1989, six years after the spill, the groundwater was still contaminated with cyanide. The company eventually bought out the landowners.[159]
Impacts to water resources	The mine resulted in groundwater contamination to four domestic wells and a veterinary clinic. Water treatment in perpetuity will be required at this mine to prevent further impacts to water resources.

Ruby Hill Mine, NV The Ruby Hill Mine is an open pit gold mine located approximately 0.7 miles northwest of Eureka, NV on private land and BLM land. Mining operations were approved in 1997.	
Reports of pipeline failures and other accidental releases[160]	**August 7, 2015:** A storm event resulted loss of containment from the Barren Tank, North Side Heap Leach Pipe Channel, and the Pregnant Solution Tank and Pregnant Solution Pond. All solution contained cyanide and may have contained elevated levels of some metals. **August 16, 2004:** 1,900 gallons of process solution was released containing 1.2 lbs. of sodium cyanide as a result of a several hour rain event which overwhelmed lined leach pad beam. **June 19, 2003:** 2,400 gallons of process solution containing about 1.8 lbs. of cyanide was released from the Ruby Hill Leach Pad containment system when a barren solution pump failed.
Seepage collection and treatment failures	None identified.
Impacts to water resources	None identified. There are no perennial streams in the permit area and intermittent stream segments were removed or filled during construction of the East Archimedes Pit.[161]

Greens Creek Mine, AK Greens Creek, which started production in 1989, is an underground mine using flotation processes to recover zinc and lead and gravity processes to recover gold and silver. It is located in southeast Alaska in the Tongass National Forest on Admiralty Island, 18 miles southwest of Juneau.	
Reports of pipeline failures and other accidental releases	**2009:** On December 21, EPA issued a Notice of Violation (NOV) to Hecla Greens Creek Mining Company resulting from a June 8, 2009 inspection, which found the following violation: on August 11, 2009, Hecla Greens Creek Mining Company drillers observed an unpermitted discharge of mud entering Greens Creek. **2007:** On April 25, EPA issued a Notice of Violation (NOV) to Kennecott Greens Creek Mining Company resulting from a July 7, 2006 inspection. The following violation was cited in the NOV: 1) the 2005 storm water monitoring report showed numerous discharges from storm water outfalls exceeding Water Quality Standards for lead and zinc.[162] **2007:** On 12/20/2007, a report of 450 gallons of diesel fuel from a broken hose connected to a barge, spilled into Hawk Inlet during fuel transfer.[163] **2007:** On 3/14/2007 a report of diesel fuel spilled into Hawk Inlet.[164] **2006:** On April 10, approximately 4,163 gallons of mine drainage discharged into Greens Creek due to a joint failure in a steel pipeline that normally transfers mine drainage from the mine to the Tailings Storage Facility Waste Water Treatment Plant. This event resulted in the Department of Environmental Compliance issuing a Notice of Violation (NOV) to Kennecott Greens Creek Mining Company on April 28, 2006 for discharging water with lead and zinc concentrations exceeding Alaska Water Quality Standards (WQS).[165] **2004:** Greens Creek was fined $12,900 for two leaks the company reported, on June 28, 2004. The first water quality violation occurred when a bucket tipped over, spilling an estimated four gallons of diesel oil into upper Zinc Creek. Greens Creek personnel tracked the diesel sheen for ½ mile downstream.[166] Drilling mud was also released into Zinc Creek due to an overflow of a mine pond. **1989:** In May, the first attempt to load a barge with ore concentrate resulted in a major spill of approximately 95-100 pounds of lead sulfide and a total of approximately 1,000 pounds concentrate into Hawk Inlet.[167] In 1995, efforts to use a suction dredge to clean up the spill occurred, however a 2015 annual monitoring report states that concentrate is still present in the sediments.[168]
Seepage collection and treatment failures	The Draft Environmental Impact Statement (DEIS) for expanding the tailings storage facility documents impacts to surface and groundwater: The water quality in Further Creek, Further Seep, and Duck Blind Drain is generally of lower quality than that of Greens Creek, Tributary Creek, and Cannery Creek. In general, these drainages and seeps have elevated sulfate, lower pH, and elevated dissolved zinc as well as some other metals. The lower pH and elevated sulfate and metals in these drainage features were from other pyritic sources such as waste rock or production rock that were outside the slurry walls of the Tailings Disposal Facility.[169] Elevated metals levels in the North Fork of Further Creek were reported to be caused by a thin veneer of tailings residue at the toe of the West Buttress that accumulated from the removal of the temporary tailings cover in 1999, and from residual tailings found in the Northwest Diversion Ditch.[170]

	GREENS CREEK MINE, AK - CONTINUED According to the DEIS, in 2006, groundwater in several bedrock wells had elevated sulfate concentrations and conductivity. These wells are down-gradient and in close proximity to the Tailings Disposal Facility (TDF). Tailings contact water from the old unlined portion of the TDF likely seeped into the bedrock aquifer. This is also shown by the increasing sulfate concentration in Monitoring Well (2S). Monitoring Well 2S is located in an area where groundwater has an upward gradient and bedrock water may discharge to the shallow aquifers and surface water. Since then, the northwestern part of the tailings facility was excavated to install a liner, before re-depositing tailings. Sulfate concentrations increased in wells MW-T-04-14 and MW-T-05-04 in the most recent sampling event. It is possible that construction for the liner installation temporarily caused the increases."[171] Seepage from D Pond Berm contains some constituents above Alaska Department of Environmental Conservation Water Quality Standards and is discharging directly into Greens Creek.[172] According to the 2013 EIS, acid mine drainage from the mine will require water treatment for hundreds of years, if not in perpetuity.[173]
Impacts to water resources	Surface water in Further Creek, Further Seep and Duck Blind Drain has been degraded with sulfates, lower pH and zinc. Water quality violations for zinc and lead have occurred as a result of discharges into Greens Creek, and discharges of diesel oil and drilling mud to Zinc Creek. Adverse impacts to sediments in Hawk Inlet from a spill of ore concentrate. Groundwater has been degraded with sulfates.

WHARF MINE, SD Wharf is an open pit cyanide heap leach mine in the northern Black Hills of South Dakota. It has been operating since 1982. The mine is located on private lands and public lands managed by the Bureau of Land Management.	
Reports of pipeline failures and other accidental releases	**2014:** Approximately 5,000 gallons of blasting agent spilled.[174] **2001:** A release of process solution from a leak in the Pregnant Pond. Wharf also violated its surface water discharge permit for selenium.[175] According to the State, the violations stem from a series of water tests between July 2000 and June 2001 that showed selenium levels have been 5.79 to 8.59 parts per billion. To protect aquatic life, the standard for long-term exposure to selenium is 5 parts per billion. Wharf was fined $31,000 for violations. **2000:** Approximately 8,000 gallons of process solution containing cyanide spilled at Wharf mine when a pipe joint fell apart. The pipe is located in the leak detection system.[176] The EPA documented the following releases from 1984-1991[177] **1991:** Cyanide (1,317 gallons per day) **1991:** Cyanide (1,288 gallons per day) **1990:** Leachate 10,000 gallons **1988:** Cyanide (500 gallons) **1988:** Leachate (100 gallons) **1987:** Diesel fuel (4,000 gallons) **1986:** Process water (1 gallon/hour, amount unknown) **1984:** Cyanide (200 gallons)
Seepage collection and treatment failures	**2008:** Wharf violated its surface water discharge permit with the release of biomass from its water treatment plant during the summer of 2007.[178] The discharge affected fish populations in Annie Creek. Wharf also violated its permit limits for ammonia, cyanide, arsenic, and pH. Wharf was issued a civil penalty of $214,930.[179] **2008:** Coincident with the in situ biotreatment of Process Area ground water, concentrations of arsenic in Process Area ground water dramatically increased.[180] Background arsenic concentrations associated with the Pahasapa limestone aquifer underlying the Process Area are very low to negligible. Prior to 2008, most process area wells only rarely yielded water with detectible concentrations of arsenic. In 2008, arsenic levels in Monitoring Well-44, Monitoring Well-47, HDH-11 and HDH-12 all increased to well above the 0.01 mg/l ground water standard. In general, as of 2011, arsenic levels in these wells appear to be stabilizing and/or decreasing. However, arsenic concentrations in MW-47, HDH-11 and HDH-12 still exceed the 0.01 mg/l standard. **2003:** Wharf violated its surface water discharge limits for ammonia and its groundwater discharge limits for nitrate down gradient of the spent ore pile.[181] **2000:** Surface water compliance point below Wharf's Reliance waste rock depository in the headwaters of Annie Creek exceeded daily maximum selenium during a period from August 1998 to July 1999.[182] Surface water monitoring below Wharf's spent ore depository in Ross Valley failed a Whole Effluent Toxicity test for the January to March 1999 quarter. Surface water compliance point 5 exceeded ammonia standards during November and December 1999. **WHARF MINE, SD - CONTINUED**

	WHARF MINE, SD - CONTINUED **1997:** Surface water compliance points below Wharf's Reliance waste rock depository in the headwaters of Rock Creek and below Wharf's spent ore depository in Ross Valley, and the instream sampling points in Annie Creek have exceeded the daily maximum total cyanide limit of 0.02 mg/l since March 1994.[183] From June 1995 to December 1997 groundwater sampling below Wharf's contingency pond in McKinley Gulch indicated nitrate concentration over groundwater standards directly attributable to the discharge of process solution. Monitoring well in the alluvium of Annie Creek approximately 450 feet upstream of its confluence with Spearfish Creek exceeded the 10 ppm groundwater for nitrate during 1996 and 1997. Also on a few occasions, Wharf exceeded selenium and copper at compliance point 1. These discharges caused numerous violations of law. **1995:** From August 21-28, Wharf discharged inadequately treated cyanide solution into Ross Valley and subsequently into Annie Creek. Approximately 300 fish were killed as a result of the discharge. The discharge caused several violations.[184] Wharf agreed to pay the department $150,000. Mining of the East and West Liberty Pits encountered sulfide rich rock. Department inspectors identified a number of small acid seeps in the Pit. Although mitigation occurred in 1999, the mine's 2011 discharge permit summary states that drainage from the West Liberty Pit area continues to impact the bedrock groundwater system in Nevada Gulch.[185] Sulfate levels in SMO1A are on an upward trend, with concentrations exceeding 1,900 mg/l. Pre-mining levels of sulfate were around 40 mg/l. The mine has also resulted in high concentrations of nitrates in groundwater, which is created from the breakdown of residual cyanide in the process area and spent ore impoundments and from blasting residues in fuel explosives found in the waste rock depositories. Since the mid-1990s, nitrate impacts have occurred in the groundwater underlying the process ponds and leach pads. Since 1995, nitrate levels have repeatedly exceeded nitrate water quality standards to protect public health.[186] Wharf identified leakage sources in the leach pad dams, process ponds, and leak detection galleries.
Impacts to water resources	Groundwater has been polluted with nitrates, arsenic and cyanide at levels above water quality standards. Annie Creek has been polluted with selenium, ammonia, cyanide, and arsenic above water quality standards. Adverse impacts to surface water in Annie Creek resulted in a fish kill; adverse impacts to fish population.

ROBINSON MINE, NV The Robinson Mine is an open pit gold and copper mine located in eastern Nevada approximately 11 km west of the town of Ely. It is located on private lands and BLM lands. It was formerly owned by BHP Copper, Magma Nevada Mining Company.	
Reports of pipeline failures and other accidental releases[187]	**November 30, 2016:** 5,490 gallons of tailings slurry was released from a failed pipeline. **May 30, 2016:** About 2,800 gallons of tailings solution was released from a leaking embankment. **January 23, 2015:** 5,200 gallons of process solution was released from a failed startup valve. **September 3, 2013:** An estimated 420,000 gallons of water and 2,500 tons of tailings solids was released from the Downstream Stormwater and Sediments Control Facility as a result of a significant storm. **July 13, 2013:** Approximately 20,000 gallons of process solution was spilled when a collection box became overwhelmed. **May 13, 2004:** Approximately 4,800 gallons of process solution was spilled when a weld on a pipeline failed. **May 5, 2004:** About 180,000 gallons of tailings slurry was released when a pipeline broke. **1996:** The mine experienced eight reported spills during 1996. Most of these spills involved tailings solution and reclaim water releases due to equipment failures. The five spills resulting in releases of copper flotation tailings had spill volumes ranging from 1,500 gallons to 66,000 gallons. Four of these spills resulted in contamination of relatively small areas of soil. The largest spill resulted in contamination of a downstream drainage bed for 2.3 miles with an average flow path width of 3 ft. Two spills resulted in a combined release of 76,000 gallons of reclaim water.[188] In August of 1996, the NDEP notified BHP Copper that it was in violation of its Water Pollution Control Permit due to increased levels of Total Dissolve Solids and pH. A consent agreement was developed in 1997 for the accidental release of tailings from the tailings storage facility on February 24, 1996.
Seepage collection and treatment failures	**2016:** The Final Environmental Assessment for expansion of the mine documents the continued degradation of groundwater from sulfates, which has occurred as a result of seepage from the tailings pond.[189] According to the EA, "The existing TSF was permitted without a liner. Groundwater fate and transport modeling completed to support the original permit considered the transport of sulfate from the facility, but not at the concentrations that now exist in groundwater downgradient from the facility. The seepage from the unlined impoundment has impacted downgradient groundwater causing exceedance of maximum contaminant levels (MCLs) of sulfate in several monitoring wells (Figure 2-3)." **2015:** In early 2015, groundwater degradation with respect to sulfate was discovered in groundwater monitoring well WCC-G7 – south of the tailings embankment.[190] The detected sulfate concentration of 711 mg/l exceeds the 500 mg/l reference value for sulfate. On April 29, 2015, the Division issued a Finding of Alleged Violation and Order, requiring the company to complete actions, which had already begun, to investigate and remediate the contamination – including groundwater wells to delineate the size of the contaminant plume.

CONTINUED **Seepage collection and treatment failures**	**ROBINSON MINE, NV - CONTINUED** **2010:** The State of Nevada issued a Finding of Alleged Violation and Order for the failure to comply with permit and regulatory requirements regarding stabilization of spent ore and associated acid rock drainage at the Intera and Green Springs area.[191] As required by the October 2010 Corrective Action Plan, the company was required to reconstruct the liner system of the Mill Water Ponds because leakage from the ponds was believed to be contributing to the Intera monitoring water flow. The Order required the mine to "submit a plan by May 11, 2010 stating whether the Mill-Water Ponds, the overhead standpipe near the Mille-Water Ponds, and any other leaking pipes or tanks in the area, would remain on the Liberty Dump or be moved off the Liberty Dump (and any other potential sources)." **1996:** A Consent Agreement and Order was developed in 1997 to resolve the Finding of Alleged Violation and Order issued August 20 1996 for alleged violations of discharge limits set by the Permit for the Giroux Wash Tailings Storage Facility.
Impacts to water resources	Groundwater degradation from sulfates, total dissolved solids, and manganese.[192] Contamination of downstream drainage bed for 2.3 miles from mine tailings process water (see spills above).

Florida Canyon Mine, NV The Florida Canyon Mine is an open pit cyanide leach gold mine on BLM land and private land approximately 7 miles southwest of Imlay, Nevada**.** It has been in operation since 1986.	
Reports of pipeline failures and other accidental releases[193]	July 7, 2016: Unknown quantity spill occurred from a leach pad (washout), but with no cyanide content. **February 21, 2011:** 100,000 gallons of pregnant solution (cyanide) was released due to a blockage of the solution ditch by ore that slid off the angle of repose slopes. The solution was high in chloride, arsenic, nitrate, mercury, sulfate, and total dissolved solids. **January 8, 2008:** 7,892.7 gallons of cyanide process solution spilled releasing 0.17 lbs. of cyanide. The spill results from an overflow in the solution collection channel from the accumulation of debris in the channel. **May 17, 2005:** Stormwater released from sedimentation pond overflow at a rate of 200 gallons per minute. There were no process contaminants suspected in the release. **December 30, 1996:** 52,500 gallons of cyanide solution (concentration less than 90 mg/L but greater than 22 mg/L) was released with a cyanide content estimated at 20.9 lbs. caused by a foreign object in a chemical pipe. **January 7, 1994:** 79,260 gallons of 65 mg/L cyanide solution flowed out of containment from a ruptured pipe releasing 22.76 lbs. of cyanide. **April 13, 1993:** 400 gallons of cyanide solution containing less than 0.002 lbs. of cyanide spilled as a result of a frozen pump. **June 4, 1991:** 112 gallons of cyanide solution was spilled from a split in a line releasing 0.10 lbs. of cyanide. **April 8, 1991:** 535 gallons of cyanide solution sprayed on an access road due to a split in the line, and about 0.47 lbs. of cyanide was released. **March 12, 1991:** 1,200 gallons of cyanide solution was released due a failure from a pipe from the barren pond to the heap leach pad. The total amount of cyanide released was about 1 lb.[194] **September 4, 1990:** 30 gallons of cyanide solution containing 0.042 lbs of cyanide leaked due to a crack in the mainline onto the leach pad perimeter road. **August 27, 1990:** Approximately 30 gallons of sodium cyanide solution containing 0.053 lbs. of cyanide was spilled due to a failure in a sump pump the process plant. **August 15, 1990:** 503 gallons of cyanide solution containing 0.61 lbs. of cyanide was released due to a pipeline rupture. **June 25, 1990:** 20 gallons and 240 gallons of cyanide containing 0.02 and 0.5 lbs. of cyanide respectively around one of the ponds. (Cause not stated) **June 22, 1990:** 52 gallons of cyanide solution containing 0.098 lbs. of cyanide leaked from a valve; 10 gallons of cyanide solution containing 0.002 lbs. of cyanide leaked due to operator error. **June 14, 1990:** 10 gallons of cyanide solution containing 0.04 lbs. of cyanide leaked due to a faulty valve. **May 16, 1990:** 13.735 gallons of cyanide solution containing 25.78 lbs. of cyanide was released when a d4 dozer torn a hole in the perimeter mainline. **May 8, 1990:** 45 gallons of cyanide solution containing 0.094 lbs. of cyanide from a valve failure as a result of a rusted bolt.

	FLORIDA CANYON MINE, NV - CONTINUED **May 2, 1990:** Approximately 2880 gallons (6 gpm for ~8 hours) of pregnant solution containing 8.28 lbs. of cyanide leaked due to a tear in the liner seam from high winds and an unanchored liner edge. **January 11, 1990:** 100 to 150 gallons of cyanide solution containing 0.33 pounds of cyanide was spilled due to operator error. **September 9, 1989:** 20 gallons of a lead nitrate solution was spilled when the barrel containing the solution was knocked over. There are no details on the amount of lead. **July 4, 1989:** 100 gallons of cyanide solution containing 0.2 lbs. of cyanide was spilled due to a break in a welded joint in a plastic pipe. **July 30, 1989:** Excessive dust from the crushing/conveying facilities was reported **November 27, 1987:** 200 to 300 gallons of cyanide solution was released. **October 2, 1987:** 6,000 gallons of barren solution sprayed off of the heap leach pad due to a cracked barren pipe. The amount of the release is unclear.
Seepage collection and treatment failures	**2000:** A contaminant plume comprised of process solution was discovered near the west side of the existing leach pad. Initially, the plume, consisting of weak acid dissociable (WAD) cyanide, mercury, and nitrates, was traced to leach pad solution channels. Routine monitoring in the second quarter of 2000 revealed elevated concentrations of process-related constituents in the vicinity of monitoring well MW-16. Continued monitoring of the area has shown that the process-related constituents have been detected in monitoring wells MW-16B, MW-F, MW-G, MW-KA, MW-M, MW-O, and MW-N.[195] In 2012, new monitoring wells confirm that groundwater in MW 28 is an area of detectable WAD cyanide and total nitrogen, with MW 29 and MW 31 within the plume.[196] **2000-2014:** Between 2000 and 2014, additional leaks were identified at various locations including the Barren Pond, solution channels, and sumps. As a result of continued contamination of groundwater NDEP issued a Finding of Alleged Violation and Order in August 2012. BLM placed the mine in Noncompliance in August 2012.[197]
Impacts to water resources	Groundwater has been polluted with cyanide, mercury and nitrates at levels that exceed drinking water standards.[198]

Mineral Ridge, NV The Mineral Ridge Project (Mineral Ridge) is an active open pit and inactive underground mine located approximately 4.5 miles northwest (by air) of the town of Silver Peak, Nevada. The project is located on both private land and public land administered by the BLM.	
Reports of pipeline failures and other accidental releases[199]	**May 11, 2011.** A cyanide waste of unknown quantity was released as an improper disposal in a landfill. The practice had been occurring for the past several months.February 26, 2005. About 100 gallons of pregnant solution was spilled when a heap well failed at a joint. **March 3, 2004**. 2,355 gallons of cyanide leach solution containing 1.57 lbs. of cyanide was released from heavy snow melt on a leach pad.
Seepage collection and treatment failures	None documented.
Impacts to water resources	None documented. See above. No seeps, springs or perennial streams are located within the mine permitted area.[200] Off-site springs are monitored only once a year. Groundwater >500 feet bgl.

Briggs Mine, CA The Briggs Mine is an open pit heap leach gold and silver mine located about seven miles north of Ballarat, CA in the Panamint Valley near Death Valley National Park on public lands managed by the BLM and private lands.	
Reports of pipeline spills and other accidental releases	**2009:** A Notice of Violation was issued for process solution discharged to the ground outside the containment of the lined leach pad area on two separate occasions n 2009. The process solution contained 120 parts per million cyanide. On December 14, 2009 approximately 50 gallons of process solution was released. On December 31, 2009 a second released occurred in which 400 gallons of process solution was discharged.[201]
Seepage collection and treatment failures	**2017**: Ground water monitoring wells continue to show elevated cyanide levels.[202] **2015:** A Notice of Violation was issued for cyanide detected in a monitoring well at levels that violate compliance action levels.[203] The initial detection of WAD cyanide in MW-6 was confirmed in subsequent sampling events at a concentration of 0.064 milligrams per liter (mg/L) on October 28, 2015 and 0.066 mg/L on December 10, 2015. The detected concentrations of WAD cyanide exceed the Water Quality Protection Standard (WQPS) concentration limit of 0.03 mg/L and constitutes verification of measurably significant evidence of a release and establishes the requirement for an EMP as required under Title 27 of the California Code of Regulations (CCR) §20420(k)(5).[204] An engineering report in 2016 determined that the cyanide in groundwater is due to leaks in the barren solution line located north and east of the solution ponds at the Site.[205]
Impacts to water resources	Groundwater contamination from cyanide.

Rochester Mine, NV The Rochester Mine has been in operation since 1986. It mines gold and silver from open pit mining and heap leach processing operations, and it is located on private land and BLM land.	
Reports of pipeline spills and other accidental releases[206]	**2013:** Report of 5,447 pounds of cyanide released onto ground.[207] **March 19, 2012:** 123.5 tons of heap leach material slide off the pad and out of containment. As a result, a calculated 4,203 gallons of solution containing 24.5 lbs. of material containing cyanide was released from a heap leach pad due to a break in a broken 8 inch solution feed line.[208] **November 23, 2007:** About 700 gallons of solution containing 3.2 lbs. of cyanide was spilled due to a frozen pipeline. **November 11, 2013:** Saturated leach pad material overwhelmed the containing berm, which was calculated to contain 6,288 gallons of solution and 47.2 lbs. of sodium cyanide. **May 6, 2013:** 1105.08 gallons of barren solution containing 6.91 lbs. of cyanide was released due to operator error. **May 23, 2007:** An estimated 3,792 gallons of pregnant solution containing cyanide, elevated levels of arsenic, mercury, silver, and nickel were released from a pipeline failure. **2007:** A report of a leak in a solutions line released 20 pounds of cyanide.[209] **1997:** A report of a broken pipe from the heap leach pad released 40 pounds of cyanide.[210] Also a report of a process line failure released 7.9 pounds of cyanide.[211] **1996:** The second spill occurred on March 6, 1996. Freezing overnight temperatures caused a line in the leach pad to rupture. Consequently, 5,500 gallons of sodium cyanide process solution escaped the heap leach pads primary containment system. 4,500 gallons of the process solution mixed with 35,000 gallons of fresh water from snowmelt. The remaining solution mixed with an unknown amount of snowmelt.[212] **1994:** Two spills have been reported at the mine facility since 1994. The first reported spill occurred on February 18, 1994. As a result of a power outage, 450 tons of ore containing process solution was displaced from the leach pad. From 1.97 to 9.861 lbs. of cyanide were washed out with the ore. **1988:** A broken pipeline resulted in the displacement of 200 tons of ore off the liner, causing 19,400 gallons of process solution containing 45.3 lbs. of cyanide to be released to the environment. Of this, ,5000 gallons of process solution containing 11.7 lbs. of cyanide were discharged off site to American Canyon, an intermittent drainage. A dike was installed in American Canyon to stop solution flows.[213] **1987:** A release of process solution from the East Pregnant Pond occurred, causing pregnant solution to run into American Canyon for 12-18 hours at a rate of 5-10 gpm. The USEPA issued a Notice of Violation on June 30, 1988 for violating the Clean Water Act by discharging pregnant to American Canyon.[214]

	ROCHESTER MINE, NV - CONTINUED
Water collection and treatment failures	Releases from the Stage I heap leach pad have contaminated groundwater. Leakage from the pad was first noticed in 1991, near the north side (HydroGeo, 2010). Concentrations of arsenic, mercury, manganese, nitrate/nitrite, TDS, and WAD CN were measured; they were found to be above the Nevada reference values in WI-16, WI-17R, WI-19, WI-29/R, MW-30/R, MW-35, MW-37, and MW54 (SWS 2014). Well TB-1, downgradient of the stage 1 pad, exceeds Nevada Profile I reference values. The maximum detected concentration at TB- 1 between March 2011 and May 2013 was 650 mg/L CN-, 0.075 mg/L arsenic, 3.8 mg/L mercury, and 2,300 mg/L TDS (SWS 2014).[215] In 2003, the Nevada Department of Environmental Protection issued Rochester a Finding of Alleged Violation (FOAV) for cyanide exceedences discovered during quarterly monitoring. The violation was issued in response to the discovery of cyanide exceedences in MW-16, a monitoring well screened in the shallow bedrock below the site. Contamination had been previously confined to the alluvium.[216] Groundwater monitoring wells downgradient of the Stage I heap leach pad showed exceedences of arsenic, mercury, cadmium, nitrate and WAD cyanide during the period 2000 to 2003. Surface water monitoring sites in a spring downgradient of the Stage I heap leach pad showed exceedances of nitrate, lead, cyanide, arsenic, mercury.[217]
Impacts to water resources	Groundwater polluted with arsenic, mercury, manganese, nitrate/nitrite, TDS and cyanide. American Canyon (an intermittent drainage) has been contaminated by a process solution spill in 1988. Exceedances of arsenic and nitrate in American Canyon springs.

Denton Rawhide Mine, NV The Denton-Rawhide Mine is located approximately 36 miles southeast of the town of Fallon, NV. The mine is located on private land and public land administered by the U.S. Bureau of Land Management (BLM). The project consists of an open pit gold and silver mine.	
Reports of pipeline failures and other accidental releases[218]	**January 18, 2015**: 6,000 gallons of cyanide solution released due to a weld failure in a HDEP pipe, and the total release was about 6.25 lbs. **January 3, 2012:** 20 to 30 gallons of 0.015 mg/L mercury solution released due to an elevated flow volume in a carbon vessel. **November 24, 2011:** Water flooded the mercury retort's outside filter and flowed out of containment. The contaminated water exceeded standards for arsenic (0.27 mg/L), mercury (0.015 mg/L), sulfate (2,600 mg/L), and total dissolved solids (3,700 mg/L). **December 13, 2008:** Approximately 3,000 gallons of process solution released do to a pipe failure form excessive corrosion and cold temperatures resulting in section pulling apart. The total release of sodium cyanide was about 0.25 pounds. **2002:** Rawhide experienced three process solution spills off the heap leach pad, the largest consisting of 40,000 gallons (47 pounds of cyanide) occurred as a result of ruptured pipe. The remaining two were 6,000 gallons (8 pounds of cyanide) and 1,000 gallons (1.5 pounds of cyanide), respectively.[219] **November 1, 2001:** 1800 gallons of cyanide solution released for a total of 2.25 lbs. of cyanide discharged. The cause of the release was a bulldozer running over a barren solution return line. **October 15, 2001:** 25,000 gallons of cyanide solution spilled for a total of 0.2 lbs. released as a result of a HDPE pipe weld splitting. **September 8, 1999:** Two cyanide spills occurred at 4,700 and 3,000 gallons of cyanide solutions at concentrations of 0.1 lbs./ton and 0.05 lbs./ton respectively due to a broken pipeline. **1990:** Safety pond solution (167 gallons per day). Unknown total amount.[220]
Water collection and treatment failures	None documented.
Impacts to water resources	Groundwater in the vicinity of the facility was not located. More than 300 exploratory holes were drilled to depths of at least 500 feet, with several drilled to 2000 feet depth. None of the holes drilled encountered groundwater. No surface water is within 5 miles of the project except for ephemeral washes that drain into the alkali flat of northwest Gabbs Valley.

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Addressing Climate Change in Enforcement and Compliance Assurance

EPA's enforcement and compliance program is focused on addressing 21st century environmental challenges, none of which are greater than global climate change. The climate crisis continues to accelerate: 2023 was the warmest on record, with more billion-dollar weather events in the United States during the first eight months of the year than in any prior calendar year. If we fail to take decisive action by the end of this decade, searing heat, widespread drought, destructive storms, and coastal flooding will become commonplace.

During his first week in office, President Biden issued Executive Order 14008 <https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad> calling on all federal agencies to "combat the climate crisis with bold, progressive action" and directed them to reduce emissions of greenhouse gases (GHGs), bolster adaptation to alter our behaviors, and increase resilience to the impacts of climate change. EPA Administrator Regan subsequently made addressing the climate crisis the top cross-cutting goal in EPA's Strategic Plan <https://epa.gov/system/files/documents/2022-03/fy-2022-2026-epa-strategic-plan.pdf>.

EPA has taken several steps to combat climate change during the last three years, including new legal requirements that must be enforced fairly and vigorously to help stave off catastrophic climate change. EPA will prioritize enforcement and compliance actions that mitigate climate change and include climate adaptation and resilience measures in enforcement and compliance activities whenever appropriate.

On this page:

- OECA Climate Enforcement and Compliance Strategy
- Combatting the Climate Crisis by Reducing Emissions of GHGs
- Climate Change Adaptation and Resiliency
- Capacity Building and Technical Assistance

OECA Climate Enforcement and Compliance Strategy

Following the mandate in President Biden's Executive Order and EPA's strategic plan, EPA's Assistant Administrator for the Office of Enforcement and Compliance Assurance issued EPA's Climate Enforcement and Compliance Strategy (pdf) <https://www.epa.gov/system/files/documents/2024-02/epasclimateenforcmentandcompliancestrategy_1.pdf> (336.37 KB) on September 28, 2023, directing all EPA enforcement and compliance offices to address climate change, wherever appropriate, in every matter within their jurisdiction.

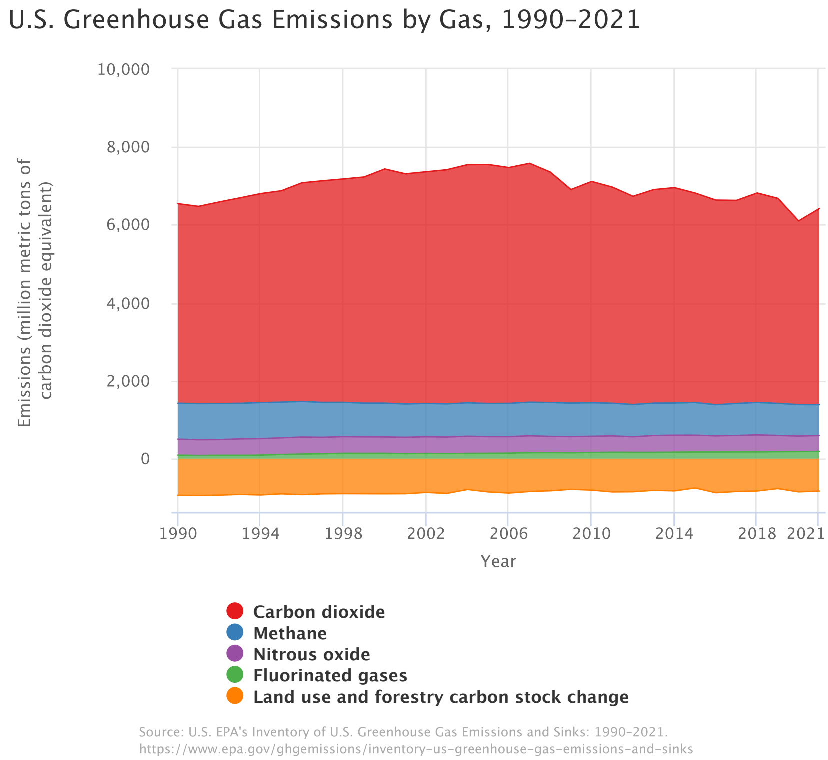
In particular, the strategy requires EPA's enforcement and compliance programs to:

- Prioritize enforcement and compliance actions to mitigate climate change;
- Include climate adaptation and resilience in case conclusions, as appropriate; and
- Provide technical assistance to achieve climate-related solutions and build climate change capacity among EPA staff and our state and local partners.

The strategy also recognizes that while the impacts of climate change affect people in every region of the country, certain communities and individuals already overburdened by environmental stressors and with less access to the resources needed to adapt to and recover from climate change impacts are especially vulnerable. Under this strategy, EPA's enforcement and compliance programs will consider climate equity <https://epa.gov/climateimpacts/climate-equity> as we factor climate change considerations into our enforcement and compliance activities.

Combatting the Climate Crisis by Reducing Emissions of Greenhouse Gases

In keeping with EPA's Climate and Enforcement Strategy, EPA, working with our state, local, and tribal partners, is prioritizing our enforcement and compliance activities to reduce air pollutants that cause or contribute to climate change (i.e., carbon dioxide, methane, and fluorinated gases). In 2021, U.S. GHG emissions totaled 6,340.2 million metric tons of carbon-dioxide equivalents, and net emissions of 5,586 million metric tons after carbon storage from the land sector is included.



National Enforcement and Compliance Initiative: Mitigating Climate Change

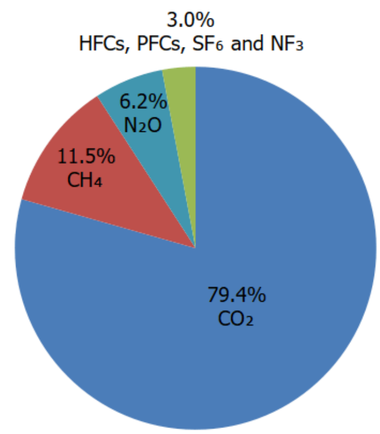
In August 2023, EPA included Mitigating Climate Change as one of six National Enforcement and Compliance Initiatives <https://epa.gov/system/files/documents/2023-08/fy2024-27necis.pdf> (NECIs) for FY 2024-2027 and will focus additional resources on reducing emissions of the highest impact super-pollutants (i.e., hydrofluorocarbons (HFCs) and methane).

HFCs are potent greenhouse gases with global warming potentials hundreds to thousands of times higher than carbon dioxide (CO_2). HFCs were used as a replacement for ozone depleting chlorofluorocarbons (CFCs) in refrigeration and air conditioning equipment and are also used in foams, fire retardants, and many other applications.

The 2020 American Innovation and Manufacturing (AIM) Act <https://epa.gov/climate-hfcs-reduction/aim-act>, authorized EPA to address these super pollutants by:

- Phasing down of the U.S. production and consumption of HFCs by 85% over the next 15 years;
- Maximizing reclamation and minimizing releases from equipment, and

- Facilitating the transition to next-generation technologies through sector-based restrictions on HFCs



More information on reducing HFCs is available on the Agency's Protecting Our Climate by Reducing Use of HFCs website <https://epa.gov/climate-hfcs-reduction>.

Methane is also a potent greenhouse gas with a global warming potential 28 times higher than CO_2. EPA will seek greater compliance with environmental laws at oil and gas facilities and landfills, the second and third largest sources of U.S. methane emissions.

Enforcement Actions to Combat Climate Change

The following cases highlight EPA enforcement actions taken to date to combat climate change. The new Mitigating Climate Change NECI will continue this work with heightened focus and additional resources to tackle this pressing issue.

- The first-ever administrative complaint for the unlawful import of super-polluting hydrofluorocarbons (HFCs) under the American Innovation and Manufacturing Act (AIM Act) brought against USA Wholesale, Inc. demonstrates EPA will not hesitate to sue to hold companies accountable. The complaint states USA Wholesale attempted to illegally import 34,480.3 pounds of HFC-134a and seeks civil penalties for violating the AIM Act. (April 10, 2024, EPA Press Release. <https://epa.gov/newsreleases/epa-files-complaint-against-california-company-unlawful-import-hfcs>)

- A settlement with Resonac America Inc. for the illegal importation of super-polluting hydrofluorocarbons (HFCs) under the American Innovation and Manufacturing Act imposed the largest penalty to date, prevented the illegal importation of approximately 6,208 pounds of HFCs, and will require for the first time the destruction of HFCs. Under the settlement, Resonac will pay a penalty of $416,003 and destroy 1,693 pounds of HFCs to resolve EPA's allegations of violations. If released into the atmosphere, these HFCs have a global warming impact equivalent to the emission of 41,676.8 metric tons of CO_2. (March 21, 2024, EPA Press Release <https://epa.gov/newsreleases/epa-reaches-settlement-resonac-america-illegal-import-super-climate-pollutant-port-los>.)
- The first arrest and criminal charges were brought against an individual for illegally smuggling and selling hydrofluorocarbons (HFCs) in violation of the American Innovation and Manufacturing Act. Illegal smuggling of HFCs undermines U.S. efforts to combat climate change and this arrest demonstrates EPA's commitment to the climate enforcement initiative and efforts to prevent refrigerants that are climate super pollutants from illegally entering the United States. (March 4, 2024, EPA Press Release <https://epa.gov/newsreleases/california-man-arrested-smuggling-potent-greenhouse-gases-united-states>.)
- A settlement with Apache Corp. will result in projects to ensure that over 400 of the company's oil and gas well pads in New Mexico and Texas are in compliance with federal and state law requirements. The projects, estimated to cost at least $5.5 million will capture and control air emissions from its oil storage vessels. Additionally, the company will pay a $4 million civil penalty for past illegal emissions. Future compliance actions will result in annual reductions of more than 900 tons of methane, which is equivalent to 25,000 tons of CO_2 or taking over 5,600 gasoline powered vehicles off the road each year. (February 13, 2024, EPA Press Release <https://epa.gov/enforcement/apache-corporation-settlement>.)

- Settlements with Open Mountain Energy, LLC and Sigma Air, LLC, will prevent the illegal import of hydrofluorocarbons (HFCs) under the 2020 American Innovation and Manufacturing Act (AIM Act). These settlements further illustrate how EPA's enforcement actions are protecting the environment from illegal emissions of climate super pollutants. (January 29, 2024, EPA Press Release <https://epa.gov/newsreleases/epa-enforcement-prevents-multiple-illegal-imports-super-climate-pollutant>.)
    - The settlement with Open Mountain Energy, LLC, prevented the illegal importation of approximately 20 metric tons of HFCs. Enforcement actions that prevent the illegal importation of HFCs is critical to achieving the goal of phasing down the use of HFCs and preventing the release of climate super pollutants., which if released into the air have a climate impact equivalent similar to the benefits describe in the Apache case summary.
    - The settlement with Sigma Air, LLC, is the first settlement finalized under EPA's HFC Expedited Settlement Agreement Pilot Program <https://epa.gov/system/files/documents/2023-07/esapilotprogram-hfcallocationregimport063023.pdf> and prevented the illegal importation of 3,736 pounds of HFCs. The pilot program addresses violations that are easily detected, can be easily and timely corrected, and are not likely to result in significant harm to human health or the environment.
- A settlement with Allied Waste Niagara Falls Landfill, LLC (Allied) resolved Clean Air Act violations at the companies landfill in Niagara Falls, New York. As part of the settlement, Allied will operate a gas collection and control system to reduce the amount of harmful chemicals, primarily methane, as well as other harmful organic compounds, released into the air. This settlement will eliminate 86,000 metric tons of CO_2 equivalent methane emissions per year (similar to the amount of greenhouse gas reductions that would be achieved by taking over 19,100 gasoline powered vehicles off the road for one year). (January 9, 2024 EPA Press Release <https://epa.gov/newsreleases/allied-waste-resolves-clean-air-act-violations-its-niagara-falls-landfill>.)

- A settlement with Mewbourne Oil Company to undertake projects to ensure 422 of its oil and gas well pads in New Mexico and Texas comply with state and federal clean air regulations and offset past illegal emissions at a cost of at least $4.6 million. A co-benefit of the actions by these companies will also result in a reduction of more than 1,300 tons of methane (equivalent to 33,000 tons of CO_2 annually or similar to the amount of greenhouse gas reductions that would be achieved by taking 7,300 gasoline powered vehicles off the road for one year). (August 8, 2023, EPA Press Release <https://epa.gov/newsreleases/united-states-orders-mewbourne-oil-company-pay-55-million-and-reduce-unlawful-air>.)
- Settlements with three natural gas processors (Williams Companies, Inc.; MPLX LP; and WES DJ Gathering LLC) that when fully implemented, the combined settlements will reduce methane emissions by approximately 1,800 tons per year (equivalent to 50,000 tons of CO_2 annually or similar to the amount of greenhouse gas reductions that would be achieved by taking 11,200 gasoline powered vehicles off the road for one year. (April 20, 2023, EPA Press Release <https://epa.gov/newsreleases/epa-and-justice-department-announce-clean-air-act-settlements-three-natural-gas>.)
- A settlement with Matador Production Company addressing Clean Air Act violations at its oil and gas well pads that will result in the reduction of criteria pollutants will, as a co-benefit also reduce approximately 1,100 tons of methane emissions per year (equivalent to 31,000 tons of CO_2 annually or similar to the amount of greenhouse gas reductions that would be achieved by taking 6,060 gasoline powered vehicles off the road for one year). (March 27, 2023, EPA Press Release <https://epa.gov/newsreleases/united-states-orders-matador-production-company-reduce-unlawful-air-pollution-its-oil>.)

Other Greenhouse Gas-Reducing Enforcement Activity

Outside the Mitigating Climate Change NECI, EPA's day-to-day enforcement actions aimed at returning facilities to compliance with existing laws are directly and indirectly resulting in the reduction of greenhouse gases. Under settlement agreements where companies agree to increase energy efficiency, conserve energy, or switch fuels, the environmental benefits include a reduction in carbon dioxide (CO_2), the largest source of U.S. greenhouse gas emissions <https://epa.gov/ghgemissions/overview-greenhouse-gases>. Also, EPA's enforcement of Title VI <https://epa.gov/ozone-layer-protection/enforcement-actions-under-title-vi-clean-air-act> of the Clean Air Act to protect the ozone layer results in the direct reduction of fluorinated gases, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which have global warming potentials thousands to tens of thousands of times greater than CO_2.

Examples of recent actions that resulted in a reduction of greenhouse gas emissions outside of the National Enforcement and Compliance Initiative activities include:

- A settlement with Derichebourg Recycling USA Inc. to resolve Clean Air Act violations at 10 scrap metal recycling facilities in Texas and Oklahoma that will prevent the release of ozone depleting refrigerants which contributes to climate change. (January 7, 2022 EPA Press Release <https://epa.gov/newsreleases/epa-settlement-texas-recycling-company-will-prevent-release-ozone-depleting>.)
- A settlement with the New York City Public Schools addresses their longstanding failure to properly monitor and control harmful emissions from their over 1,300 oil-fired boilers. When these boilers are not properly maintained, they can emit excess hazardous air pollutants, particulate matter, nitrogen oxides, sulfur oxides, carbon monoxide and greenhouse gases. The school system agreed to convert to natural gas or replace seven large oil-fired boilers, which is projected to reduce the city's Department of Education's oil consumption and combustion by over three million gallons by November 2027. (September 27, 2021, DOJ Press Release <https://www.justice.gov/opa/pr/united-states-announces-settlement-civil-action-addressing-clean-air-act-violations-new-york>.)

Multiple enforcement actions with HFC importers who failed to report their imported quantities in violation of the Clean Air Act's (CAA) Greenhouse Gas Reporting Program support national and international goals to reduce the use of HFCs. Failure to timely report GHG emissions to the Greenhouse Gas Reporting Program harms the regulatory program by undermining the usefulness of the program's data. The data is used by interested entities to track and compare importers' and facilities' emissions, identify opportunities to cut pollution, minimize wasted energy, and save money. Communities can also use the data to find high emitting facilities in their area.

- The civil penalties in these actions include six landmark settlements totaling more than $1.4 million:
    - IGas Companies <https://epa.gov/system/files/documents/2023-02/bmpigasscalesnstuffcafo.pdf> ($382,473 penalty) (2/6/2023),
    - Artsen Chemical America, LLC <https://epa.gov/system/files/documents/2023-03/artsenchemicalamericallcratified.pdf> ($247,601 penalty) (1/5/2023),
    - Harp USA, Inc <https://epa.gov/system/files/documents/2023-02/harpusaincratified.pdf>. ($275,000 penalty) (1/3/2023),
    - Combs Investment Property, LP <https://epa.gov/system/files/documents/2023-02/combsinvestmentpropertylp.pdf> ($241,562 penalty) (3/14/2022),
    - Waysmos USA, Inc. <https://epa.gov/system/files/documents/2023-02/waysmosusainc.pdf> ($209,000 penalty) (3/14/2022), and
    - Nature Gas <https://epa.gov/system/files/documents/2023-02/naturegasimportandexportinc.pdf> Import and Export Inc. ($84,546 penalty) (3/14/2022).

These HFC importers' violations diminished the ability of federal, state, and local, and tribal governments to compare emissions between similar facilities and develop common-sense climate policies, making it harder to address climate change.

Incorporating clean renewable energy solutions and facilitating electrification infrastructure in case resolutions:

To help reduce GHGs and other pollutant emissions, EPA's enforcement program is including clean renewable energy (wind, solar, etc.), energy efficiency, and electrification requirements into settlement agreements where appropriate. Recent examples include:

- Louisville Gas & Electric settlement requiring truck electrification and electric vehicle charging installation to reduce air pollution in the Louisville area (December 1, 2021 EPA Press Release <https://epa.gov/newsreleases/louisville-gas-electric-company-permanently-limit-harmful-air-pollution>);
- JEG'S Automotive settlement resulted in the replacement of diesel school buses with electric buses in response to air emission control "defeat device" violations in an area of Columbus, Ohio overburdened with pollution and environmental justice concerns (September 13, 2021 EPA Press Release <https://epa.gov/newsreleases/epa-settlement-jegs-automotive-inc-delaware-ohio-resolves-clean-air-act-violations>); and

- Indianapolis Power & Light settlement requiring installation of solar panels at an electric utility station that violated clean air requirements (August 31, 2020 Consent Decree <https://epa.gov/sites/default/files/2020-09/documents/indianapolispowerlight-cd.pdf>).

Climate Change Adaptation and Resiliency

The impacts of climate change (e.g., floods, fires, hurricanes, extreme weather events) pose additional challenges for regulated entities to remain in compliance with environmental laws and for communities to prepare for and recover from extreme weather events.

Figure 1 Frequency of Flooding Along U.S. Coasts, 2013–2022 Versus 1950–1959

EPA's enforcement and compliance programs factor in the changing climate in our activities to ensure that regulated entities and communities strengthen their adaptive capacity, consider climate change risk in their planning, and increase their resilience so that they are better able to anticipate, prepare for, withstand, and recover from the disruptive impacts of climate change while also remaining in compliance with environmental laws. EPA is also incorporating climate resilient remedies in our cleanups, as appropriate. Examples of such climate change adaptation and resiliency efforts in EPA's enforcement and compliance programs include:

- A settlement with Jersey City Municipal Utilities Authority (JCMUA) will incorporate climate change adaptation and resilience best practices for upgrades to its sewer system to ensure it is better prepared to withstand severe storms and hurricanes. JCMUA proposes to expand the scope of work for the pump station improvements beyond the Consent Decree's requirements in order to prepare for and adapt to climate change by incorporating higher minimum design thresholds that the Federal Emergency Management Agency (FEMA) established after Superstorm Sandy, including raising elevations and adding resiliency measures for 500-year storm events, which are required by the state for loan funding approval. (January 27, 2022 EPA Press Release <https://epa.gov/newsreleases/jersey-city-municipal-utilities-authority-make-significant-improvements-jersey-citys-0>.)
- Settlements with the cities of Greenville and Hattiesburg, Mississippi require that the work to eliminate sanitary sewer overflows and maintain compliance with the Clean Water Act be performed using sound engineering practices, including practices to improve the resilience of the sewer systems. Overview of Greenville settlement web page <https://epa.gov/enforcement/greenville-mississippi-clean-water-settlement> | Overview of Hattiesburg settlement web page <https://epa.gov/enforcement/city-hattiesburg-ms-clean-water-act-settlement-information-sheet>.
- A settlement with the U.S. Army for violations of the Safe Drinking Water Act's (SDWA) Risk and Resilience Assessment (RRA) and Emergency Response Plan (ERP) requirements at U.S Army Garrison Fort Buchanan in Puerto Rico requires the Army to conduct an assessment of the risks to, and resilience of, its community water system, including risk from natural hazards. The Army certified completion of an RRA and ERP for the Fort Buchanan community water system and paid an administrative penalty, the first such penalty issued under Section 1433 of the SDWA. December 6, 2022 Consent Agreement <https://yosemite.epa.gov/oa/rhc/epaadmin.nsf/advanced%20search/8b33b586bd99ec3e85258911005dbee0/$file/fort238401cafo.pdf>.

Capacity Building and Technical Assistance

To build capacity and provide technical assistance through EPA's climate and enforcement strategy, EPA is working to provide technical assistance to achieve climate-related solutions and build climate change capacity among EPA staff and our state and local partners.

The Agency's enforcement and compliance program is taking steps to improve our own adaptive capacity so that climate change does not interfere with EPA's ability to conduct compliance monitoring activities and enforce the nation's environmental laws.

In October 2022, EPA issued the OECA Climate Adaptation Implementation Plan <https://epa.gov/system/files/documents/2022-10/bh508-oeca_climate_adaptation_implementation_plan_-final_to_op_9.15.2022.pdf>, which identifies actions to ameliorate the potential impacts of climate change on OECA's mission and operations and specified priority actions OECA would undertake each year. Similarly, the enforcement and compliance program is committed to working with our state, local, and tribal, partners to build capacity to ensure environmental protection for future generations.

Enforcement and compliance and other EPA program office climate-related resources and training include:

- OECA's Compliance Advisors for Sustainable Water Systems <https://epa.gov/compliance/compliance-advisors-sustainable-water-systems-program>: Brings one-on-one technical assistance right to the door of drinking water and wastewater systems serving experiencing compliance problems that serve smaller communities, many of which are overburdened by pollution. The technical assistance is intended to bring these systems into compliance, build operator capacity, and provide sustainable, clean, and safe water that is adaptive and resilient to changes in climate.
- Climate Resilience Evaluation and Awareness Tool (CREAT) <https://epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool-creat-risk-assessment-application-water>: Assists water sector utilities in assessing climate-related risks to utility assets and operations. Contains five modules for users to consider climate impacts and identify adaptation options to increase resilience.
- EPA's Adaptation Resource Center (ARC-X) <https://epa.gov/arc-x>: Interactive resource to help local governments effectively deliver services to their communities even as the climate changes by creating an integrated package of information tailored specifically to their needs. Provides information about: the risks posed by climate change to the issues of concern; relevant adaptation strategies; case studies illustrating how other communities have successfully adapted to those risks and tools to replicate their successes; and EPA funding opportunities.

- EPA's Green Infrastructure for Climate Resiliency website <https://epa.gov/green-infrastructure/green-infrastructure-climate-resiliency>: Provides information about how green infrastructure practices can help communities plan for and manage the effects of climate change, including managing flooding, preparing for drought, reducing urban heat islands, lowering building energy demands, spending less energy managing water, and protecting coastal areas.
- The Superfund Climate Resilience website <https://epa.gov/superfund/superfund-climate-resilience>: Provides an overview of climate-related initiatives within the Superfund program and shares information about strategies that can be used to evaluate and strengthen climate resilience at Superfund sites.
- The Climate Smart Brownfields Manual <https://epa.gov/land-revitalization/climate-smart-brownfields-manual>: Resource for communities that want to consider climate change as they assess, clean up, and redevelop brownfield sites. The manual provides communities with best practices and case studies regarding climate change mitigation, adaption, and resilience from planning to redevelopment of brownfields.
- FedCenter.gov is the federal government's home for comprehensive environmental stewardship and compliance assistance information for federal facility managers and their agencies, and provides continually updated climate adaptation resources, tools, and lessons learned.
- Greener Cleanups <https://epa.gov/greenercleanups/learn-about-greener-cleanups> website: Provides information on the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup actions.

Enforcement Home <https://epa.gov/enforcement>

Enforcement Basics <https://epa.gov/enforcement/basic-information-enforcement>

National Enforcement and Compliance Initiatives <https://epa.gov/enforcement/national-enforcement-and-compliance-initiatives>

Enforcement and Compliance Annual Results for FY 2023 <https://epa.gov/enforcement/enforcement-and-compliance-annual-results-fiscal-year-2023>

- Air Enforcement <https://epa.gov/enforcement/air-enforcement>
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United States
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Region 10
Office of Water

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

Acknowledgments

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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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To obtain a copy of this guidance free of charge, contact:

EPA Region 10's Public Environmental Resource Center
Phone: 1-800-424-4372

This guidance, along with other supporting material, is available on the internet at:

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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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.

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

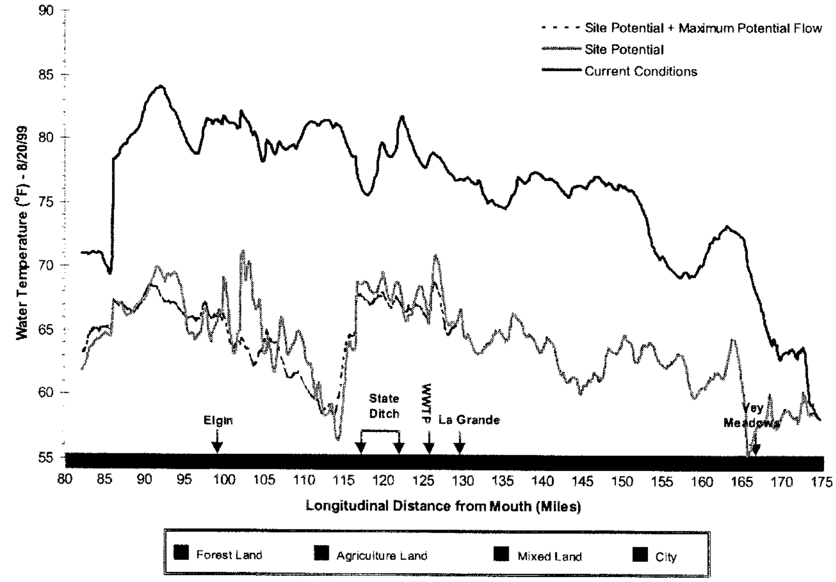

Figure 12. Percent of River Temperatures Below Specified Temperature

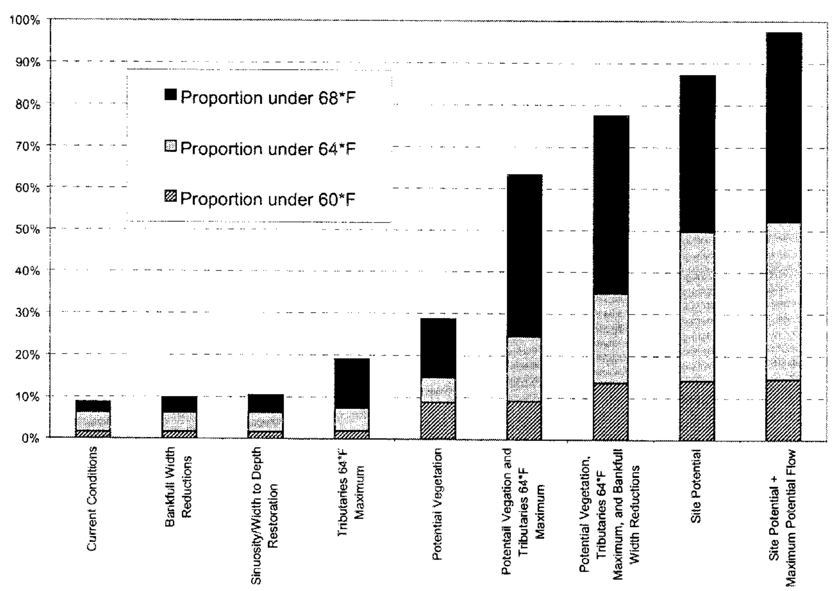

Figure 1. Grande Ronde River temperature modeling using ODEQ's Heat Source Model, showing site potential.

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 4^{th} and 5^{th} 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.

V.1.A. Overall Context for Recommended Uses and Criteria

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 Issue Paper 5; pp 7 and 57-65
	*Impairment to Steelhead Smoltification	> 12°C (constant)	
	*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 90^{th} 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 90^{th} 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

<u>V.1.C. Discussion of Uses and Criteria Presented in Table 3</u>

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.

<u>V.1.D. Discussion of Uses and Criteria Presented in Table 4</u>

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.

VI.1.A. Site-Specific Numeric Criteria that Supports the Use

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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Health Effects of Exposures to Mercury

Mercury is a neurotoxin. How someone's health may be affected by an exposure to mercury depends on a number of factors:

- The form of mercury (for example, methylmercury or elemental (metallic) mercury);
- The amount of mercury in the exposure;
- The age of the person exposed (unborn infants are the most vulnerable);
- How long the exposure lasts;
- How the person is exposed -- breathing, eating, skin contact, etc.; and
- The health of the person exposed.

The effects of mercury exposure can be very severe, subtle, or may not occur at all, depending on the factors above. Anyone with concerns about mercury exposure can consult their physician and/or their poison control center at 1-800-222-1222.

Note on Mercury and Cancer: No human data currently tie mercury exposure to cancer, but the data available are limited. In very high doses, some forms of mercury have caused increases in several

Related Health Information for All Types of Mercury

- Agency for Toxic Substances and Disease Registry (ATSDR):
  - ToxFAQs for mercury
  - Public health statement
  - Toxicological profile

types of tumors in rats and mice. When EPA published its Cancer Guidelines in 2005 <https://epa.gov/risk/guidelines-carcinogen-risk-assessment>, the Agency concluded that environmental exposures to inorganic mercury and methylmercury are not likely to cause cancer in humans. Technical information about mercury and cancer is available in:

- National Institute of Environmental Health Sciences (NIH): Mercury <https://www.niehs.nih.gov/health/topics/agents/mercury/>

- Volume V of the 1997 Mercury Study Report to Congress <https://epa.gov/mercury/mercury-study-report-congress>; and
- IRIS Chemical Assessment Summaries for elemental mercury (PDF) <http://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0370_summary.pdf> and methylmercury (PDF) <http://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0073_summary.pdf>.

On this page, you can learn more about health effects associated with the most common exposures to:

- Methylmercury
- Elemental (metallic) mercury
- Other mercury compounds

Methylmercury

Effects on People of All Ages

Exposure to methylmercury most commonly occurs when people eat kinds of fish and shellfish that have high levels of methylmercury in their tissues. Almost all people have at least small amounts of methylmercury in their bodies, reflecting the widespread presence of methylmercury in the environment. U.S. Centers for Disease Control and Prevention (CDC) data <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5343a5.htm> show that most people have blood mercury levels below levels associated with possible health effects. Methylmercury, however, is a powerful neurotoxin, and people exposed to high levels may experience adverse health effects. If you are concerned about your exposure to methylmercury, you should consult your physician.

Possible symptoms of methylmercury poisoning may include:

- Loss of peripheral vision;
- "Pins and needles" feelings, usually in the hands, feet, and around the mouth;
- Lack of coordination of movements;
- Impairment of speech, hearing, walking; and/or
- Muscle weakness.

Effects on Infants and Children

Infants in the womb can be exposed to methylmercury when their mothers eat fish and shellfish that contain methylmercury. This exposure can adversely affect unborn infants' growing brains and nervous systems. These systems may be more vulnerable to methylmercury than the brains and nervous systems of adults are. Children exposed to methylmercury while they are in the womb can have impacts to their cognitive thinking, memory, attention, language, fine motor skills, and visual spatial skills.

Additional Resources

- Guidelines for eating fish that contain mercury <https://epa.gov/mercury/guidelines-eating-fish-contain-mercury>
- How people are most commonly exposed to methylmercury <https://epa.gov/mercury/how-people-are-exposed-mercury#methylmercury>
- Technical summary of risk assessment for methylmercury in EPA's IRIS database

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Elemental (Metallic) Mercury

Exposures to metallic mercury most often occur when metallic mercury is spilled, or when products that contain metallic mercury break, so that mercury is exposed to the air. If you are concerned about your exposure to metallic mercury, you should consult your physician.

Metallic mercury mainly causes health effects when inhaled as a vapor where it can be absorbed through the lungs. Symptoms of prolonged and/or acute exposures include:

- Tremors;
- Emotional changes (such as mood swings, irritability, nervousness, excessive shyness);
- Insomnia;
- Neuromuscular changes (such as weakness, muscle atrophy, twitching);
- Headaches;
- Disturbances in sensations;
- Changes in nerve responses; and/or
- Poor performance on tests of mental function.

Higher exposures may also cause kidney effects, respiratory failure and death.

Note that metallic mercury vapor is not the same as methylmercury.

Additional Resources

- How people are most commonly exposed to elemental (metallic) mercury <https://epa.gov/mercury/how-people-are-exposed-mercury#metallicmercury>
- Technical summary of risk assessment for elemental mercury in EPA's IRIS database

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Other Mercury Compounds

High exposure to inorganic mercury may result in damage to the gastrointestinal tract, the nervous system, and the kidneys. Both inorganic and organic mercury are absorbed through the gastrointestinal tract and affect other systems through this route. Symptoms of high exposures to inorganic mercury include:

- Skin rashes and dermatitis;
- Mood swings;
- Memory loss;
- Mental disturbances; and/or
- Muscle weakness.

Some people who drink water containing inorganic mercury substantially in excess of the maximum contaminant level (MCL) for many years could experience kidney damage. If you are concerned about an exposure to inorganic mercury, you should consult your physician.

Additional Resources

- How people are most commonly exposed to other mercury compounds <https://epa.gov/mercury/how-people-are-exposed-mercury#mercurycompounds>
- Information about inorganic mercury in drinking water
- Technical summary of risk assessment for mercuric chloride in EPA's IRIS database

Mercury Home <https://epa.gov/mercury>

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- Technical summary of risk assessment for methylmercury in EPA's IRIS database

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- Mental disturbances; and/or
- Muscle weakness.

Some people who drink water containing inorganic mercury substantially in excess of the maximum contaminant level (MCL) for many years could experience kidney damage. If you are concerned about an exposure to inorganic mercury, you should consult your physician.

Additional Resources

- How people are most commonly exposed to other mercury compounds <https://epa.gov/mercury/how-people-are-exposed-mercury#mercurycompounds>
- Information about inorganic mercury in drinking water
- Technical summary of risk assessment for mercuric chloride in EPA's IRIS database

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Mercury Home <https://epa.gov/mercury>

Basic Information <https://epa.gov/mercury/basic-information-about-mercury>

How People are Exposed <https://epa.gov/mercury/how-people-are-exposed-mercury>

Health Effects

What EPA is Doing <https://epa.gov/mercury/what-epa-doing-reduce-mercury-pollution-and-exposures-mercury>

What You Can Do <https://epa.gov/mercury/mercury-your-environment-steps-you-can-take>

Laws & Regulations <https://epa.gov/mercury/environmental-laws-apply-mercury>

Guidelines for Eating Fish <https://epa.gov/mercury/guidelines-eating-fish-contain-mercury>

Products that Contain Mercury <https://epa.gov/mercury/mercury-consumer-products>

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TECHNICAL DOCUMENT

ACID MINE DRAINAGE PREDICTION

December 1994

U.S. Environmental Protection Agency
Office of Solid Waste
Special Waste Branch
401 M Street, SW
Washington, DC 20460

DISCLAIMER AND ACKNOWLEDGEMENTS

This document was prepared by the U.S. Environmental Protection Agency (EPA). The mention of company or product names in this document is not to be considered an endorsement by the U.S. Government or by the EPA.

This technical document consists of a brief review of acid forming processes at mine sites, followed by a summary of the current methods used to predict acid formation, selected state regulatory requirements, and case histories. This report was distributed for review to the U.S. Department of the Interior's Bureau of Mines and Bureau of Land Management, the U.S. Department of Agriculture's Forest Service, the Interstate Mining Compact Commission, the American Mining Congress, the Mineral Policy Center, representatives of state agencies, and public interest groups. EPA is grateful to all individuals who took the time to review this technical document.

The use of the terms "extraction," "beneficiation," and "mineral processing" in this document is not intended to classify any waste stream for the purposes of regulatory interpretation or application. Rather, these terms are used in the context of common industry terminology.

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ACID MINE DRAINAGE PREDICTION

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA), the states, and the Federal Land Management Agencies all need better tools to manage acid mine drainage at mine sites. This report examines acid generation prediction methods as they apply to non-coal mining sites. Following a brief review of acid forming processes at mine sites, the report summarizes the current methods used to predict acid formation including sampling, testing, and modeling. Selected State requirements for testing the potential of mining wastes to generate acid are summarized. Case histories from active mining sites and sites on the Superfund National Priorities List (NPL) are also presented. It is hoped that this report will assist states and the mining industry in their use of predictive methods. The Agency has not yet determined whether any one method is more accurate than another. This report also does not incorporate material presented at the Third International Conference on the Abatement of Acidic Drainage, held in Pittsburgh, Pennsylvania, in April 1994. The Agency is preparing additional reports to update this information, including a document containing extended summaries of selected papers presented at the conference.

The formation of mine acid drainage and the contaminants associated with it has been described by some as the largest environmental problem facing the U.S. mining industry (U.S. Forest Service 1993, Ferguson and Erickson 1988, Lapakko 1993b). Commonly referred to as acid rock drainage (ARD) or acid mine drainage (AMD), acid drainage from mine waste rock, tailings, and mine structures such as pits and underground workings is primarily a function of the mineralogy of the rock material and the availability of water and oxygen. Because mineralogy and other factors affecting the potential for AMD formation are highly variable from site to site, predicting the potential for AMD is currently difficult, costly, and of questionable reliability. The U.S. Forest Service sees the absence of acid prediction technology, especially in the context of new mining ventures, as a major problem facing the future of metal mining in the western United States (U.S. Forest Service 1993).

Acid mine drainage from coal and mineral mining operations is a difficult and costly problem. In the eastern U.S., more than 7,000 kilometers of streams are affected by acid drainage from coal mines (Kim et al. 1982). In the western U.S., the Forest Service estimates that between 20,000 and 50,000 mines are currently generating acid on Forest Service lands, and that drainage from these mines is impacting between 8,000 and 16,000 kilometers of streams (U.S. Forest Service 1993). In addition to the acid contribution to surface waters, AMD may cause metals such as arsenic, cadmium, copper, silver, and zinc to leach from mine wastes. According to the Forest Service, the metal load causes environmental damage, and is of greater concern than the acidity in environmental terms.

Acid mine drainage prediction tests are increasingly relied upon to assess the long-term potential of acid generation. This concern has developed because of the lag time at existing mines between waste emplacement and observation of an acid drainage problem (Univ. of California, Berkley 1988). The issue of long-term, or perpetual care of acid drainage at historic mines and some active mines has focussed attention on the need for improving prediction methods and for early assessment of the potential during the exploratory phase of mine development. In addition to many other mines, examples of three mine sites where the potential to generate acid was either not considered or not expected but later developed include: Cyprus Thompson Creek in Idaho; the Newmont Gold Company's Rain Mine in Nevada; and the LTV Dunka Mine in Minnesota. Case studies for these mines are presented in Section 4.0 of this report. Also included are short case studies of four sites on the NPL due, in part to acid drainage (U.S. EPA 1991).

Wastes that have the potential to generate acid as a result of metal mining activity include mined material such as spent ore from heap leach operations, tailings, and waste rock units, including overburden material. While not wastes or waste management units, pit walls in the case of surface mining operations, and the underground workings associated with underground mines and subgrade ore piles, also have the potential to generate ARD.

As mineralogy and size variables change, the ability to accurately predict the acid potential becomes quite difficult (Brodie, et al. 1991). Waste rock piles and subgrade ore piles, when left onsite, are both characterized by wide variation in mineralogy and particle size. Changes in these variables appear to influence drainage water quality (Doepker 1993). Coarse grain material allows air circulation; however, fine grain material exposes more surface area to oxidation (Ferguson and Erickson 1988). Drainage water quality from waste rock piles at several mines in British Columbia have demonstrated wide variability. Research at these sites focussed on variables affecting the frequency of acid effluent observed in permit-related monitoring (British Columbia AMD Task Force, 1990). The results reflect the diurnal and seasonal fluctuations in drainage quality as well as variation in mineralogy and particle size common to waste rock piles. In contrast, drainage from tailing impoundments are more likely to carry a more uniform contaminant load due to their more uniform mineralogy and texture. Table 1

Table 1. Comparison of Acid Rock Drainage Factors In Waste Rock Piles and Tailings Impoundments

Acid Generation Factors Affecting	Waste Rock Piles	Tailings Impoundment
Sulphide Source	• Variable in concentration and location. • Conditions may vary from sulphide rich to basic over short distances.	• Conditions uniform, often with very high sulphide content.
Particle Size	• Average rock size typically greater than 20 cm (but highly variable).	• Tailings may be 100% less than 0.2mm.
pH Variation	• Highly variable conditions over short distances.	• Fairly uniform conditions with a few major horizontal zones.
Initiation Of Rapid Oxidation	• Usually starts immediately after first rock is placed (in "trigger" spots).	• Usually starts after tailings placement ceases at end of mine life.
Oxygen Entry	• pid along preferential flow paths. • Seasonal variations in flow path "flushes" out stored products resulting in concentration peaks.	• Seepage slow and uniform. • Reduced flow path variation and stored product "flushing."
ARD Releases	• Large infiltration resulting in large seepage from toe and to groundwater. • Rapid release following generation, sometimes with both neutralized and acid ARD seeps.	• Large early top surface ARD runoff. • Lower infiltration. • Gradual transition in seeps from process water to neutralized ARD to low pH ARD.

(Source: Brodie et al., 1991)toS

compares acid rock drainage factors of waste rock piles and tailings impoundments. In examining this table, it is important to note that diffusion of oxygen into water is slow and, therefore, oxidation of iron sulfide is inhibited until the water level drops, which can occur periodically or seasonally in some cases.

1.1 Oxidation of Metal Sulfides

Acid is generated at mine sites when metal sulfide minerals are oxidized. Metal sulfide minerals are present in the host rock associated with most types of metal mining activity. Prior to mining, oxidation of these minerals and the formation of sulfuric acid is a function of natural weathering processes. The oxidation of undisturbed ore bodies followed by release of acid and mobilization of metals is slow. Discharge from such deposits poses little threat to receiving aquatic ecosystems.

Extraction and beneficiation operations associated with mining activity increase the rate of these same chemical reactions by exposing large volumes of sulfide rock material with increased surface area to air and water.

The oxidation of sulfide minerals consists of several reactions. Each sulfide mineral has a different oxidation rate. For example, marcasite and framboidal pyrite will oxidize quickly while crystalline pyrite will oxidize slowly. For discussion purposes, the oxidation of pyrite (FeS_2) will be examined (Manahan 1991). Other sulfide minerals are identified in Table 2.

Table 2. Partial List of Sulfide Minerals

Mineral	Composition
Pyrite	FeS_2
Marcasite	FeS_2
Chalcopyrite	$CuFeS_2$
Chalcocite	Cu_2S
Sphalerite	ZnS
Galena	PbS
Millerite	NiS
Pyrrhotite	$Fe_{1-x}S$ (where $0<x<0.2$)
Arsenopyrite	FeAsS
Cinnabar	HgS

(Source: Ferguson and Erickson 1988)

$$2FeS_2(s) + 2H_2O + 7O_2 \dashrightarrow 4H^+ + 4SO_4^{2-} + 2Fe^{2+}$$

In this step, S_2^{2-} is oxidized to form hydrogen ions and sulfate, the dissociation products of sulfuric acid in solution. Soluble Fe^{2+} is also free to react further. Oxidation of the ferrous ion to ferric ion occurs more slowly at lower pH values:

$$4Fe^{2+} + O_2 + 4H^+ \text{-->} 4Fe^{3+} + 2H_2O$$

At pH levels between 3.5 and 4.5, iron oxidation is catalyzed by a variety of *Metallogenium,* a filamentous bacterium. Below a pH of 3.5 the same reaction is catalyzed by the iron bacterium *Thiobacillus ferrooxidans*. Other bacteria capable of catalyzing the reaction are presented in Table 3. If the ferric ion is formed in contact with pyrite the following reaction can occur, dissolving the pyrite:

$$2FeS_2(s) + 14Fe^{3+} + 8H_2O \text{-->} 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

This reaction generates more acid. The dissolution of pyrite by ferric iron (Fe^{3+}), in conjunction with the oxidation of the ferrous ion constitutes a cycle of dissolution of pyrite. Ferric iron precipitates as hydrated iron oxide as indicated in the following reaction:

$$Fe^{3+} + 3H_2O \text{<-->} Fe(OH)_3(s) + 3H^+$$

$Fe(OH)_3$ precipitates and is identifiable as the deposit of amorphous, yellow, orange, or red deposit on stream bottoms ("yellow boy").

Table 3. Sulfide Ore Bacteria and Their Growth Conditions

Microorganism	pH	Temp., °C	Aerobic	Nutrition
Thiobacillus thioparus	4.5-10	10-37	+	autotrophic
T. ferrooxidans	0.5-6.0	15-25	+	"
T. thiooxidans	0.5-6.0	10-37	+	"
T. neapolitanus	3.0-8.5	8-37	+	"
T. denitrificans	4.0-9.5	10-37	+/-	"
T. novellus	5.0-9.2	25-35	+	"
T. intermedius	1.9-7.0	25-35	+	"
T. perometabolis	2.8-6.8	25-35	+	"
Sulfolobus acidocalderius	2.0-5.0	55-85	+	"
Desulfovibrio desulfuricans	5.0-9.0	10-45	-	heterotrophic

(Source: Thompson 1988)

1.2 Source of Acid and Contributing Factors

The potential for a mine to generate acid and release contaminants is dependent on many factors and is site specific. Ferguson and Erickson identified primary, secondary, and tertiary factors that control acid drainage. These factors provide a convenient structure for organizing the discussion of acid formation in the mining environment. Primary factors involve production of the acid, such as the oxidation reactions. Secondary factors act to control the products of the oxidation reaction, such as reactions with other minerals that consume acid. Secondary factors may either neutralize acid or react with other minerals. Tertiary factors refer to the physical aspects of the waste management unit (e.g., pit walls, waste rock piles, or tailings impoundments) that influence the oxidation reaction, migration of the acid, and consumption. Other downstream factors change the character of the drainage by chemical reaction or dilution (Ferguson and Erickson 1988). These downstream factors are beyond the scope of this paper and are not discussed herein.

Primary factors of acid generation include sulfide minerals, water, oxygen, ferric iron, bacteria to catalyze the oxidation reaction, and generated heat. Some sulfide minerals are more easily oxidized (e.g., framboidal pyrite, marcasite, and pyrrhotite) and hence, may have a greater impact on timing and magnitude during acid prediction analysis compared to other metal sulfides. Also important is the physical occurrence of the sulfide mineral. Well crystallized (euhedral) minerals will have smaller exposed surface areas than those that are disseminated.

Both water and oxygen are necessary to generate acid drainage. Water serves as both a reactant and a medium for bacteria in the oxidation process. Water also transports the oxidation products. A ready supply of atmospheric oxygen is required to drive the oxidation reaction. Oxygen is particularly important to maintain the rapid bacterially catalyzed oxidation at pH values below 3.5. Oxidation of sulfides is significantly reduced when the concentration of oxygen in the pore spaces of mining waste units is less than 1 or 2 percent. Different bacteria are better suited to different pH levels and other edaphic factors (edaphic factors pertain to the chemical and physical characteristics of the soil and water environments). The type of bacteria and their population sizes change as their growth conditions are optimized (Ferguson and Erickson 1988). Table 3 identifies some of the bacteria involved in catalyzing the oxidation reactions and their growth conditions.

The oxidation reaction is exothermic, with the potential to generate a large amount of heat, and therefore thermal gradients within the unit. Heat from the reaction is dissipated by thermal conduction or convection. Research by Lu and Zhang (undated) on waste rock using stability analysis indicates that convective flow can occur because of the high porosity of the material. Convection cells formed in waste rock would draw in atmospheric air and continue to drive the oxidation reaction. Convection gas flow due to oxidation of sulfide minerals depends on the maximum temperature in the waste rock. The maximum temperature depends on ambient atmospheric temperature, strength of the heat source, and the nature of the upper boundary. If the sulfide waste is concentrated in one area, as is the case with encapsulation, the heat source may be very strong.

Secondary factors act to either neutralize the acid produced by oxidation of sulfides or may change the effluent character by adding metals ions mobilized by residual acid. Neutralization of acid by the alkalinity released when acid reacts with carbonate minerals is an important means of moderating acid production. The most common neutralizing minerals are calcite and dolomite. Products from the oxidation reaction (hydrogen ions, metal ions, etc.) may also react with other non-neutralizing constituents. Possible reactions include ion exchange on clay particles, gypsum precipitation, and dissolution of other minerals. Dissolution of other minerals contributes to the contaminant load in the acid drainage. Examples of metals occurring in the dissolved load include aluminum, manganese, copper, lead, zinc, and others (Ferguson and Erickson 1988).

Some of the tertiary factors affecting acid drainage are the physical characteristics of the material, how acid generating and acid neutralizing materials are placed, waste, and the hydrologic regime in the vicinity. The physical nature of the material, such as particle size, permeability, and physical weathering characteristics, is important to the acid generation potential. Particle size is a fundamental concern since it affects the surface area exposed to weathering and oxidation. Surface area is inversely proportional to particle size. Very coarse grain material, as is found in waste dumps, exposes less surface area but may allow air and water to penetrate deeper into the unit, exposing more material to oxidation and ultimately producing more acid. Air circulation in coarse material is aided by wind, changes in barometric pressure, and possibly convective gas flow caused by heat generated by the oxidation reaction. In contrast, fine-grain material may retard air and very fine material may limit water flow; however, finer grains expose more surface area to oxidation. The relationships between particle size, surface area, and oxidation play a prominent role in acid prediction methods. As materials weather with time, particle size is reduced, exposing more surface area and changing physical characteristics of the unit. Though difficult to weigh, each of these factors influences the potential for acid generation and are therefore important considerations for the long-term (Ferguson and Erickson 1988, Lu and Zhang undated).

The hydrology of the area surrounding mine workings and waste units is also important in the analysis of acid generation potential. When acid generating material occurs below the water table, the slow diffusion of oxygen in water retards acid production. This is reflected in the portion of pits or underground workings located below the water table. Where mine walls and underground workings extend above the water table, the flow of water and oxygen in joints may be a source of acid. A similar relationship is evident with tailings, which are typically fine grained and disposed of subaqueously; the slow diffusion of oxygen inhibits formation of acid. However, since tailings are placed in either raised or valley impoundments, they are likely to remain saturated for only a limited period of time during mine operation. Following mine closure, the free water surface in the impoundment may be drawn down substantially, favoring AMD conditions.

The spatial distribution of mining wastes in units, or waste placement, affects acid generation potential. For example, the distribution of acid generating wastes with neutralizing wastes may be controlled by the stacking sequence. Calcareous material may be mixed with or placed above sulfidic wastes to buffer acid production or provide alkalinity to infiltrating solution prior to contact with acid generating wastes. An alternative to layering or mixing is encapsulation. This technique attempts to isolate acid generating wastes from oxygen and water, thereby reducing its potential to produce acid. It is unclear if encapsulation is feasible over the long-term.

Wetting and drying cycles in any of the mine workings or other waste management units will affect the character of any acid drainage produced. Frequent wetting will tend to generate a more constant volume of acid and other contaminants as water moves through and flushes oxidation products out of the system. The build-up of contaminants in the system is proportional to the length of time between wetting cycles (Ferguson and Erickson 1988, Doepker 1993). As the length of the dry cycle increases, oxidation products will tend to accumulate in the system. A high magnitude wetting event will flush accumulated contaminants out of the system. This relationship is typical of the increase in contaminant load observed following heavy precipitation for those areas having a wet season.

2. ACID GENERATION PREDICTION

The objectives of predictive testing are to: (1) determine if a discrete volume of mining waste will generate acid and (2) predict the quality of the drainage based on the rate of acid formation measured (California Mining Association 1991). There are two important points that must be considered when evaluating the acid generation potential of a rock material. The first is how to collect samples from the field for use in analytical testing. The second is which analytic test method should be used. Both points have a profound impact on the reliability of analytical tests. Results from any analytical test are only as reliable as the samples used for the test. Once the sampling strategy is selected, an appropriate analytical method (or methods) can be selected. Methods used to predict the acid generation potential are classified as either static or kinetic. Factors affecting the selection of the sampling regime and analytical method include an existing knowledge of the geology, costs, and length of time available to conduct the test. This section will examine sample methodology and analytic tests used to predict acid generation potential.

The following list of components describes the solid phase composition and reaction environment of sulfide minerals. Potential contaminants are included to indicate their importance in the scope of acid generation. These components should be kept in mind while evaluating information on acid generation potential.

Components affecting the total capacity to generate acid are characterized by:

- Amount of acid generating (sulfide) minerals present [Note: assumes total reaction of sulfide minerals]
- Amount of acid neutralizing minerals present
- Amount and type of potential contaminants present.

Components affecting the rate of acid generation include:

- Type of sulfide mineral present (including crystal form)
- Type of carbonate mineral present (and other neutralizing minerals, as appropriate)
- Mineral surface area available for reaction
    - Occurrence of the mineral grains in the waste (i.e., included, liberated)
    - Particle size of the waste
- Available water and oxygen
- Bacteria.

Analytical tests used to assess a material's acid generation potential are either static or kinetic in nature. A static test determines both the total acid generating and total acid neutralizing potential of a sample. The capacity of the sample to generate acidic drainage is calculated as either the difference of the values or as a ratio of the values. These tests are not intended to predict the rate of acid generation, only the potential to produce acid. Static tests can be conducted quickly and are inexpensive compared to kinetic tests. Kinetic tests are intended to mimic the processes found at mining sites, usually at an accelerated rate. These tests require more time and are considerably more expensive than static tests. Data from the tests are used to classify wastes or materials according to their acid generating potential. This information can be collected and evaluated during the economic analysis of mines in their exploratory phases. Based on this information, decisions can be made with respect to specific mitigation practices for existing mines.

In this discussion, it will be useful to keep in mind sources of information needed to assess acid potential. Some of the primary and secondary factors that affect the drainage character from waste management units are presented in Table 4. The variables identified may be appropriate when considering other than waste units, such as mine pits and underground workings.

Table 4. Sources of Information on Acid Generation Potential for New and Operating Mines

Information Type	New Mine	Operating Mine
Mine Rock Classification	• Outcrop exposures • Exploration drill samples, logs • Geological sections • Core assays	• Outcrop and excavation exposures • Drill core • Production sampling • Core assays • Specific sampling from working areas and piles
Mine Rock Distribution	• Mine planning	• Mine planning • Mine rock placement records • Pit and underground plans and exposures • Pile surveys • Pile drilling and sampling • Site personnel
Acid Generation, Leaching Potential	• Static testing • Short term leach extractions • Mineralogy • Site comparisons	• Observation of old cores • Field sampling • Static testing of distinct sub-units from working areas
Drainage Water Quality	• Kinetic testing • Background water quality	• Regular monitoring • Seep surveys • Kinetic testing • Leach extraction

(Source: Modified from Robertson and Broughton, undated)

Efforts by both the mining industry and state regulatory agencies to develop the best protocols for sampling and/or analytical methods to predict acid generation potential have demonstrated that site specific conditions (e.g., climate and geology) dictate a case-by-case approach when evaluating acid potential. This is complicated by the fact that a variety of research efforts on different methods by the Bureau of Mines, EPA, and the Canadian Mine Environment Neutral Drainage (MEND), as well as those used by mining companies and their consultants, make comparison of data difficult. Several authors have conducted comparative evaluations of predictive tests (Lapakko 1992, Bradham and Caruccio 1990, Coastech 1989). Kim Lapakko of the Minnesota Department of Natural Resources has conducted comparative evaluations of static and kinetic test methods using a range of rock types. Bradham and Caruccio conducted a comparative study on tailings.

When evaluating the acid generation potential, a phased testing plan selects samples appropriate for the detail needed (California Mining Association 1991). This approach allows investment in acid prediction testing to be commensurate with a deposit's economic potential and saves time and expense associated with unnecessary tests. Sampling and testing should be an iterative process, collecting, testing, and evaluating a small amount of information to establish the acid generation potential. Based on the preliminary findings, subsequent sampling and testing can be selected to refine the information as needed.

The typical steps in predicting the acid forming potential, as described in summary documents on the subject, are listed below (California Mining Association 1991, British Columbia AMD Task Force 1989):

1. Define the geologic (or lithologic) units that will be encountered during mining. Describe the geology and mineralogy of these units in detail.
2. Develop a sampling plan based on understanding of geology (rock mass, etc.). Collect samples to represent ranges of compositional variation within a rock unit (see Lapakko 1988, 1990a).
3. Select static or kinetic tests and evaluate potential for acid formation.
4. Evaluate sampling criteria and conduct additional kinetic tests as required.
5. Develop a model as appropriate.
6. Based on findings, classify geologic (lithologic) units as acid, non-acid forming, or uncertain. (Note: the potential to produce acid may vary within a given geologic unit.)

2.1 Sampling

Selection of samples has important implications for subsequent acid prediction testing. The purpose of testing rock material is to allow classification and planning for waste disposal based on the predicted drainage quality from that material. Samples must be selected to characterize both the type and volume of rock materials and also account for the variability of materials that will be exposed during mining. When to collect samples for testing is an equally important consideration. Researchers agree that sampling and testing should be concurrent with resource evaluation and mine planning (Lapakko 1990a, British Columbia AMD Task Force 1989). Sampling techniques used to evaluate recoverable mineral resources (assay samples) are similar to those required for prediction of acid generation potential. Active mining operations for which predictive tests were not conducted in advance of mining lack the advantage of front end planning; however, these mines can still use these samples and other information collected to establish the acid generating potential.

The pressure is increasing for new operations or those in the exploratory phase to accurately predict future drainage water quality. By comparison, the acid drainage potential at old mines may be well established. Examples of information needed from existing operations are the quantity of existing acid products, the potential and stage of acid generation in each of the waste units, and the acid forming potential of future wastes to be generated (see Table 4). Broughton and Robertson recommend that the first two stages of an acid prediction analysis for either new or existing mines are (1) to review the geology and mineralogy and (2) classify the rock and collect samples (Robertson and Broughton, undated; Broughton and Robertson, 1992).

Sample collection for prediction tests for both old and new mines should consider both geologic and environmental factors. Geologic factors for sample selection are primarily a good understanding of the local geology. If available, this may include information from mines, core logs, or other sources in the immediate area. The exploration geologist or mine geologist is probably the best resource for understanding and describing the mine's geology in detail. This information is important to both the sampling program and application of test results. Environmental factors include consideration of the potential environmental contaminants in the rock and climatic variables. A quality assurance/quality control program should be developed and coordinated with the mine plan for sample collection and acid generation testing.

There are many opinions concerning the number of samples to be collected in a fixed-frequency sampling program. One mining consulting firm recommends about 8 - 12 samples of each significant rock type or 1 sample for each 1 million tons, at a minimum (Schafer 1993). In this case a significant rock type represents one or two percent of the total mine rock volume. Gene Farmer of the U.S. Forest Service suggests that one sample (about 1,500 grams) be collected per 20,000 tons of waste rock, or about 50 samples for each 1 million tons (USDA Forest Service 1992). These samples would be collected by compositing from individual drill hole cuttings prior to blasting. The British Columbia AMD Task Force recommends a minimum number of samples based on the mass of the geologic unit. Their recommended minimum sample number is 25 for a 1 million ton geologic unit, or one sample for every 40,000 tons. Using the British Columbia method, as waste volume increases, the number of samples decreases. For example, for a unit of 10 million tons, the minimum sample number is 80, or one sample for every 125,000 tons (British Columbia AMD Task Force 1989).

There are reservations to prescribing a fixed number of samples for collection per volume of material. This is particularly true for existing mines when collecting samples from waste rock dumps for acid generation potential tests. Waste rock dumps are usually constructed by end-dumping of rock from trucks, creating heterogeneous deposits that are very difficult to sample with confidence. Tailings are comparatively more uniform due to milling and depositional methods used, and it is easier to characterize their variability. Fixed-frequency sampling does not encourage the use of best judgement on the part of the sample collector (typically a mining company). It also does not provide the statistical basis to account for variability among samples. The determination of how many samples should be taken at any one time appears to be dependent on variability of the site's geology and how the mine will be developed. Due to general uncertainty regarding AMD predictive methods, it may be prudent to sample wastes or material throughout the life of the mine.

Factors to consider in a sampling program for existing or planned mines include the method of sample collection, length of time samples are to be (or have been) stored, and the sample storage environment. Each of these can affect the physical and chemical characteristics of a sample. Samples collected from cores exposed to the environment may be physically and/or chemically altered. If samples are collected from drill core, contamination may be a problem if a lubricant was used. At existing mines, tailings samples should be taken over a variety of depths to determine if oxidation of sulfide minerals is occurring. The influence of lime addition during milling may maintain alkaline conditions. Collecting samples of waste rock is difficult because of the variability inherent in these waste units. Drilling is considered to be the preferred method for collecting samples from waste rock piles (Ferguson and Morin 1991).

Since individual samples will be used to test and classify larger volumes of waste, it is important to consider how representative samples are to be collected. Compositing is a common practice used to sample large volumes of material. Typically, composite samples are collected from drill hole cuttings on benches prior to blasting. However, compositing merges information about the variation of sample that would be identified if more samples were collected and analyzed. Therefore, information about sample variability is lost (British Columbia AMD Task Force 1990, Robertson and Broughton undated). Composite sampling of tailings may be useful as a "first look" for characterizing tailings; compositing with stratification by lithology and alteration can help to avoid the problems of simple composite samples (Schafer 1993).

2.2 Static Tests

Static tests predict drainage quality by comparing the sample's maximum acid production potential (AP) with its maximum neutralization potential (NP). The AP is determined by multiplying the percent of total sulfur or sulfide sulfur (depending on the test) in the sample by a conversion factor (AP = 31.25 * %S). NP is a measure of the carbonate material available to neutralize acid. The value for NP is determined either by adding acid to a sample and back titrating to determine the amount of acid consumed or by direct acid titration of the sample; the endpoint pH is usually 3.5 (Ferguson and Morin 1991, Lapakko 1993a). Lapakko (1992) reported that using an endpoint pH of 3.5 measures a sample's acid neutralizing potential below 6.0, but noted that a drainage pH in the range of 3.5 may not be environmentally acceptable. The net neutralization potential (NNP), or acid/base account (ABA) is determined by subtracting the AP from the NP (NNP = NP - AP). A ratio of NP to AP is also used. An NNP of 0 is equivalent to an NP/AP ratio of 1 (Ferguson and Morin 1991). Units for static test results (AP, NP, and NNP) are typically expressed in mass (kg, metric ton, etc.) of calcium carbonate ($CaCO_3$) per 1000 metric tons of rock, parts per thousand.

If the difference between NP and AP is negative then the potential exists for the waste to form acid. If it is positive then there may be lower risk. Prediction of the acid potential when the NNP is between -20 and 20 is more difficult. If ratios are used, when the ratio of a sample's neutralization potential and acid production potential is greater than 3:1, experience indicates that there is lower risk for acid drainage to develop (Brodie et al. 1991). For ratios between 3:1 and 1:1, referred to as the zone of uncertainty, additional kinetic testing is usually recommended. Those samples with a ratio of 1:1 or less are more likely to generate acid. Prediction of drainage quality for a sample based on these values requires assumptions that reaction rates are similar and that the acid consuming minerals will dissolve (Lapakko 1992). When reviewing data on static tests, an important consideration is the particle size of the sample material and how it is different from the waste or unit being characterized.

Information on these and other static acid prediction tests, including summaries of test results, is available (Coastech 1989, Lapakko 1993b). The following descriptions are excerpted from Lapakko (1993b). Lapakko (1992) has also conducted comparison tests of static methods using mine waste samples from different mines. Additional summaries of static tests have been completed by Coastech (1989) as part of the MEND Project, and the California Mining Association (1991). Five static tests will be summarized here and in Table 5.

Table 5. Summary of Static Test Methods, Costs, Advantages, and Disadvantages

Acid Base Accounting (Sobek et al, 1978)	**MODIFIED Acid Base Accounting** (Coastech, 1989)	**BC RESEARCH INITIAL** (Duncan and Bruynesteyn, 1979)	**Alkaline Production Potential: Sulfur** (Caruccio et al, 1981)	**Net Acid Production** (Coastech 1989)
ACID PRODUCTION DETERMINATION				
Acid Producing Potential = 31.25 * Total S	Acid Producing Potential = 31.25 * Total S	Total Acid Production = 31.25 * Total S	Total S used as indicator	300 mL H_2O_2 added to 5 g rock to directly oxidize sulfides present
NEUTRALIZATION POTENTIAL DETERMINATION				
-60 mesh (0.24 mm) sample add HCl as indicated by fizz test, boil one minute than cool titration endpt pH 7.0 cost: 34-110	-60 mesh (0.24 mm) sample add HCl as indicated by fizz test agitate for 23 hours at room temperature pH 1.4 - 2.0 required after six hours agitation titration endpt pH 8.3 cost: 34-110	-300 mesh (0.038 mm) sample titrate sample to pH 3.4 with 1.0 N H_2SO_3 titration endpt not applicable cost: 65-170	-0.023 mm sample 20 mL 0.1 N HCl to 0.4g solid for 2 hours at room temperature titration endpt pH 4.0 cost: 34-110	particle size not presented acid produced by iron sulfide oxidization dissolves buffering minerals titration endpt pH 7.0 cost: 25-68
ADVANTAGES AND DISADVANTAGES				
simple and short time[1,3] no special equipment and easy interpretation[1] many samples can be tested[3] does not relate to kinetic[2] assumes parallel acid/ alkaline release[2,3] if APP and NP are close, hard to interpret and different particle size not reflected[3]	simple, short time, no special equipment, and easy interpretation[1] does not relate to kinetic[2] assumes parallel acid/ alkaline release[2,3] if AP and NP are close, hard to interpret and different particle size not reflected[3]	simple and fairly short time[1,3] no special equipment and easy interpretation[1] many samples can be tested[3] assumes parallel acid/ alkaline release, different particle size not reflected, and if APP and NP are close, hard to interpret[3]	simple, short time, and no special equipment[1] moderate interpretation[1]	simple, short time, no special equipment, and easy interpretation[1] limited reproducibility[4] uncertain if extent of sulfide oxidation simulates that in field

1 = Coastech 1989, as referenced in Lapakko 1993
2 = Bradham and Caruccio 1990, as referenced in Lapakko 1993
3 = Ferguson 1984, as referenced in Lapakko 1993
4 = Lawrence 1991, as referenced in Lapakko 1993

(Source: Lapakko 1993b)

2.2.1 Acid-Base Accounting (ABA)

The acid-base accounting test, a form of static testing, was developed in 1974 to evaluate coal mine waste and was modified by Sobek et al. in 1978. The acid production potential (APP) is determined from the total sulfur content as follows:

$$31.25 \text{ x percent S} = \text{APP}$$

and assumes that two moles of acid will be produced for each mole of sulfur. Units for APP are tons of acidity per ton of rock. Neutralization Potential (NP) is determined first by a simple fizz test to select the acid strength to use in the next step. Based on this information, hydrochloric acid is added to the sample and the sample is boiled until the reaction stops. The resulting solution is back titrated to pH 7 with sodium hydroxide to determine the amount of acid consumed in the reaction between HCl and the sample.

The net neutralizing potential (NNP) is determined by subtracting the APP from the NP and is a measure of the difference between the neutralizing and acid forming potentials. The value for NNP may be either positive or negative. Tests conducted by Ferguson (reported by Lapakko 1993b) indicate that NNP values less than 20 (kg $CaCO_3$/ton) are likely to form acid. Those with NNP values greater than 20 were not likely to form acid. For NNP values between -20 and 20 it was difficult to determine the acid potential.

Assumptions of the test are that all the sulfur in the sample is reactive. This assumption does not take into account the presence of gypsum and other non-reactive sulfur minerals. A shortcoming of the technique is the potential to overestimate NP in one or more of the following ways: (1) use of strong acid may dissolve minerals that would not otherwise react to maintain drainage pH within an environmentally acceptable range; (2) use of boiling acid may cause an overestimation of NP by reacting with iron and manganese carbonates, which would not otherwise factor in the natural NP (this observation is problematic with samples that contain large quantities of these carbonates; (3) the NP may be underestimated by contribution from metal hydroxides that precipitate during the titration with sodium hydroxide.

2.2.2 Modified Acid Base Accounting

The Modified Acid Base Accounting method is similar to the previous method with some exceptions. It calculates APP on the sulfide sulfur content (Lawrence 1990). This is different from the total sulfur calculation used in the ABA test in that the sulfur contribution from non-sulfide sources is not included. Determination of NP uses a longer (24-hour) acid digestion at ambient temperature, rather than boiling hydrochloric acid as used in the ABA method. When back titrating with sodium hydroxide to determine the acid consumed in the digestion, an endpoint of 8.3 is used instead of 7.

This modified method assumes that sulfur present as sulfate is not acid producing, and therefore may underestimate available APP if jarosite or other acid producing sulfate minerals are present. Conducting the acid digestion at standard temperature may reduce the contribution of iron carbonate minerals when determining the NP.

2.2.3 British Columbia Research Initial Test (BC)

The B.C. Research Initial Test, as developed by Duncan and Bruynesteyn (1979), is similar to the ABA test in that it calculates APP based on total sulfur. Consequently, similar concerns should be kept in mind for the APP values. NP (or acid consuming capability) is determined by titrating the sample with 1.0 normal sulfuric acid to pH 3.5. Coastech (1989) notes that this requires more sophisticated equipment (i.e., automatic titrator) than the ABA procedure and is more time consuming. Samples are crushed to minus 400 mesh. Data for APP and NP are compared by difference or ratio, as described above. If a sample is determined to be potentially acid generating, the B.C. Confirmation kinetic test may be conducted. This test is presented in the next section.

2.2.4 Alkaline Production Potential : Sulfur Ratio (APP:S)

The Alkaline Production Potential : Sulfur Ratio test was developed by Caruccio et al. (1981) and modified by Coastech (1989) to measure the acid forming potential of coal waste. Like the ABA and B.C. initial tests, the APP:S test uses total sulfur to determine the total acid potential. Again, similar problems exist for the APP:S test as were experienced with these other tests. A change in nomenclature should be noted here. The acid consuming potential (NP in the previous tests) is referred to as the Alkaline Production Potential. The value is determined by grinding a 500 mg sample to minus 23 micron and adding 20 mL of 0.1N HCl and allowing it to react for 2 hours at ambient temperature. The sample and solution are then titrated to pH 5 to determine the alkaline production potential.

Samples representative of the geologic variation at the site are collected as in other tests and the Alkaline Production Potential is determined. Results from the alkaline production potential test are plotted with the results for total sulfur content of the same samples. Samples of several APP:S ratios are selected for kinetic testing to determine which will be acid producing. With this calibration, the acid producing potential of future samples from the various geologic units can be projected based on the APP:S ratio, rather than depending on kinetic tests, which require more time.

Because this test uses total sulfur, similar to the ABA, to determine acid production, it also tends to overestimate potential acid production for samples containing sulfate minerals. Coastech (1989) noted the shorter exposure to less concentrated acid used in the digestion reaction would tend to underestimate Alkaline Production Potential (NP), and preclude the complete reaction of all buffering carbonates present.

2.2.5 Net Acid Production Test

In the Net Acid Production Test, hydrogen peroxide is used to accelerate the oxidation of sulfide (Lawrence et al. 1988). For the test, five grams of material are oxidized by 100 mL of 15 percent hydrogen peroxide to oxidize the metal sulfide minerals. The reaction generates acid which in turn reacts with the buffering minerals in the sample. The reaction is allowed to continue for one hour after all visible signs of reaction have ended. The pH of the solution is determined and then titrated to pH 7. This gives a value for the Net acid or neutralizing potential of the sample. This test is different from static tests described above in that it mimics the reaction of APP and NP and determines a single value, NNP. One potential limitation of the test was noted. If the extent of oxidation in the field setting is greater than in the test, the potential exists for the test to underestimate acid production, creating the possibility that some acid producing waste may be incorrectly classified as non-acid-producing.

2.3 Kinetic Tests

Kinetic tests are distinguished from static tests in that they attempt to mimic natural oxidation reactions of the field setting. The tests typically use a larger sample volume and require a much longer time for completion than for static tests. These tests provide information on the rate of sulfide mineral oxidation and therefore acid production, as well as an indication of drainage water quality. Of the different kinetic tests used, there is no one test that is preferred. The preference for tests changes with time as experience and understanding increase. In a 1988 summary article by Ferguson and Erickson, the B.C. Research Confirmation Test was considered to be the most widely used. A similar 1991 article by Ferguson and Morin stated that the use of modified humidity cells was becoming more common. From information reviewed for this report, there does seem to be a trend toward the preference for modified humidity cell and column type tests.

Kinetic tests can be used to assess the impact of different variables on the potential to generate acid. For example, samples may be inoculated with bacteria (a requirement for some tests); temperature of the sample environment may also be controlled during the test. Most tests require the sample particle size to be less than a specified sieve size (e.g., minus 200 mesh). Larger sample volumes and test equipment may examine acid potential from coarse particles. Acid drainage control mechanisms, such as increasing alkalinity by adding lime, may also be examined using kinetic tests.

It is helpful to supplement kinetic tests with an understanding of empirical data characterizing the sample. Examples include analysis of specific surface area, mineralogy, and metals. Such information may affect the interpretation of test data and are important when making spatial and temporal comparisons between samples based on the test data. As with static tests, it is important to consider the particle size of the test sample, particularly when comparing test results with field scale applications.

Seven kinetic tests are summarized primarily from Lapakko's (1993b) review and the BC AMD Task Force, Draft Technical Guideline, Volume I (1989). Other sources are noted in the text. Brief descriptions of the kinetic tests discussed are also presented in Table 6.

2.3.1 Humidity Cell Tests

Both Standard and Modified Humidity Cell Tests are used to determine the rate of acid generation. Tests are conducted in a chamber resembling a box with ports for air input and output. The modified humidity cell uses crushed samples and resembles a column. There is no standard for either humidity cell test.

The Humidity Cell Test, as conducted by Sobek (1978), leaches a 200 g sample crushed to minus 2.38 mm in an enclosed plastic container. The test is typically run for ten weeks and follows a seven day cycle. The sample may be inoculated with bacteria. During the seven day cycle, dry air is passed through the sample container for the first three days and humidified air for the next three days. On the seventh day the sample is rinsed with 200 mL of distilled water. The solution may be analyzed for pH, acidity, alkalinity, and specific conductance; redox potential (the oxidation-reduction potential of an environment), sulfate, and dissolved metals may also be tested. The humidity cell test method is very similar to the column test described below.

Depending on the sample, the test duration may need to be extended. Monitoring sulfate and dissolved metal loads is important to track both the oxidation reaction and metal mobility. Two points are important when using this and other kinetic tests: (1) if the sample was allowed to react before testing began (e.g., in storage) there may be a build up of oxidation products in the sample—this would be flushed out in the early water rinses, and (2) neutral drainage may lead to an incorrect prediction of acid potential if the test period is not long enough.

2.3.2 Soxhelet Extraction Tests

This test simulates geochemical weathering using a soxhelet extraction apparatus to recirculate solution through the sample. The sample is placed in a thimble in the unit and solution is circulated from a reservoir. Two procedures are used—one is the standard test described by Singleton and Lavkulich (1978); the other is the modified test described by Sobek et al. (1978). In the standard test the sample is leached using a 70°C solution of acetic acid or distilled water over a period of six weeks (duration of the procedure may vary). The modified test uses only distilled water at 25°C.

Research by Coastech (1989) determined that use of acetic acid yielded unrealistic results. Soxhelet extraction test conditions are more extreme than other kinetic tests. However, it is a shorter test and may be useful in simulating long weathering trends in a relatively short test time. Drawbacks include the complex equipment required and the more complex nature of the test in general.

Table 6. Summary of Some Kinetic Test Methods, Costs, Advantages, and Disadvantages

HUMIDITY CELLS (Sobek et al., 1978)	**SOXHELET EXTRACTION** (Singleton and Lavkulich, 1978; Sullivan and Sobek, 1982)	**COLUMN TESTS** (Bruynesteyn and Hackl, 1982; Hood and Oertel, 1984)
SUMMARY OF TEST METHOD		
-2.38 mm particle size 200g of rock exposed to three days dry air, three days humidified air, and rinsed with 200 mL on day seven cost: 425-850	particle size not presented T=70°C (Singleton and Lavkulich, 1978) T=25°C (Sullivan and Sobek, 1982) water passed through sample is distilled and recycled through sample cost: 212-425	variable particle size columns containing mine waste are leached with discrete volumes or recirculating solutions cost: dependent upon scale
ADVANTAGES AND DISADVANTAGES		
models AP and NP well and models wet/dry[3] approximates field conditions and rate of acidity per unit of sample moderate to use, results take long time, and some special equipment[1] moderate ease of interpretation[1,3] large data set generated[2]	simple, results in short time, and assessment of interaction between AP and NP[3] moderate to use and need special equipment[1] moderate interpretation[1,3] in developmental stage and relationship to natural processes not clear[3]	models AP and NP, models effect of different rock types, models wet/dry, and models different grain sizes[3] difficult interpretation, not practical for large number of samples[3] large volume of sample[2] lots of data generated, long time, and potential problems: uneven leachate application, channelization[2,3]

(Source: Lapakko 1993b)

BC RESEARCH CONFIRMATION (Duncan and Walden, 1975)	**BATCH REACTOR** (Halbert et al., 1983)	**FIELD TESTS** (Edger and Lapakko, 1985)
METHOD		
-400 mesh particle size 15-30g added to bacterially active solution at pH 2.2 to 2.5, T=35°C if pH increases, sample is non acid producer if pH decreases, 1/2 original sample mass is added in each of two increments cost: 170-340	-200 mesh particle size[1] sample/water slurry is agitated 200g/500 mL[1] cost: 425-850	field scale particles 800 to 1300 metric ton test piles constructed on liners flow and water quality data collected tests began in 1977 and are ongoing cost: initial construction is expensive, subsequent costs are comparable
ADVANTAGES AND DISADVANTAGES		
simple to use, low cost, assesses potential for biological leaching[3] moderate to use, longer time needed, and some special equipment needed[1] difficult interpretation if pH change is small, does not model initial AP step, and long time for pH to stabilize[3]	able to examine many samples simultaneously and relatively simple equipment[4] subject to large sampling errors and lack of precision[4]	uses actual mine waste under environmental conditions can be used to determine drainage volume mitigation methods can be tested expensive initial construction long time

(Source: Lapakko 1993)

1 = Coastech 1989, as referenced in Lapakko 1993

2 = Bradham and Caruccio 1990, as referenced in Lapakko 1993

3 = Ferguson 1985, as referenced in Lapakko 1993

4 = Babij et al. 1980, as referenced in Lapakko 1993

2.3.3 Column Tests

Column Tests are conducted by stacking the waste or material in a cylinder or similar device. Wetting and drying cycles are created by adding water and then allowing the column to dry. Each of the cycles may occur over a period from several days to a week or more, though they typically last for three days each. Care must be taken to avoid piping along the sample-wall interface when packing the column. Water added to the column is collected and analyzed to determine the current oxidation rate, sulfate production, metal release, and other parameters.

Column test equipment, like humidity cells, is a relatively simple apparatus compared to a soxhelet extraction device. It is easily modified to test control options, such as the addition of limestone, the influence of bacteria, and water saturation (Water Resources Control Board 1990). Results from research indicate that column tests of well sorted tailings material greater than 0.5 cm in diameter accurately represents field test conditions (Bradham and Caruccio 1990). Tests of waste rock material were not reported. Some of the disadvantages of column type tests are that the long time required, the associated high costs, and as mentioned above, the potential for channeling.

2.3.4 British Columbia Research Confirmation Test

Originally developed by Duncan and Bruynesteyn (1979), this test is intended to confirm results of the B.C. Initial (static) Tests; specifically, it is intended to determine if bacteria can catalyze enough reactions to satisfy their acid demands. As described in the Draft Technical Guide, Volume I (1989), sulfuric acid is added to a sample volume to a pH of 2.5. Although not identified in the Draft Technical Guide, other researchers use sample volumes in the range of 15 to 30 g of material passing a 400 mesh screen (Lapakko 1993b). The sample is shaken for four hours and acid is added to maintain a solution pH between 2.5 and 2.8. The sample is then inoculated with *Thiobacillus ferrooxidans* and the flask weighed. The flask is plugged with cotton, incubated at 35°C, and shaken continuously. The pH and metals in solution are monitored for the first three days and the pH maintained below 2.8. Distilled water is added to maintain constant weight. When the pH is established below 2.8, monitoring for pH and the metal is performed every second day until microbiological activity stops. This occurs when pH and metal values remain constant. Additional sample material is then added to the flask and this is shaken for 24 hours. When tested, if the pH is 3.5 or higher, the test is terminated. If the pH of the solution is less than 3.5, more of the sample is added and is shaken for 24 hours. The pH is tested; if it is greater than 4 or less than 3.5, the test is terminated. If the pH is less than or equal to 4, or greater than or equal to 3.5, the sample is shaken for 48 more hours and a final pH reading is taken (British Columbia AMD Task Force 1989).

If the bacteria are sustained in the sample, there is a strong possibility that acid drainage will be generated in the waste unit being characterized (British Columbia AMD Task Force 1989). If insufficient acid is produced, the solution pH will approach the natural pH (above 3.5), and the sample is determined to be non-acid producing. If the solution remains below 3.5 then there is a strong possibility that the sample will be an acid producer.

The initial acidification of the sample in this test presents conditions significantly different than in a typical waste unit. The test does not examine mineral/bacterial reactions above a pH of 2.5 (2.8 as described above). Reactions above these levels may be a major influence in determining if acid drainage is generated (Lapakko 1993b). Other disadvantages are that the test ignores neutralization potential and sulfide oxidation rates (British Columbia AMD Task Force 1989).

2.3.5 Batch Reactor (Shake Flask) Tests

In the Batch Reactor test, like the British Columbia Confirmation test, a mine sample and water are slurried together in a flask. The solution is usually distilled water, however, nutrients may be added. Sample size and solution volume are determined by the user. Coastech (1989) conducted tests using 250 g of waste and 500 mL of distilled water. Flasks are shaken continuously during the test. Water samples are taken at regular intervals to determine water quality parameters such as pH, sulfate, and metals in solution. Sampling for water quality analysis during longer tests may require addition of water to maintain volume. This would complicate interpretation of test data. Data from the tests are used to estimate the rate of sulfide mineral oxidation and release of contaminants, such as metals.

The batch reactor is relatively simple and allows examination of multiple factors, such as pH and temperature, which can be tested simultaneously. The influence of bacteria and control measures may be used as test parameters. The primary difficulty with the method is that the duration of the test may not exceed the lag time prior to acid formation (Lapakko 1993b). Other concerns are that the water volume in the flask may inhibit acid formation and bacteria may not acclimate in the test conditions (British Columbia AMD Task Force 1989).

2.3.6 Field Scale Test

Field Scale Testing, similar to On-site Rock Piles described by B.C. AMD Task Force, use large volumes of material to construct test cells in ambient environmental conditions, typically at the mine site in question. These tests are very different from laboratory tests where the experiment is conducted under controlled conditions. Sample size varies and may be as much as 1000 metric tons or more, depending on space availability. Particle size of the test material is not usually reduced for the test to better approximate field conditions. The sample is loaded on to an impervious liner to catch solutions and a vessel is used to collect the leachate. The volume of solution is determined and an aliquot is analyzed for pH, sulfate, dissolved metals, and other parameters.

Consideration of climatic conditions is important when evaluating results from field scale tests. Climatic effects must be distinguished from the rate of sulfide oxidation, acid generation, neutralization, and metal dissolution as determined by analysis of the leach solution. This is necessary because climatic effects, especially precipitation, determine the flushing rate but do not influence either reaction rate or the subsequent chemical composition of the leachate (British Columbia AMD Task Force 1989).

Lapakko (1988) demonstrated that carefully constructed kinetic tests in the laboratory could be extrapolated to field scale tests. That research is summarized in Section 5.3 of the report.

Field scale tests have the advantage of being conducted under the same environmental conditions as the waste or other units they are simulating. They also allow monitoring of the influence of bacteria and control measures. Drawbacks to field tests are that they require long test durations. Unlike other kinetic tests, field test do not accelerate environmental conditions, which tend to assess the potential to generate acid more quickly. Consequently, field tests will provide information on acid generation potential for a mine waste unit for that amount of time that they are started before waste emplacement begins. For some operations this may be 10 years or more and test results may be used to optimize reclamation design (Lapakko 1993b).

2.4 Application of Test Results in Prediction Analysis

Results from static and kinetic tests are used to classify mine wastes on the basis of their potential to generate acid. Static tests yield information about a sample's ability to neutralize and generate acid. The difference or ratio of these values becomes the basis of the classification. As discussed, for samples with NNP values greater than 20 tons $CaCO_3$/1000 tons of waste (ratio of 3:1), the potential to generate acid is low (Smith and Barton-Bridges 1991). For NNP values between -20 and 20 (ratios between 1:1 and 3:1), the potential for acid generation remains, and uncertainty will exist. It is important to note that each of these values are generalities and can be affected by the relative availability of surface areas of iron sulfides and calcium-magnesium carbonates.

The determination of AP based on estimated or reactive sulfur content in the sample has some inherent limitations. When total sulfur is used as the basis to estimate sulfide content, this uncertainty may be attributable to possible errors in: (1) assessment of true acidity and neutralization in the sample; (2) calculated acidity based on total sulfur conversion value; and (3) analytical error. Similar errors exist for static tests that determine reactive sulfide mineral concentrations. Estimating long-term reactive sulfide based on short-term tests may result in uncertainty due to difficulties in making oxidation rate predictions (British Columbia AMD Task Force 1989).

Acid base accounting tests conducted on an iterative basis, where the initial sample set is small, are helpful when establishing boundaries between lithologic units. As data from static tests is collected and evaluated, the sampling selection can be refined. The goal of sampling is to collect representative samples that define the variability of the lithologies present. If significant variability in the acid generation or neutralization potential is identified in the initial sample test results, additional sampling to refine lithologic boundaries is necessary (California Mining Association 1991).

Kinetic tests are often conducted to confirm results of static tests and estimate when and how fast acid generation will occur. The test provides insight on the rate of acid production and the water quality potentially produced and is used to evaluate treatment and control measures. Unlike static tests, there is no standardized method for evaluating test results. Data are examined for changes through time and water quality characteristics. Kinetic tests tend to accelerate the natural oxidation rate over those observed in the field. This may have the advantage of condensing time, and providing earlier insight into the potential for acid generation.

Generally, kinetic tests are evaluated for changes in pH, sulfate, acidity and a host of potential metals. According to the B.C. AMD Task Force (1989), samples with pH values less than 3 are considered strongly acid; between 3 and 5 the sample is acid generating and there may be some neutralization occurring; at pH values >5, the sample is not significantly acid, or an alkaline source is neutralizing the acid. Sulfate is a by-product of sulfide oxidation and can be used as a measure of the rate of oxidation and acid production. When evaluating test data it is important to examine the cumulative sulfate production curve as an indicator of sulfide oxidation, in addition to other parameters. An analysis of metals in the sample solution serves as an indicator of contaminant load but is not a good indicator of acid generation.

Based on test data, decisions with respect to the mine plan are made. Similar to static tests, kinetic tests are refined to address variability of the geology. Information collected from kinetic tests, such as oxidation rates and water quality, are more commonly being used as inputs to models, which are discussed in the following section.

2.4.1 Some Experience With Static and Kinetic Tests

Ferguson estimated that for about 50 percent of the mines it is easy to determine whether acid generation is a problem, and noted that predicting the potential for the other 50 percent is more difficult (U.S. EPA 1992a). When data collected from static and kinetic tests is inconclusive it may be necessary to extrapolate from existing data using oxidation rates and other factors and project how a sample may react. The soundness of the extrapolation is dependent on the representativeness of the sample, accuracy of the tests data, and the interpretation of the data.

Ferguson and Morin (1991) found that samples with an NP/AP ratio of less than 0.1 tended to produce acid during typical laboratory timeframes. They expected that if laboratory tests were conducted for longer time periods the NP/AP ratio would shift closer to 1 and did not speculate on what the values for NNP and NP/AP would be in the future. Extrapolating a sample's ability to generate acid was divided into short (less than one year), medium (a few years), and long-term (many years) time frames. Short term projections are based on laboratory data. Medium term projections require knowledge of the neutralization process, primarily consumption of carbonate. Long-term extrapolations of acid generation potential will require an understanding of weathering rinds and diffusion of oxygen into and reaction products out of that rind. Long-term projections were identified as being extremely problematic.

Researchers in British Columbia, Canada, have examined results of static and kinetic tests conducted on tailings and waste rock (Ferguson and Morin 1991). The results are based on a study of 20 active or abandon mines in British Columbia. Their findings indicate that for tailings, only those samples having a negative NNP produced acid. The test method was not identified and the limitations are therefore not discussed here.

According to this report, waste rock data from static tests is very limited and demonstrates the variability expected with these waste units. They observed that samples of waste rock that had weathered for one month (prior to sample collection) needed to be flushed initially to remove existing oxidation products.

Lapakko (1990b) used solid phase characterization of the sample in conjunction with acid base accounting data and the rates of acid production and consumption to extrapolate information beyond the timeframe of kinetic tests. The rates of acid production and consumption were based on kinetic test results over a 20 week period. The time required to deplete sulfide and carbonate minerals was determined using rates established from kinetic tests. Based on these observations the time required to deplete the iron sulfide content was 950 weeks and the time to deplete the carbonate content was 40 weeks. This prediction agreed with an observed drop in pH between week 36 and week 56 from 8.7 to 6; after another 20 weeks the pH dropped below 5. This research appears to indicate that kinetic tests should be run for periods of at least 20 weeks in length.

2.5 Mathematical Modeling of Acid Generation Potential

As the preceding discussion indicates, static and kinetic testing provide only a partial picture of the potential of mine wastes to produce ARD. Static testing estimates the ultimate APP and NP of waste material but is generally silent with regard to the rates of generation of acidic and alkaline flows in actual waste matrices. Kinetic testing is more helpful with regard to estimating the rates of oxidation and neutralization. As discussed above, actual waste units can be very non-homogenous and anisotropic with respect to the distributions of mineral types, particle size, hydrologic conditions and so forth. Thus, while a given kinetic test may well approximate the potential for ARD in a portion of a waste unit, the result may not be representative of the "global" potential for ARD. Equally important is the practical limitation on the duration of kinetic tests: because kinetic tests are generally short-lived with respect to the potential period of persistence of AMD, they inadequately mimic the evolutionary nature of the process of acid generation.

To overcome the uncertainties inherent in short-term testing, as well as avoid the prohibitive costs of very long-term testing, some researchers have developed mathematical models to aid in predicting the long-term effects on water quality of acid generating wastes. Predictive modelling offers the hope of providing tools for estimating the potential extent of acid generation prior to its occurrence. Ideally, such information may be compared for scenarios entailing alternative management options to identify the design, operating, and closure methods that best meet economic and environmental objectives. As a practical matter, existing AMD models fall short of the ideal. Nevertheless, these models may provide valuable information for planning purposes, and may have an important role in understanding and predicting AMD.

2.5.1 Overview of Existing Models

A number of distinct approaches to modelling ARD have emerged to date. In general, all the models attempt to describe the time-dependant behavior of one or more variables of a mine waste geochemical system in terms of observed behavior trends (empirical models) or chemical and/or physical processes that are believed to control ARD (deterministic models). Empirical models extrapolate values for the desired output variables (e.g., acid generation) from laboratory or field data (British Columbia AMD Task Force 1989). Deterministic models simulate the changes in system values according to the causal mechanisms relating each element of the system to the others.

It is important to remember that all ARD models are simplifications of reality. Simplification is required by incomplete understanding of all factors influencing ARD. Simplification can substantially reduce the cost and time required to model the system under study. However, simplifying assumptions can lead to incorrect conclusions if they result in the omission of important causal mechanisms. For instance, failure to consider the presence of neutralizing materials in a waste pile could result in an overestimation of the rate of acid generation. Similarly, failure to consider hydrogeochemical conditions within a waste pile may preclude consideration of adsorption/precipitation reactions involving metals, thereby miscalculating the potential for metals loading in effluent streams. Because the importance of any given controlling factor may vary from site to site, the significance of a simplifying assumption for any particular modelling effort must be weighed carefully.

2.5.2 Empirical Models

As stated above, empirical models extrapolate values of sulfide oxidation from existing laboratory and field test data. The method of extrapolation typically involves determination of the "best-fit lines" through test data points (British Columbia AMD Task Force 1989). The equations so derived may then be solved to provide, for instance, the acid generation rate of a particular waste unit at some time in the future. Using the projected acid generation rate as an input to a separate hydrogeochemical model that accounts for attenuation of seepage constituents in soils and dilution in receiving waters, the estimated constituent loading rates and consequent receiving water quality at time T may be estimated (Broughton and Robertson 1991).

Empirical models generally do not explicitly consider the causal mechanisms driving oxidation of sulfides and neutralization of seepage. Rather, such models assume that the operation of such controls is accurately represented in the test data. Therefore, the accuracy of empirical models in predicting AMD depends heavily on the quality of the test data used in the models. Principle sources of uncertainty may be expected to include variations in the spatial and particle size distribution of sulfide and alkaline minerals not captured by the data due to insufficient spacial distribution of samples; changes in the distribution of particle sizes throughout the waste unit (due to weathering) not captured by the data; and failure to accurately calibrate the model to reflect the actual quantity and type of materials disposed of (British Columbia AMD Task Force 1989).

It is important to note that empirical models, by their nature, are site-specific. Because the models rely on actual trends observed at a specific site, rather than generic causal mechanisms, the best fit lines for one site can not be assumed to be representative for another site. Further, significant changes in waste unit composition, geometry, or controls over time may invalidate previous representativeness of empirical models. Nevertheless, empirical models may provide cost-effective and reasonably reliable estimations of short-term future AMD conditions for sites with sufficient spatial and temporal data.

2.5.3 Deterministic Models

Deterministic models simulate AMD by solving systems of equations that represent the various controlling factors in the waste reaction process (Broughton and Robertson 1991). The simulation approach allows the users to examine the potential sulfide oxidation rate and resulting seepage quality over periods of tens to hundreds of years in the future. The greatest promise of deterministic models is that they may allow the user to predict AMD as it evolves over time under the changing influence of rate controlling factors. Existing models have built upon earlier work on acid releases from coal mine spoils as well as work on leachate quality in metals heap leach operations (Nicholson 1992). The models may rely solely on the causal relationships described in the equations, or may include empirical data as exogenous drivers (outside the model structure) to solve for certain aspects of the system (Nicholson 1992; Broughton and Robertson 1991). The most important differences between the models lie in the particular causal mechanisms (e.g., oxygen diffusion, changing particle size, temperature variations due to exothermic reactions) addressed within each model structure.

Nicholson presents a review of AMD models. In that review, Shumate (1971)[1] is credited with first recognizing that diffusion of oxygen within mine rock limits the overall rate of oxidation of sulfides (Nicholson 1992). The first working models to incorporate this process (Morth 1972[1], Rica and Chow 1974[1]) used the acid generation rate to calculate resulting drainage water quality. Rittchie (1977)[1] added to this concept by explicitly accounting for the removal of oxidized sulfur from the store of available unreacted sulfide. Other models have included convection as a means of oxygen transport within waste piles (Lu and Zhang undated). Convection may be influenced by changes in barometric pressure or by the release of heat from the exothermic oxidation of sulfides. Some researcher's have modelled the feedback mechanisms operating between temperature and biological and chemical oxidation rates, noting that the mechanism is only significant where waste permeabilities are high enough to allow convective oxygen transport to occur (Nicholson 1992).

More recent models have addressed the hydrologic and geochemical conditions in waste unit matrices, as well as reaction product transport, to more realistically represent changes in seepage quality (Nicholson 1992). Bennett (1990)[1] and others found that water flow through the waste pile strongly influences sulfide oxidation rates by acting as a heat sink and removing heat produced by oxidation.

Jaynes et al. (1986)[1] and Schafer (1991)[1] have incorporated chemical equilibrium relationships of varying complexity to model the mobilization and attenuation of oxidation and dissolution products within the waste pile. These relationships drive the residence times of various constituents within "mixing cells" of the waste matrix, and, along with allowing for consumption of acid by alkaline materials, result in changes in effluent chemistry as conditions within the matrix evolve (Nicholson 1992).

[1]As cited in Nicholson 1992.

Model developments such as those listed above have significantly contributed to understanding of the processes controlling AMD. For instance, explicit consideration of oxygen diffusion reveals that, in instances where diffusion is restricted, fast processes such as biologically catalyzed oxidation can be unimportant to the overall rate of oxidation. Similarly, consideration of hydrologic flow within the waste matrix shows that the rate of release of oxidation products from waste piles depends strongly on the flow characteristics within the wastes (Nicholson 1992). More recent models have corroborated the proposition that waste dump geometry can be important to oxidation rates by influencing the surface area exposure and air infiltration rates (Nicholson 1992).

2.6 Conclusions

Notwithstanding the understanding that existing models have provided, AMD models to date have not found extensive applications in predicting oxidation rates and effluent quality at operating or proposed sites (Ferguson and Erickson 1988). As stated above, models are simplifications of reality, and consequently are subject to a high degree of uncertainty. Among the sources of uncertainty are incomplete or invalid model structure; natural variability of certain parameters; and lack of parameter calibration and model verification (British Columbia AMD Task Force 1989).

Among the greatest concerns facing the reliability of predictive deterministic models are model calibration and validation. Model parameters must be adjusted to match the conditions prevailing at an actual site. Therefore, reliable waste characteristics, hydrologic and geochemical data must be collected and incorporated into the model structure. Validation requires comparison of model predictions with actual field sampling results. To date, the availability of field data for validation is very limited.

Regulatory programs for five states were reviewed for their requirements concerning acid generation prediction. A summary of the regulatory requirements for California, Minnesota, Idaho,

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994) (Continued)

Regulations/Guidance	Sampling	Analysis
Nevada[5]		
Regulations address process components, Nevada regulations, § 445.242 Guidance documents include the Nevada Division of Environmental Protection's (NDEP's) "Waste Rock and Overburden Evaluation" document, dated September 14, 1990. This evaluation document requires the use of the Meteoric Water Mobility Test (MWMT) to determine a sample's potential to release pollutants. This test does not test for AGP, but is required as a precursor to acid generation tests. Procedural requirements for the MWMT are provided in NDEP's September 19, 1990 guidance document titled, "Meteoric Water Mobility Procedure," dated September 19, 1990.	Wasterock and overburden must be evaluated for its potential to release pollutants and its acid generation potential. (NDEP 1990) Drill core samples should be collected during initial orebody definition, and used to characterize materials. Samples should be sent to an assay lab. During active mining operations, samples can be collected from remaining, saved, assayed materials to be "representatively composited" (not defined) on a quarterly basis for on-going evaluations. Samples are also required of waste materials that were not subject to assaying. (NDEP 1990) A representative sampling program must consider lithological and mineralogical variation, the extent of "sulfide" mineralization, color variation, degree of fracturing and of oxidation, and extent of secondary mineralization. (NDEP 1990)	The Meteoric Water Mobility Procedure should be used to determine the potential release of pollutants from samples. Consult NDEP's "Meteoric Water Mobility Procedure", dated September 19, 1990 for specifics regarding the procedure requirements. Acid generation potential must be evaluated using the Static Test, Acid/Base Accounting procedure, to determine neutralization potential (NP). (NDEP 1990) Acidification potential (AP) should be determined based on two alternatives: (1) determining total sulfur content, or (2) determining peroxide oxidizable sulphur. For alternative (1), compare results to NP. If NP exceeds AP value by 20%, material is considered non-acid generating. If less than 20%, determine total sulfide sulfur content according to <u>Standard Methods of Chemical Analyses</u>, or equivalent procedure. If NP is less than 20% greater than AP, kinetic testing must be initiated. For alternative (2), if NP value exceeds value by 100%, material is non-acid generating. If less than 100%, initiate kinetic testing. (NDEP 1990) Operating facilities with positive acid generating results from static testing, must notify the NDEP and begin kinetic testing within 10 days. Kinetic testing is required to be conducted according to procedures identified in attachment I. If kinetic testing confirms acid generating potential, containment/neutralization methods must be evaluated on site specific basis and proposed to the NDEP for approval. (NDEP 1990)

(Source: Based on phone conversations with State personnel and collected documents)

(Source: [1]Humphries, 1994)

(Source: [2]Lapakko, 1994)

(Source: [3]Schuld, 1994)

(Source: [4]Miller, 1994)

(Source: [5]Gaskin, 1994)

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994)

Regulations/Guidance	Sampling	Analysis
California[1]		
Regulations: Waste classification under §2571C of Chapter 15, of the California Mining Code. No other requirements specified.	No specific requirements indicated. Each site is considered on a case-by-case basis.	California is considering adoption of new regulations. These new regulations require testing of rock using a procedure for predicting AMD. Neither specific static or kinetic testing procedures are identified. Test results would be analyzed and interpreted by the mining company or its contractor. The state sets a trigger level at a 3:1 ratio (NP/AP) with a 95 percent confidence interval. If samples do not meet this requirement, kinetic tests are required, or the mine has the option to develop a management plan for waste disposal.
Minnesota[2]		
Regulations: Under §6132.1000 Mine Waste Characterization:	Sample types include material generated from exploration, pre-production sampling, and process testing. An outline of chemical and mineralogical analyses and laboratory tests must be conducted and presented to the commissioner for use in evaluating mining and reclamation plans. Mine waste characterization data submitted must include laboratory tests describing acid generation and dissolved solids release from mine waste. (Minnesota §6132.100)	Based on results of analyses and tests, additional mine waste characterization may be required. May include laboratory dissolution tests to describe a material's acid-producing and acid consuming mineral content. (Minnesota §6132.100) Results of mine waste characterization data should be submitted throughout the life of the operation to regulatory agencies establishing water quality and compliance monitoring standards. (Minnesota §6132.100)
Idaho[3]		
Regulations: There are no formal policies or regulations that specifically address AMD. Under Chapter 47-1513 of Idaho's Surface Mining Act and Dredge and Placer Mining Act, reclamation and operating plans are required that are protective of Idaho's water resources. (Schuld 1993) Protocols based on BC Acid Mine Task Force Report "Acid Rock Drainage Technical Guide." Also, a proposed "Policy Guidance Memorandum" has been submitted to the DEQ, but has not been signed by Administrator as of April 1993. (Schuld 1993) Under this policy, Idaho may request Federal land managers (BLM, USFS) to determined AGP for sites on Federal lands.	Sampling should begin during exploration. The state requires that exploration plans stipulate that half the samples collected should be kept in storage. Storage should minimize potential for sample weathering. Materials selected for sampling should include waste rock, overburden, and ore/subore. Composites of core samples should be obtained as samples. The number of samples obtained for AMD prediction testing should be based on the size of probable ore reserves and overburden. Consult "Acid Rock Drainage Guide" or other technical guidance document, in addition to best professional judgement, to determine minimum number of samples. (Schuld 1993) The sampling interval is based on lithology and changes in units. Reporting should occur prior to excavation and continue after mining has commenced. Results of static tests must be reported in order to prepare permit.	Idaho does not require the use of a specific static or kinetic test, however, the state must be informed of, and approve, the test methodology selected. Tests are conducted by U.S. EPA approved CLP laboratories only. Idaho uses BMPs in place of monitoring requirements to prevent any contact of AMD with groundwater or surface waters of the State. BMPs must function to avoid AMD generation, or should collect and treat AMD until it no longer exists. Future goals for BMPs will include (1) Leachate Detection/Collection Systems, (2) Closure requirements and monitoring, and (3) Bonding. If the ratio of acid potential (AP) to neutralization potential (NP) is greater than 2:1, the State requires a kinetic test to be performed. If State waters are impacted, an NOV and/or Consent Order may be issued, and other site specific requirements may be imposed.

Montana,andNevada is presented in Table 7

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994) (Continued)

Regulations/Guidance	Sampling	Analysis
	Montana[4]	
Regulations: Under Title 82, "Metal Mine Reclamation", § 82-4-336 (7), reclamation plans are required to provide for "...reclamation of disturbed land to comparable utility and stability,...". The State interprets this to mean both chemical and physical stability. Review and approval of reclamation plans gives the State the authority to reject plans that do not adequately assess AMD potential. **Guidance:** DRAFT, "Geochemical Characterization Checklist", Montana Department of State Lands. This provides specific recommendations that are only summarized in this table.	Sample collection is preferred during the advanced exploration stage of project. This allows data to be compiled and long term leachate extraction tests to be performed before submittal for a mining permit. Information requested includes descriptions of climate, topography, hydrology, vegetation, geology, mineralogy especially iron sulfides, and total element content for mineralized and unmineralized lithologies. The number of samples to collect is dependent on the variability of the lithology/alteration assemblage. The British Columbia Draft Task Force Guide (SRK, 1989) and the Saskatchewan Mine Rock Guidelines (SRK, 1992) are used as references for a rough guide as to methods and sample sizes needed to characterize mine waste. Samples should not be composited if possible. Samples should be split 4 ways. For each sample please record: sample location, sample description including mineralogy/petrology especially sulphur fractionation and carbonates, grain size and crystal form of iron sulfides, particle size distribution, paste pH, and slaking characteristics after Brodie et al, 1991. Two suites of samples should be collected. 1) Collect representative samples from each lithology for a reference suite. This suite should incorporate samples from unmineralized areas to establish regional background. The "representativeness" for each sample should be determined by the geologist who is most familiar with the site. This sample set will be biased. 2) Collect random samples over the entire deposit to limit bias. This sample set will be much larger than the representative suite. At least 8 samples should be analyzed for each lithology or alteration assemblage. A statistical analysis of the data should be compiled.	For splits from each sample provide analyses for: total element or trace element and any static test. After data is reviewed and compared to average crustal abundances and/or regional background values, a carefully picked subset of samples should be analyzed using any humidity cell test method and/or any field leachate extraction test method to help establish limits for suitable and unsuitable material. The definition of "suitable" and "unsuitable" may vary with each site depending on the regional geology. Any laboratory and/or method may be used but must be approved by the agency prior to use. Rationale must be given as to why certain methods were used. After all information has been compiled and reported for each suite decisions are made as to what materials are suitable for reclamation purposes and which materials are unsuitable and need to be isolated. The above mentioned testing sequence will not predict whether a material will produce contaminants. It will define which lithologies/alteration assemblages are suspect with respect to contaminant production and should be segregated from the suitable waste materials. Independent interpretations of the data set can be forwarded but the agencies' interpretation will comprise the effective recommendation. Testing should be ongoing throughout mine life to better substantiate preliminary conclusions made during the permitting process. More detail and references are given in "Permitting Guidelines for Mine Rock Characterization" available from the Department of State Lands, Hard Rock Bureau, 1625 11th Ave, Helena, MT 59620. (406) 444-2074. (References: Brodie, 1991; Steffen et al, 1989; Steffen et al, 1992)

. In addition, the U.S. Forest Service is developing a protocol. In the meantime, the acid generating potential associated with mines on Forest Service land is considered on a case-by-case basis as part of their review of proposed plans of operation.

3. CASE HISTORIES

Presented below are selected case studies for mines where acid drainage from mine wastes or mine works has occurred. Both active sites and sites on the National Priorities List are described. The active sites were selected to represent sites where the potential to generate acid was either not considered, or not expected, but later developed. Case histories for the Newmont Rain facility in Nevada, Cyprus Thompson Creek in Idaho, and the LTV Steel Mining Company Dunka site in Minnesota are presented below in Sections 4.1, 4.2, and 4.3, respectively. EPA visited each of these sites to further its understanding of the mining industry. Each site has experienced acid generation problems; however, it is important to note that each is also taking corrective action to mitigate the problem. The companies are working with appropriate State and Federal agencies to determine long-term treatment needs.

The EPA (1991) has prepared National Priorities List (NPL) Site Summary Reports for the mining sites on the NPL. NPL sites were selected from these reports if acid generation was identified as a problem. Using this criteria, seven of 56 mining-related sites were selected for review. The purpose of the review was to determine if acid generation predictive tests were conducted at individual sites, and if such tests were conducted, how the data were used. The review included examination of available literature on each site and interviews with each site's Remedial Project Manager (RPM). Based on incomplete information for the seven sites studied, tests for either acid prediction or pH prediction have not been conducted at Silver Bow Creek, Eagle Mountain Mine, Tar Creek, and Whitewood Creek. Eagle Mountain Mine and Silver Bow Creek have not conducted prediction tests because acid generation is such a clear and extreme problem (Taylor 1993, Forba 1993, and Overbay 1993).

Sites that have assessed the acid generation potential include Clear Creek/Central City, California Gulch, and Iron Mountain. At Clear Creek acid/base potentials were calculated for waste materials and potential acid generation testing is being required by the City of Clear Creek for any new development that disturbs the ground. Both the RPM and State contact for Iron Mountain indicate that acid generation predictive tests have been done while mucking out tunnels. Acid generation prediction has also occurred at California Gulch. Further details on the sampling and analytical methods used to predict acid generation have not been obtained. Sections 4.4 through 4.7 provide details on acid generation prediction experiences at these three NPL sites (Fliniau 1993, Hyman 1993, and Sugarek 1993).

3.1 Newmont Rain Facility, Elko County, NV

3.1.1 Introduction

EPA visited Newmont Gold Company's Rain facility in September of 1991 (U.S. EPA 1992b). The facility is located on approximately 627 acres, 9 miles southeast of Carlin in Elko County, Nevada. The facility is a mining-milling-leaching operation for beneficiating disseminated gold ore. Ore and waste rock are mined from an open pit. Of the ore removed from the mine, over forty percent is milled and beneficiated by the carbon-in-leach method at a current rate of about 840,000 tons per year (TPY). The remaining ore (about 1,000,000 tons per year) is leached using a modified heap method referred to as a valley leach. An average of 35,000 tons of material was being removed from the mine each day as of late 1991. Of this, 5,500 tons was ore grade, 29,500 tons was waste rock. This rate varies between 7,000 and 40,000 tons per day, respectively.

Most of the ore-grade material is taken from the oxidized sediments of the Webb Formation, proximal to the Rain fault. Gold concentrations in this material range from 0.01 to 0.15 ounces of gold per ton of rock. According to Newmont, sulfide-bearing rock does not contain gold in sufficient quantity to be economically recoverable, and is therefore disposed of as waste rock.

3.1.2 Waste Rock

Projected waste rock tonnage was estimated to be 41.4 million tons by the end of 1990, and 62.5 million tons during the life of the mine. In late 1991, the waste rock dump covered 211 acres north and east of the pit. Waste rock production from the pit averaged 29,500 tons per day. Of this, 7,500 tons were sulfidic and 22,000 tons oxide. Newmont had estimated that by mine closure in 1995, there will be 62.5 million tons of waste rock; of this, 77.8 percent was expected to be mostly oxidized mixed sedimentary material of the Webb Formation (some of which will contain sulfide mineralization), 15.4 percent carbonaceous and potentially sulfidic, 4.3 percent limestone of the Devil's Gate Formation, and 2.5 percent alluvium from surface deposits.

Prior to the spring of 1990, sulfide, oxide, and calcareous waste rock were disposed of together. On May 8, 1990, acid drainage was observed flowing from the base of the waste rock dump and into the unnamed drainage above Emigrant Spring, toward Dixie Creek. Inspection of the drainage downstream of the dump revealed that approximately two miles of the channel contained a red-brown precipitate. Discharge to the drainage was estimated by Newmont to be 3 gpm. According to Newmont, snow removed from the roads was disposed of on the waste dump. As the snow melted, it infiltrated the waste rock pile, oxidizing sulfur-bearing minerals and generating acid. The solution migrated along pre-mining topography and discharged at the toe of the dump.

Surface-water samples were taken along 5 points in the drainage above and below Emigrant Spring in May, June, and July of 1990. They showed pH values ranging from 2.37 to 3.21 near the base of the waste rock at the discharge point, and from 6.5 to 8.64 about 4,000 feet downstream. Arsenic levels near the effluent point were 46 ppm in May and 1.5 ppm in July; at the distant sampling point, arsenic levels were 0.023 ppm in May and 0.005 ppm in July. Mercury levels near the discharge point were 0.19 ppm in May and 0.0019 ppm in July; at the distant sampling point, mercury levels were <0.0001 ppm in May and 0.0003 ppm in July.

3.1.3 Acid Generation Prediction

Following detection of the acid generation in 1991, Newmont's Rain facility Water Pollution Control Permit was revised. As part of the revised Permit, Newmont is required to report quarterly on results of Meteoric Water Mobility testing and Waste Rock Analysis. The meteoric water mobility test is an extraction procedure that determines moisture content of the waste, percent of a sample passing -200 mesh, pH of deionized water, and final pH of extract (following 24-hour extraction time). Following the meteoric water mobility test, total carbon, organic-carbon, and sulfur assays are obtained on the composite waste sample by combustion-infrared analysis to measure sulfur and sulfide contents, and to estimate carbonate content. Acid neutralization potential is then measured using titration. The extracted solution is analyzed for nitrate, phosphorous, chloride, fluoride, total dissolved solids, alkalinity, sulfate, and metals. Waste rock analysis is intended to determine the net acid generation potential of the material placed in the waste rock dump during the quarter.

Data for the third and fourth quarters of 1990 and the first quarter of 1991 were examined by EPA following the site visit (U.S. EPA 1992b). Third quarter results for the waste rock analysis indicated a net acid generation potential of -10.6 tons of $CaCO_3$ for each 1,000 tons of waste. This suggests that the wastes generated during this quarter had sufficient buffering capacity to neutralize any acid solution generated by sulfidic material. Fourth quarter results showed a large shift, with an acid generating potential of 5.35 tons of $CaCO_3$ for each 1,000 tons of waste. The total acid generating potential of waste rock disposed during this quarter was equivalent to the amount of acid neutralized by 5.35 tons of $CaCO_3$ for each 1,000 tons of waste rock. For the first quarter of 1991, waste rock analysis data showed a net acid generating potential of 8.57 tons. In these circumstances, Newmont is required to perform kinetic testing according to State of Nevada protocol. Results of this analysis were not available; however, in the third Quarterly Monitoring Report for 1991, Newmont indicated that column studies were underway to fulfill this requirement.

3.1.4 Treatment

In response to the drainage, Newmont took the following actions. By May 9 (one day after the drainage was noted), a small pond was constructed to collect the flow from the dump. On May 11, an HDPE liner was installed in the pond, and on May 18, Newmont constructed a cutoff trench across the channel downstream of the collection pond to collect subsurface solution. The trench was twenty feet deep and forty feet across and included a HDPE liner. Inflow to this trench was pumped to the collection pond and then trucked to the tailings impoundment for disposal.

The State and BLM approved Newmont's long-term mitigation plan with construction beginning in November of 1990, and completed in March of 1991. The solution collection and return system consists of surface and subsurface water collection and recovery system. Surface water is collected in a ditch and drains to a sump located at the toe of the waste rock pile. Drainage collected in the sump drains by gravity to a 200,000-gallon capacity, double-lined pond. Subsurface flow is recovered in an HDPE-lined trench and also drains to the double-lined pond. Flows average 23.8 gpm with a maximum of 183 gpm. In the event of a power failure, the pond has a capacity to retain in excess of 65 hours of inflow at the maximum projected flow rate. In addition, storm water from the surface of the waste rock dump and surrounding area is collected in a single-lined, 600,000-gallon pond located just below the double-lined pond. Solution from both ponds is pumped to the mill area and added to the tailings pipeline.

As a long-term mitigation/prevention measure, Newmont began encapsulating sulfidic waste rock within oxidized and/or calcareous waste rock that has either no net acid generating potential or some acid neutralizing potential. As of late 1991, this was being accomplished by placing a pervious layer of coarse oxidized waste rock on the native soil. On this, five feet of compacted oxidized ore was placed. Additional oxide ore was placed against the natural hillslope to act as a barrier. These layers were to act as barriers to water movement into and out of the sulfidic waste rock. Following these steps, sulfidic waste rock was placed on and in front of the oxide ore. Several lifts were expected to be added to the sulfidic waste pile. In addition, haul trucks follow random routes during construction to compact the material, thereby reducing its permeability. Eventually, the front edge and top will be covered with 15 feet of oxidized material to complete the encapsulation. Prior to encapsulation, sulfide waste rock will be mixed with oxidized material or the limited quantity of calcarious material available to buffer any acidic solution generated. The sulfidic materials are fine to coarse grain sedimentary rocks extracted primarily from the Webb Formation.

Neither the draft nor the final Environmental Assessment prepared for the Rain Facility discussed the potential for sulfidic material to generate acid drainage.

3.2 Cyprus Thompson Creek, Challis, ID

3.2.1 Introduction

EPA conducted a site visit of the Cyprus Minerals Corporation Thompson Creek (Cyprus) facility in September 1991 (U.S. EPA 1992c). Cyprus mines molybdenite (molybdenum disulfide, MoS_2) from an open pit mine near Challis in central Idaho. Cyprus staked its first mineral claims at Thompson Creek in 1967. In 1981, mining operations began and the first concentrates were produced in 1983. In late 1991, the Cyprus Thompson Creek Mine site consisted of (1) an open pit mine and two waste rock dumps; (2) a primary in-pit crusher; (3) a mill with grinding and flotation, and (4) a tailings impoundment.

Cyprus has been conducting a study to investigate the potential for the waste dumps and the tailings impoundment to generate AMD. The results of the AMD study of the waste rock and tailings were to be provided to USFS by March 1, 1992. Proposed revisions to the facility's reclamation plan were also to be submitted to the U.S. Forest Service (U.S.FS). According to USFS personnel, the revisions to the Plan of Operations were to be subjected to the environmental review requirements of National Environmental Policy

Act (NEPA). This review may include preparation of a supplemental Environmental Impact Statement (U.S. EPA 1992c). The AMD study has been requested.

3.2.2 Waste Rock

When mining began in 1981, approximately 130 million tons of overburden were initially removed as "pre-production stripping." Most of the overburden was placed in two waste rock dumps (the Buckskin and Pat Hughes dumps) located adjacent to the pit. In 1990, approximately 16.2 million cubic yards of waste rock were generated, consisting mainly of metasediment, quartz monzonite, challis volcanics, and clayey rock (i.e., decomposed volcanics).

3.2.3 Acid Generation Prediction

Both intrusive and metasedimentary rocks have high sulfur content (up to 1.13 and 1.66 percent, respectively). Therefore, in 1990, Cyprus began a study of the potential for AMD generation from the waste rock and tailings, using both static and kinetic test methods. As of late 1991, static testing had been performed on twenty intrusive rock, and 58 metasedimentary rock samples collected from both the lower and upper benches of the pit. For each sample, Cyprus calculated the neutralization potential (NP) and the acid generation potential (AP) to determine the net neutralization potential (NNP) and the NP/AP ratio. The NNP represents the neutralization potential (the tons of calcium carbonate required to neutralize 1,000 tons of waste rock) minus acid generation potential (calculated based on the total sulfur content). According to Cyprus personnel, waste rock with an NP/AP ratio in excess of 3:1 was considered non-acid generating. According to USFS personnel, a NP/AP ratio of at least 5:1 should be required before a material is determined to be non-acid forming (U.S. EPA 1992c).

Static testing of eight intrusive rock samples from the lower benches of the pit, close to the ore zone, yielded an average net neutralization potential (NNP), and neutralization ratio (NP/AP) of 0.53 and 1.88:1, respectively. These results exhibited more AMD potential than the average NNP (4.93) and average NP/AP (3.80:1) values obtained from 12 intrusive rock samples from the upper bench. They indicate a greater potential for AMD with intrusive waste rock in the vicinity of the ore zone. The AMD potential decreased with distance from the ore zone. The difference between intrusive rock samples collected from the upper and lower benches was believed to be caused by a relatively predictable pattern of mineralization and alteration zoning around the ore body.

According to Cyprus, the metasedimentary rocks did not appear to be sources of AMD. Cyprus has performed static testing on the metasedimentary rock in the lower benches and found average NNP and NP/AP values of 24.95 and 3.11:1, respectively. It should be noted that, while the metasedimentary rocks are considered non-acid forming by Cyprus (NP/AP greater than 3:1), the average NP/AP ratio is less than the minimum (5:1) ratio suggested by the USFS. Metasedimentary rock samples obtained from the upper benches showed average NNP and NP/AP values of 19.02 and 8.52:1, respectively. Though the average

NNP value did not increase in samples from the upper bench, the NP/AP ratio increased significantly, supporting the theory that AMD potential decreases with distance from the ore zone.

Kinetic testing of intrusive and metasedimentary rock was ongoing in 1991 for those static test samples showing acid generating potential. Results of these tests were to be incorporated into the AMD study as they became available.

3.2.4 Tailings

During the ongoing acid drainage study, indications of acid generation were found in the tailings. As of late 1991, the tailings impoundment covered a total of approximately 150 acres with the embankment covering about 60-70 acres and the tailings pond behind the embankment approximately 90 acres. According to Cyprus personnel, tailings oxidation to a depth of several feet had been evident for over two years (U.S. EPA 1992c).

3.2.5 Acid Generation Prediction

In October 1990, ten hollow stem auger borings were completed in the tailings embankment. Samples collected from the these borings were subjected to humidity cell testing, and showed that the average sulfur content of the tailings sands was 0.79 percent and the pH ranged from 3.5 to 7.3 s.u. (Analyses of tailings sands have shown pH levels as low as 3.0 s.u.) In addition, of eight samples tested, six produced elevated iron and sulfate concentrations, and associated increased acidity, within a 15-week test period. The kinetic tests affirm the reactive nature of the tailings found in static test results.

According to Cyprus personnel, the tailings pond and the seepage return pond were not a problem (pH > 5.7 s.u.). However, in 1991, Cyprus conducted a water quality trend analysis for six surface water quality monitoring locations in the tailings impoundment area. These locations included the main drain of the rock toe, springs located on the left and right abutments of the rock toe, the discharge from the rock toe, the sump below the seepage return pond dam, and Bruno Creek (immediately downstream of the sump). This analysis found that during the period 1981-1990, (1) pH decreased at four locations (but not at the left and right abutment springs), (2) sulfate had increased at all locations, (3) iron had increased at four locations (not at the left and right abutment springs), and (4) no trends in zinc, copper, or arsenic were recognized. The increase in sulfate concentrations was attributed to tailings oxidation and acid generation.

3.2.6 Treatment

Cyprus applied trisodium phosphate (TSP) to tailings embankment sand to address the AMD problem. Previous column testing had found that TSP addition increased the pH, and reduced iron concentrations in leachate samples. According to Cyprus's consultant, two TSP tests, humidity cell tests and large scale tests, were being conducted in 1991 to determine TSP's effectiveness in controlling AMD from the embankment, and maintaining impoundment water quality. However, because the tailings impoundment unit has no discharge and water from the impoundment, seepage return pond, and pump back system is returned to the mill, the TSP application were expected to cause elevated phosphorus levels in the reclaim water. Cyprus personnel indicated these levels may adversely affect flotation operations and that this issue was being studied.

Cyprus' original plan for reclamation of the tailings impoundment indicates that Cyprus initially anticipated that water quality standards could be met by diluting impoundment seepage with natural runoff. No water treatment beyond sediment control was expected to be required. However, the original reclamation plan did not consider the AMD issue. According to Cyprus personnel, the AMD problem could extend well beyond the life of the mine and perpetual care/treatment may be necessary. Therefore, Cyprus was evaluating remedial alternatives (other than perpetual care) and was preparing to submit a revised tailings pond reclamation plan (as a modification to their operating plan).

Alternatives to be considered included installing an additional flotation unit to remove pyrite and/or in-place treatment of tailings with trisodium phosphate as a buffer. Preliminary flotation tests have been conducted to investigate the possibility of removing sulfides from the tailings prior to disposal in the impoundment. Test results indicated that a high percentage of pyrite may be recovered. Limited static testing performed on a whole tailings sample from which pyrite was recovered indicated a NP/AP ratio in excess of 4:1 compared to an average value of 0.84:1 for all tailings analyses.

According to Cyprus personnel, oxidation had only been found to occur in the top two to three feet of tailings (despite the results of analyses of the 1990 borehole samples that showed oxidation at all depths down to 150 feet). Therefore, an additional alternative under consideration was to encapsulate the tailings. Information on specific types of cover materials was not provided. Additionally, Cyprus was investigating the potential use of wetlands treatment.

3.3 LTV Steel Mining Company, The Dunka Site, Minnesota

3.3.1 Introduction

EPA visited the LTV's Dunka site in August 1991 (U.S. EPA 1992d). The site is located approximately 20 miles northeast of LTV Steel Mining Company's (LTV SMCo.) Hoyt Lakes facility. The site is on private, State, Bureau of Land Management, and U.S. Forest Service lands; LTV SMCo. holds surface and mineral leases for the area. The Dunka pit is part of the eastern-most extension of the Biwabik iron formation and is one of the smaller pits on the Mesabi Range at three miles in length. Although additional material may be removed from the pit for beneficiation, in 1991, plans called for no further exploration activity at the site or enlargement of the pit.

3.3.2 The Acid-Generating Duluth Complex

The taconite ore at the Dunka site contacts Duluth Complex material (DCM), which must be removed to reach portions of the taconite ore deposit. The Duluth Complex is a sulfur-containing, mafic intrusive rock unit, considered to be one of the largest known sources of copper and nickel resources. As of late 1991, LTV SMCo. had removed and placed in "gabbro" stockpiles approximately 50 million tons of Duluth Complex material containing an average of more than 0.2 mass percent copper oxides and/or 0.05 mass percent nickel oxides as gabbro stockpiles.

The remaining Duluth Complex material stockpiles were categorized as waste rock stockpiles and are made up of material containing less than 0.2 percent copper oxide and less than 0.05 percent nickel. Since these waste rock stockpiles were constructed in 1976, monitoring of drainage from the piles has revealed a decrease in pH levels, as well as an increase in trace metal concentrations. Copper and nickel concentrations as high as 1.7 and 40 mg/L, respectively, were observed in seepage/runoff from Duluth Complex waste rock stockpiles at the site. In addition, during sampling conducted by the Minnesota Department of Natural Resources between 1976 and 1980, pH values as low as 5.0 at Seep 1 were reported.

3.3.3 Acid Rock Drainage Prediction Methods

To address this drainage, the Minnesota Department of Natural Resources in conjunction with LTV SMCo., constructed full scale test piles of the Duluth Complex material to monitor its acid generation potential. The MDNR continues to monitor the test piles and study acid generation. Lapakko (1988) conducted kinetic tests of Duluth Complex material using a humidity cell. Nine samples were selected from core material and one sample from a test stockpile. This experimental method was selected based on ongoing field test results, which demonstrated a strong correlation between sulfur content, trace metal mobility, and acid production. Laboratory scale tests provided better control and simplified analysis. Sulfur content was identified as the independent variable. Samples that had variable sulfur content were selected. Part of the study was to determine the feasibility of extrapolating laboratory results to operational conditions.

Each cell was loaded with 75 gram rock samples passing 100 mesh but less than 270 mesh. Samples were rinsed with 200 ml of distilled-deionized water, which was allowed to remain in contact with the sample for five minutes. Rinse water was collected and filtered through a 45 micron filter. At the beginning of the experiment, the samples were rinsed five times to remove oxidation products generated during sample preparation. Two rinses were used each week during the remainder of the experiment. Between the weekly rinsings, the samples were stored in a box fitted with temperature and humidity controls.

The laboratory study found that drainage pH decreased as the sulfur content of the sample increased. Drainage pH also decreased as the experiment time increased. Both of these findings are consistent with field observations on pH variation correlated with sulfur content and time. Based on the data, Lapakko (1988) concluded that the small particles (<2.0 mm) have a large influence on field stockpile drainage quality. The weighted average sulfur content for particles in this fraction is 1 percent compared to 0.6 percent in the bulk rock. Most of the sulfur occurs as pyrrhotite. The higher sulfur content combined with the higher surface area of these particles make this fraction susceptible to more intense oxidation reactions.

3.3.4 Environmental Risks

Toxicity testing of the leachate showed that copper and nickel concentrations exceeded the 48-hour lethal concentration (LC50) for *Daphnia pulicaria*; nickel concentrations also exceeded the 96-hour LC50 for fathead minnow. Concentrations of calcium, magnesium, and sulfate in the stockpile drainage were also elevated. According to LTV SMCo., there was some question whether the metals were the toxic agent.

Most of the seepage from waste rock piles at the Dunka site has historically been discharged to Unnamed Creek. Unnamed Creek flows into Bob Bay, a part of Birch Lake. In a 1976-1977 study of trace metals in Bob Bay, it was found that concentrations of copper, nickel, cobalt, and zinc in the waters of the Bay were higher than the regional average concentrations and decreased with distance from the mouth of Unnamed Creek. Elevated metal concentrations were also observed in the sediments, as well as in aquatic plant and clam tissue. In the study, it was estimated that the total discharge from the Dunka watershed into Bob Bay through Unnamed Creek was 500 million gallons per year. Unnamed Creek contributes more than 90 percent of the trace metals load to Bob's Bay. Annual loading is over one ton of nickel. Less than 40 percent of this nickel load was found to be removed from the system through natural lake processes. According to LTV SMCo., carbon dating of sediment samples from Bob Bay indicates significant metal concentrations which predate mining.

3.3.5 Treatment

As of late 1991, the State and LTV SMCo. were working to develop technologies to mitigate leachate generation and release of trace metals associated with stockpile drainage. The technologies being tested and employed included pile capping/channeling to limit infiltration, active treatment in a neutralization pond to lower pH and remove metals, and use of artificial wetlands to remove metals. The ultimate goal was a passive treatment system that would require little or no maintenance (U.S. EPA 1992d).

3.4 California Gulch

The California Gulch NPL site is located in the upper Arkansas River Valley in Lake County, Colorado. It is bounded by the Arkansas River to the west and the Mosquito Mountains to the east, and is approximately 100 miles southwest of Denver. The study area for the remedial action encompasses approximately 15 square miles, and includes California Gulch and the City of Leadville. California Gulch is a tributary of the Arkansas River. Mining for lead, zinc, and gold has occurred in the area since the late 1800's. This site was added to the NPL in 1983 (U.S. EPA, 1991).

A Remedial Investigation conducted by EPA in 1984 indicated that the area is contaminated with metals (including cadmium, copper, lead, and zinc migrating from numerous abandoned and active mining operations). A primary source of the metals contamination in the Arkansas River is acid-mine drainage from the Yak Tunnel into California Gulch. The Yak Tunnel was built to drain the mine workings in the area of California Gulch. The acid dissolves and mobilizes cadmium, copper, iron, lead, manganese, zinc, and other metals. The tunnel and its laterals and drifts collect this metal-laden acidic water, and drain it to the tunnel portal. The tunnel drains into California Gulch and then to the Arkansas River. The Yak Tunnel's discharge contributes to the contamination of California Gulch, the Arkansas River, and the associated shallow alluvial ground-water and sediment systems. From previous investigations and sampling data, it was concluded that, as of the early 1980's, the Yak Tunnel discharged a combined total of 210 tons per year of cadmium, lead, copper, manganese, iron, and zinc into California Gulch, which is biologically sterile (U.S. EPA 1991). Results of acid generation predictive tests of tailings and waste rock samples were not available for this report.

3.5 Clear Creek/Central City

The Clear Creek/Central City NPL site is located approximately 30 miles west of Denver, Colorado, and includes the Clear Creek mainstem and the North and West Forks of Clear Creek. Active operations, which began in 1859, include gold, silver, copper, lead, molybdenum, and zinc mining. Initial investigations at the site focused on the discharges of Acid Mine Drainage (AMD) and milling and mining wastes from five mines/tunnels in the Clear Creek and North Clear Creek Drainages. The five mines/tunnels of interest are: (1) the Argo Tunnel; (2) the Big Five; (3) the National Tunnel; (4) the Gregory Incline; and (5) the Quartz Hill Tunnel. The first two are portals along Clear Creek and the last three are in the North Clear Creek Drainage. They are close to the Cities of Idaho Springs, Black Hawk, and Central City. Associated with the AMD is contamination of surface drainages by metals in solution such as cadmium, chromium (VI), lead, manganese, nickel, and silver (U.S. EPA 1991).

Acid/base potentials, similar to acid/base accounting, of waste materials were tested as part of the Remedial Investigation. The acid/base potentials (NNP) were calculated as the neutralization potential (NP) minus the potential acidity (AP). Results indicated that waste materials at the Gregory Incline, the Quartz Hill Tunnel, and the Argo Tunnel have the capacity to generate large quantities of acid leachate. The mill tailings at the Gregory Incline are especially capable of producing acid through the oxidation of large quantities of pyrite. For example, the average acid potential for the Gregory Incline mill tailings was -21.5, the waste rock was 1.7, and the alluvium was 11.6 (a negative acid/base potential indicates acid forming potential). In the waste rock and alluvium, 11 of 18 and 2 of 13 samples showed acid forming potential. Information on the types of sampling and analytical methods used was not available.

The City of Blackhawk, with guidance from EPA, is requiring, through a city ordinance, acid generation potential testing of onsite materials prior to any development activities. Central City is in the process of doing the same. The ordinance requires that, for any excavation or site development, a sample collection plan that includes chemical analysis of acid-base potential must be prepared. The ordnance requires that the tests conform to the methods outlined in EPA-670/2-74-070, *Mine Spoil Potential for Soil and Water Quality or an equivalent method*, and that sampling must be representative of the conditions at the property. If the acid/base potential is negative, the applicant must have a mitigation plan approved by the city (Fliniau, 1993).

3.6 Iron Mountain Mine

The Iron Mountain Mine is a 4,400-acre NPL site in Shasta County, California, approximately nine miles northwest of the City of Redding. Between 1865 and 1963, the area was used for the mining and processing of copper, silver, gold, zinc, and pyrite. In 1983, Iron Mountain Mine was added to the NPL. Acid mine drainage, leaching from both the underground mine workings and from the tailings piles located at the site, is causing zinc, cadmium, and copper contamination of the Spring Creek Watershed and the Sacramento River. Environmental damage is primarily in the Sacramento River and tributaries in the Spring Creek and Flat Creek watersheds, where fishery productivity loss and periodic fish kills have been observed. Drinking water drawn from the Sacramento River for the City of Redding (population 50,000) is also threatened (U.S. EPA 1991).

In general, acid mine drainage generation is seasonal and is accelerated during periods of heavy rainfall. According to EPA, the annual average rate of acid mine drainage at the site is 100 gallons per minute (gpm) with peak flows of 300 to 600 gpm. The average loading per day to the Spring Creek Watershed from Iron Mountain Mine is 423 lbs of copper, 1,466 lbs of zinc, and 10.4 lbs of cadmium (U.S. EPA 1991, Biggs 1991).

According to the Remedial Project Manager acid generation potential tests were conducted while the tunnels were being mucked out. The procedures used are those required by California State law. Information on test results and sampling and analytical methods used was not available (Hyman 1993 and Sugarek 1993).

3.7 Silver Bow Creek/Butte Area Site

The Silver Bow Creek/Butte Area NPL site is one of four separate but contiguous Superfund Sites located along the course of the Clark Fork River in southwestern Montana. The Silver Bow Creek/Butte Area Superfund Site is the largest (450 acres) and most complex of the four sites. The site was listed on the NPL in 1983. The Silver Bow Creek/Butte Area site includes the Cities of Butte and Walkerville (population 38,000), the Berkeley Pit (a nonoperating open-pit copper mine); numerous underground mine workings; the Continental Pit (operated by Montana Resources); Silver Bow Creek; Warm Springs Ponds (mine tailings); and Rocker Timber Framing and Treating Plant.

In the early 1980s the Berkely Pit open pit mine was closed and dewatering pumps were shut down. As a result, the interconnected underground workings and the open pit began filling with water. EPA is concerned with the waters filling Berkeley Pit because they are highly acidic (the RI shows pH values ranging between 2.5 and 3.3, depending upon at what depth the samples were taken) and contain high concentrations of copper, iron, manganese, lead, arsenic, cadmium, zinc, and sulfates. If the water continues to rise in the Berkeley Pit, contaminated water may eventually flow into shallow ground water (alluvial aquifer) and into

Silver Bow Creek, creating the potential for significant environmental impacts and human health problems (U.S. EPA 1991). There have been no tests performed to predict pH changes either in Berkely Pit or the drainages that feed the Berkely Pit (Forba 1993). Total acidity has been tested for some samples collected at the Silver Bow Creek site. Information on the materials sampled, analytical methods, and results were not available.

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Review

Heavy Metal Pollution from Gold Mines: Environmental Effects and Bacterial Strategies for Resistance

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Abstract: Mining activities can lead to the generation of large quantities of heavy metal laden wastes which are released in an uncontrolled manner, causing widespread contamination of the ecosystem. Though some heavy metals classified as essential are important for normal life physiological processes, higher concentrations above stipulated levels have deleterious effects on human health and biota. Bacteria able to withstand high concentrations of these heavy metals are found in the environment as a result of various inherent biochemical, physiological, and/or genetic mechanisms. These mechanisms can serve as potential tools for bioremediation of heavy metal polluted sites. This review focuses on the effects of heavy metal wastes generated from gold mining activities on the environment and the various mechanisms used by bacteria to counteract the effect of these heavy metals in their immediate environment.

Keywords: bioremediation; environmental pollution; metal toxicity; mine wastes

1. Introduction

Increased urbanization and industrialization have led to large amounts of toxic contaminants being released into the environment worldwide. Some of these contaminants occur naturally, but anthropogenic sources, especially mining activities, have contributed significantly to their increase. Although mining provides enormous social and economic benefits to nations, the long-term adverse effects on the environment and public health cannot be overlooked [1].

Mining, mineral processing and metallurgical extraction are the three principal activities of gold mining industries which produce wastes. Mineral processing also known as beneficiation aims to physically separate and concentrate the ore mineral(s) using physical, chemical and sometimes microbiological techniques. Metallurgical extraction breaks the crystallographic bonds in the ore mineral in order to recover the desired element or compound [2]. Large quantities of waste are produced during this activity. particularly in gold mines which release over 99% of extracted ore as waste to the environment [3].

The use of bacteria in gold extraction, known as biomining, has received considerable attention due to the potential roles played by these bacteria in the recovery of gold from gold-bearing ores. Acidophilic, chemolithotrophic iron and sulphur oxidizing bacteria such as *Acidithiobacillus* (*At.*) *ferroxidans*, *At. thioxidans*, *Leptospirillum (L.) ferriphilum* and *L. ferroxidans*, *Sulfobacillus acidophilus Sulfolobus metallicus* have been identified and utilized in gold extraction. These bacteria help in solubilizing the sulphide matrix of the gold deposits thereby making the gold more reachable to leaching by the chemical lixiviants [4–6]. Biomining is known to be more environmentally friendly than many physicochemical extraction processes. In addition, the wastes generated using bacteria are less biologically reactive compared to those obtained using the physicochemical methods [5].

Tailings are the major wastes produced from gold extraction and they contain high amounts of heavy metals (HM). These metals leach out in an uncontrolled manner into surrounding environments on exposure to water or through dispersal by wind. The presence of elevated concentrations of HM in the environment is a serious health issue worldwide due to their non-degradative nature which makes them persistent and thereby exert long-term effects on the ecosystem [7]. Heavy metals affect the natural population of bacteria in the soils. This leads to loss of bacterial species responsible for nutrient cycling with a consequent negative effect on ecosystem functioning [8]. To survive in metal polluted sites, some bacteria have devised various ways to withstand the potentially deleterious conditions. They are known to develop and adopt diverse detoxifying mechanisms such as biotransformation, bioaccumulation and biosorption which can be utilized in either ex-situ or in-situ bioremediation of HM polluted sites [9]. This review focuses on environmental impacts of increasing heavy metal pollution caused by gold mining activities on human health and the environment and how bacteria interact with these metals.

2. Gold Processing and Extraction and the Role Played by Bacteria

Gold mining can be open-pit or deep shaft mixed with other HM such as copper (Cu), silver (Ag) and lead (Pb). Its location determines the type of mining process to be used in extraction and the amount of wastes that will be generated. In the past, small quantities of waste were generated by mining activities because higher grade ores were being exploited. There was also limited capacity to move large quantities of materials and so the waste generated was discarded within a few meters of the mine opening or pit. Open-pit mining produces eight to 10 times as much waste as underground mines because a greater amount of topsoil, overburden and barren or waste rock has to be removed. Gold mining in South Africa over the centuries has resulted in the accumulation of thousands of voluminous tailings dumps which are scattered all over the country with lots of potentially negative impact on the environments [10].

To separate the gold (Au) from the mineral bearing rock, mercury is mixed with the ores dug from the ground or from stream beds to form an amalgam. The burning of the amalgam leads to vaporization of the elemental mercury into a toxic plume leaving the gold behind. Mercury amalgamation was the initial method used for centuries to process gold and is still in use today by artisanal and small-scale gold mining (ASGM). Globally, ASGM is the second largest source of atmospheric mercury pollution after coal combustion [11]. Another method of Au extraction uses cyanide in a two-stage process; extraction and recovery. Gold is first dissolved using cyanide in the extraction stage and the dissolved gold is then recovered from the cyanide solution by cementing with zinc or adsorption onto activated carbon. The cyanide extraction processes could be heap leach or vat/tank leach depending on the quality of the ores. In ores of higher gold content, the vat/tank leaching is employed, which involves leaching of the crushed and ground ore in large enclosed tanks equipped with agitators to dissolve the gold which then adheres to pieces of the activated carbon. The activated carbon and the gold are then stripped of the solution and the barren solution together with the leached ore are discarded. The heap leach is used for low-grade ore and involves extraction of crushed oxide gold ore piled onto plastic-lined pads with leaching solvents such as acids or cyanide to dissolve the gold which is collected at the bottom of the pad [2].

The equation below explain how cyanide dissolves gold:

$$4\mathrm{Au}(s) + 8\mathrm{NaCN}(aq) + \mathrm{O_2}(g) + 2\mathrm{H_2O}(l) \rightarrow 4\mathrm{NaAu(CN)_2}(aq) + 4\mathrm{NaOH}(aq)$$

The high demand for gold and the fluctuating gold prices have necessitated the need for processing of lower grades ores, waste rock dump materials and scrap residues. Bacteria are now increasingly being used to facilitate the extraction of metals from low grades ores and concentrates (bio mining) that cannot be economically processed by conventional methods. These bacteria help in enrichment of metals in water from gold ores and mines, in a solubilization process called bioleaching. This process occurs in Nature under suitable environmental conditions that favor the growth of the bioleaching bacteria [5]. The sulphidic nature of many gold deposits hinder accessibility of lixiviants but activity of several acidophilic, chemolithotrophic iron and sulphur oxidizing bacteria has been reported to assist in the oxidation of the sulphide matrix. The bacteria include; mesophilic iron and sulphur oxidizing *Acidithiobacillus* (*At.*) *ferroxidans*, sulphur-oxidizing *At. thioxidans*, iron-oxidizing *Leptospirillum* (*L.*) *ferriphilum* and *L. ferroxidans*, moderately thermophilic bacteria such as sulphur-oxidizing *At. caldus* and sulphur and iron oxidizing *Sulfobacillus* spp. [12,13]. These bacteria obtain energy by oxidizing ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) or elemental sulphur (S^0) or other reduced sulphur compounds to sulphuric acid (H_2SO_4). The released Fe^{3+} and hydrogen ions then break down the sulphide matrix [14]. This is summarized in the equations below using pyrite as a typical example of gold bearing ores:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \quad (1)$$

$$2S^0 + 3O_2 + 2H_2O \rightarrow 4H^+ + 2SO_4{}^{2-} \quad (2)$$

$$FeS_2\ (Au) + 2Fe^{3+} \rightarrow 3Fe^{2+} + 2S^0 + (Au) \quad (3)$$

$$FeS_2\ (Au) + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4{}^{2-} + 16H^+ + Au \quad (4)$$

Bio-oxidation of sulphide contained in refractory gold ores enhances liberation of gold particles from the sulphide matrix thereby rendering the gold amenable to dissolution using lixiviants such as cyanide. Bio-oxidation is a pretreatment method of gold processing that helps to decrease the use of lixiviant for gold solubilization in subsequent parts of the operation and in the long run increasing the gold yields [6]. This method is usually used in conjunction with other methods since it does not actually solubilize gold. Bacteria also excrete ligands that are capable of stabilizing gold by forming gold-rich complexes and/or colloids. Biologically produced amino acids, cyanide and thiosulphate can also aid gold solubilization [6]. Gold solubility can also be reduced with the use of bacteria that help in consuming the ligands that bind the gold or by bio-sorption, enzymatic reduction and precipitation and by using gold as micronutrient [6]. In addition, bacteria can also indirectly influence gold solubilization by enhancing the permeability of gold-bearing ores bodies [15].

Distinct advantages have been reported for bio-leaching of gold over traditional physicochemical methods. Microbial extraction procedures are more environmentally friendly: (1) they do not produce environmentally noxious gaseous emissions; (2) they do not require high energy consumption used during roasting or smelting; (3) they enhance extraction of low grade gold ores that are too expensive to process using conventional methods; and (4) tailings produced from bio- mining processes are less chemically and biologically active since they are already bio-leached [6].

Characteristics of Gold Mine Tailings

Tailings are a mixture of finely ground rock that is left after retrieval of the precious mineral and water used in processing. Considerable volumes of open-dump tailings are found in many countries where environmental regulations are not strongly adhered to [16]. The chemical and physical nature of tailings particles can be likened to typical river sand and silt and their properties are determined by the nature of the ore, geochemistry, the processing method used in extracting the ore, the particle size of the crushed material and the type of chemical process used in extracting the ore [17,18]. Gold mine tailings are characterized by poor physical properties like poor aggregation, high hydraulic conductivity, fine texture and very limited cohesion ability. These properties make tailings different from soil [19,20] and the lack of cohesion is responsible for the varied moisture content and temperature seen in this toxic waste. Chemically, tailings contain up to 6% pyrite, high salinity, are nutritionally deficient with low contents of organic matter [21]. The high sulphides content result in high acidity and high metal concentrations in ground water in the vicinity of the tailings [19]. Rafiei et al. [22], reported a pH value of 7.35 in gold mine tailings in Iran, whereas Mitileni et al. [23], reported pH values of 3.25–6.28 in South Africa and Harish and David [24] pH value of 3.48–8.12 in India. Highly acidic pH has also been observed in acid mine drainage arising from gold mining activity in other studies [25,26]. The characteristic features of gold mine tailings are the elevated concentrations of toxic HM such as arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), copper (Cu), zinc (Zn), cobalt (Co) and mercury (Hg) [27]. The largest fraction of the total HM may exist as silicates [28] which are limitedly accessible to microbial life. These characteristics of gold mines result in complex stresses for the bacteria inhabiting these environments and leads to selection of different resistant bacterial species. The differences in prevailing environmental conditions, levels of contamination, geographic and geologic origin as well as the site of origin are factors determining the bacterial diversity [29].

Aside from the acidophilic mesophilic species known to be involved in bio oxidation of gold, diverse metallophilic Gram positive and negative bacteria belonging to the phylum *Proteobacteria* such as *Pseudomonas*, *Aeromonas*, *Shewanella*, *Brevundimonas*, *Agrobacterium* and *Acinetobacter* and the phylum *Firmicutes* (*Bacillus*, *Serratia*, and *Exiguobacterium*) and so on have been reported in gold mine tailings using culture-dependent techniques [30–33]. A number of studies also investigated bacterial diversity in gold mines using culture independent techniques based on bacterial 16SrRNA gene identification. Santini et al. [34] in the Northern Territory of Australia also discovered the *Agrobacterium/Rhizobium* branch of the *Proteobacteria* while Rastogi et al. [35], using the same method obtained bacteria diversity mainly composed of phylotypes related to the phylum *Proteobacteria* and other phyla *Acidobacteria*, *Actinobacteria*, *Bacteroidetes*, *Chloroflexi*, *Chlorobi*, *Firmicutes*, *Nitrospirae*, *Verrumicrobia* in deep subsurface homestake gold mine soil in the USA.

3. Environmental Pollution from Gold Mine Tailings

Environmental pollution from gold mines is associated mainly with the release of harmful elements from the tailings and other mine wastes. The infiltration of water through sulphide- containing tailings piles and ponds, surface and underground workings, waste and development rock leads to leaching of large volumes of metals like Zn^{2+}, Ni^{2+}, Pb^{2+}, AS^{2+}, Cu^{2+} and sulphate ions into stream and river ecosystems [36,37]. This results in acid mine drainage (AMD) with severe detrimental effect on the receiving water bodies. Heavy metal pollution and acid mine drainage is a very important environmental concern where waste materials containing metal-rich sulfides from mining activity have been stored or abandoned [38]. Tailings and rock dumps are associated with the surface impacts which greatly affect surface and ground water quality. The underground impacts are caused by the influx of water into the underground workings and the subsequent dewatering of the aquifer [39]. Another source of environmental pollution from gold mines is the chemicals used in processing the gold. An estimated 1400 metric tons of mercury was used in 2011 by ASGM and an annual average of 1000 metric tons of inorganic Hg was discharged. One-third of this estimated value goes into the air and the rest is mixed up in heaps of tailings, soil and waterways [40]. Mercury can also be released into the environment as a result of present reprocessing of some old gold tailings dumps. Pacyna et al. [41] reported that Hg emissions in South Africa are second only to China. The cyanidation method of extraction also gives rise to the emission of hydrogen cyanide, global warming and production of huge amounts of tailings a potential source of HM due to the extraction of low-grade ores [42].

Heavy Metal Toxicity in Gold Mine Environment

Heavy metals play a vital role in metabolic and physiological processes of plants, humans and microorganisms. Heavy metals like Zn, Cu, Ni, Co and Cr, function as micronutrients and are essential in redox-processes. They are important in the stabilization of molecules through electrostatic interactions, regulation of osmotic pressure and cofactors for numerous enzymes and electron transport chains. Hence, HM ions play an essential role in complex biochemical reactions [43]. The non-essential HM like Ag, As, Cd, Pb and Hg are of no biological importance to living organisms and are very toxic when found in the ecosystem.

The disruption and acceleration of the natural process of the geochemical cycle through anthropogenic activities like gold mining has led to most soils of rural and urban settings accumulating HM above the recommended levels [44]. Studies of the effect of HM in soil, plants and water have been reported by [38,45–47].

Elevated levels of HM in gold mine tailings greatly affects the diversity, population size, and overall activity of bacteria. Heavy metals affect the metabolism, growth and morphology of soil bacteria as a result of functional disturbance, destruction of cell membrane integrity or protein denaturation [48,49]. Bacteria are essential in the decomposition of soil organic matter and any decline in bacterial diversity or biomass may have a profound effect in nutrient absorption from the soil to plants [47]. Many studies using culture dependent and independent techniques have shown that HM contamination gives rise to shifts in microbial populations [50–52].

Diverse toxicological and biological effects of HMs in the environment occur as a result of the different forms (oxidation) in which the HMs exists which also relates to compounds with great variation in toxicity. The oxidation state is a function of the type and quantity of the metal's redox potential, pH and microbial activity [53]. Heavy metal toxicity results from modification in the conformational structure of nucleic acids, proteins or by interference with oxidative phosphorylation and osmotic balance [54]. Some HM like Cd^{2+}, Ag^{2+}, Hg^{2+} can attach to the sulfhydrl (SH) groups of important enzymes used in microbial metabolism, thereby hindering the activity of sensitive enzymes [55]. These HMs may enter the food chain as a result of their uptake by edible plants [56].

Cadmium

Cadmium is one of the most toxic HM to most organisms. Its concentration in unpolluted soil is usually 1 mg/kg [57], but in gold mine tailings, concentrations ranging between 6.4 and 11.7 mg/kg have been reported in Tanzania [45]. It occurs in gold bearing orebodies as an isometric trace element in sphalerite and its concentration depends on the concentration of the sphalerite in the ore body. Cadmium is of serious concern as a result of its accumulation in the food chain, drinking water and soil. It has an exceptionally long biological half-life (>20 years), highly mobile in soil-plant systems and can also exert a great effect on the proper functioning of the ecosystems [58]. The bioavalability of Cd and associated toxicity to soil bacteria depends on the bacterial species, concentration, environmental factors, time, speciation, soil properties and ageing [59]. Cadmium affects many metabolic activities of soil bacteria such as nitrogen mineralization, carbon mineralization, CO_2 production and enzyme activities. Negative effect of Cd at concentrations of 50 and 500 mg Cd/kg were observed on dehydrogenase activities in soil bacteria by Landi et al. [60], while Smolders et al. [61] also noted 14% decrease in nitrification activity of soil bacteria in a soil having pH 6.6 at Cd concentration of 2 mg Cd/Kg.

Zinc

Zinc also occurs in gold ore bodies in the form of sphalerite (ZnS) which is often associated with galena. The average natural level of Zn in the Earth's crust is 70 mg/kg (dry weight), ranging between 10 and 300 mg/kg [62]. In gold mine tailings, concentration ranging between 8.9 and 65.7 mg/kg have been reported in South Africa by Mitileni et al. [23] while a higher concentration of 177.56 mg/kg was reported by Bempah et al. [63] in Ghana. Though a micronutrient needed by plants, bacteria and human beings for vital cell functions, its presence beyond the normal physiological value is toxic due to its interaction with sulfhydryl groups or replacement of other essential metals in a wide range of proteins [64]. Zinc speciation is very important in determining its toxicity to bacteria because it varies considerably with pH. High concentrations of Zn show varied inhibitory or toxic effect on cellular activities and growth of bacterial cells. Mertens et al. [65], noted that the nitrification process by *Nitrosospira* sp. was reduced by 20% in soil contaminated with zinc at pH 4.8–7.5.

Lead

Lead is toxic at the lowest concentration and naturally non-degradable unless it is removed from the medium where it is found. Standard mean concentration for Pb in surface soils worldwide averages 32 mg/kg with a range of 10–67 mg/kg [66] but concentration ranging between 80 mg/kg [67] and 510 mg/kg [68] have been reported in gold mine tailings. It occurs in the form of galena (PbS) in gold ore and this form is found when sulphide concentration of the ore is high [69]. Lead exists in various oxidation states (0, I, II, IV) and the most stable forms are Pb(II) and lead-hydroxy complexes. The ionic form, Pb(II) is the most reactive and most common form which forms mononuclear and polynuclear oxides and hydroxides. This ionic form together with lead oxides and hydroxides are the forms that are released into surface water, ground water and soil. Lead gains access to bacterial cells through the uptake pathways for essential divalent metals like Mn^{2+} and Zn^{2+} and exerts its toxic effects on bacterial species by changing the conformation of nucleic acids, proteins, inhibition of enzyme activity, disruption of membrane functions and oxidative phosphorylation as well as alterations of the osmotic balance of the bacterial cells [43].

Chromium

Chromium is widely distributed in soils and rocks where it occurs in minerals such as chromite [(Fe, Mg, Al) Cr_2O_4]. Chromium concentration ranges between 2 and 60 mg/kg in unpolluted soil [70] but a higher concentration of 486 mg/kg was reported in gold mine tailings in Oman [67]. Chromium is mainly found in chromate $FeCr_2O_4$ having 70% of pure Cr_2O_3. It can be found in the environment in several forms (with oxidation states from −2 to +6) depending on pH and redox conditions but Cr(III) and VI are the most stable forms with differing chemical and physical features as well as biological effects [71]. Chromium(III) species are less soluble and relatively immobile as a result of their adsorption to clays and oxide minerals below pH 5 while low solubility above pH 5 is as a result of $Cr(OH)_3$ (S). Hexavalent chromium (Cr(VI)) is the most oxidized form, a potentially dangerous substance due to its high solubility and mobility which allows it to infiltrate biological membranes and pollute soil and water [72]. This is the form usually found at contaminated sites, its major species are chromate $CrO_4{}^{2-}$ and dichromate ($Cr_2O_7{}^{2-}$). Studies have shown that Cr(VI) is 100 times more toxic and 1000 times more mutagenic and carcinogenic compared to Cr(III) [73]. It damages bacterial DNA and this genotoxic ability has been attributed to its intracellular reduction to Cr(III) through reactive intermediates. The two types of resulting DNA damage produced are (1) oxidative DNA damage; and (2) Cr(III)-DNA interactions [74].

Nickel

Nickel levels in soils greatly depend on the concentration of the parent rocks and this concentration has been estimated to range from 3 to 100 mg/kg for world soils [75]. In gold mine tailings, a higher concentration of 583 mg/kg was found by Matshusa et al. [76] in South Africa. Bitala et al. [45] also reported concentrations as high as 11,200 mg/kg in Tanzania. Nickel exists in gold bearing ore as pyrrhotite ($Fe_{(1-X)}S$), which can contain up to 5% Ni and pentlandite $(FeNi)S_8$. Other mineral sources are chalcopyrite (CuFeSz) and gersdorffite (NiAsS). It exists in the 0 and +2 oxidation states and less often in the −1, +1, +3 and +4 oxidation states. Among its species, the +4 oxidation state is known to be more toxic and carcinogenic compared to +2 [77]. Nickel toxicity arises due to its tendency to substitute other metal ions in proteins, enzymes or attach to cellular compounds [78]. It also intermingles with not less than 13 essential elements in living organisms. The major toxicity of Ni to bacterial cells include: (1) replacement of essential metal of metalloproteins; (2) attachment to catalytic residues of non-metalloenzymes; (3) allosteric inhibition of enzyme; (4) oxidative stress that enchanced DNA damage, protein impairment, lipid peroxidation along with increased titers of oxidative stress defense systems [79].

Arsenic

Arsenic is one of the most dangerous heavy metals of worldwide environmental concern [80] due to its potential toxicity. It occurs as arsenopyrite [FeSAs], realgar [As_2S_2] and orpiment [As_2S_3] in gold bearing rock [81]. Elevated levels of As have been reported in gold mine tailings at Obuasi, Ghana. Ahmad and Carboo [82], reported 8305 mg/kg while Bempah et al. [63] found a concentration of 1752 mg/kg. The Obuasi region has been reported to be one of the regions in the world with elevated levels of As which has been attributed to the richness of arsenopyrite (FeAsS) mineralization in the gold-bearing ore [82,83]. The highest toxicity level of As is seen in the inorganic forms As(III) and arsenate As(V) which are the predominant forms in mine tailings. The arsenate acts like phosphate and can therefore gain access to microbial cells via the transport system meant for the uptake of this essential salt. Once inside the cell, it inhibits oxidative phosphorylation due to its interference with the phosphate based energy generating processes. Arsenite, on the other hand, enters through a different path (aqua-glycerolporins) and targets a wider range of cellular processes, binding to the thiol groups in essential cellular proteins such as pyruvate dehydrogenase and 2-oxoglutarate dehydrogenase [84].

Copper

Copper is widely distributed in sulphides, arsenites, chlorides and carbonates in gold ores. The mean concentration of 5 to 70 mg/kg exists in unpolluted soil while higher concentrations are found in contaminated environments like mining sites. Bempah et al. [63], found a concentration of 92.17 mg/kg in gold mine tailings in Ghana. Gold mining has greatly increased Cu concentration in the environment which upon release binds to particles of organic matter, clay minerals and sesquioxides leading to great accumulation in the soil [85]. Copper exists in two states, oxidized state Cu(II), and reduced state, Cu(I). The ability to exist in these two states makes this metal potentially toxic because the conversion between Cu(II) to Cu(I) could lead to a generation of superoxide and hydroxyl radicals [86]. Excessive Cu concentration has deleterious effects on soil microbes [87]. Copper toxicity is as a result of its harmful effects on the bacterial cell membranes and nucleic acid structure as well as its ability to alter enzyme specificity and disrupt cellular functions [43].

Mercury

Large amounts of Hg are released into the environment as a result of its usage in gold extraction. About 1.32 kg of Hg is lost for every 1 kg of gold produced which goes directly into water, soil and streams as inorganic Hg and later converted into organic forms [76]. Several researchers have reported on its high concentration in gold mine tailings. Rafiei et al. [22] reported 100 mg/kg concentrations of Hg in Iran whereas Mathusa et al. [76] reported concentrations as high as 1920 mg/kg in Kenya. Some of the inorganic Hg that reaches aquatic ecosystems is converted by microbes into organic methylmercury (MeHg), which accumulates in fish. Mercury is also inhaled during the mining and roasting processes and dangerous levels remain suspended in air due to its volatile nature. When inhaled by humans, this could lead to a series of health conditions outlined in Table 1. Mercury compounds cause oxidative stress to bacterial cells due to imbalance between pro-oxidant and anti-oxidant homeostasis. They have high affinity for thiol group containing enzymes and proteins that serve as a line of cellular defense against Hg compounds. On gaining access to the cell, both Hg II (Hg^{2+}) and MeHg form covalent bonds with cysteine residues of proteins and deplete cellular antioxidants [88]. The various toxicological effects of heavy metals in human and microbes are summarized in Tables 1 and 2.

Table 1. Effects of heavy metals on human health.

Metals	Effects	References
As	Peripheral vascular disease, lung, skin, kidney and bladder cancer, severe disturbances of the cardiovascular and central nervous systems which may lead to death, bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy may also be observed.	[89]
Cd	Bronchial and pulmonary irritation, kidney stone, liver damage, various system disorders such as nervous and immune system, blood, bone and Itai itai disease.	Satarug [90]
Cr	Skin rashes, stomach and ulcers upset respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer and death chromium hinder enzyme activity, DNA damage, altered gene expression and causes mutations.	[91]
Cu	Accumulation in liver, kidney, brain and cornea leading to cellular damage and Wilsons disease, upper respiratory tract and nasal mucous membrane irritation, hemolytic anaemia, epigastric pain, nausea, dizziness, headache and death may occur.	[92]
Pb	Blood related disorders such as colic, constipation and anemia, high blood pressure, decrease of hemoglobin production, kidney, joints, reproductive and cardiovascular systems disorder, long-lasting injury to the central and peripheral nervous systems, loss of IQ, low sperm count, loss of hearing.	[93,94]
Hg	Affect gene expression, kidney damage, tremor, restlessness, anxiety, depression and sleep disturbance, paresthesia and numbness in the hands and feet while high doses may lead to death. Total brain damage can occur in early exposure while late exposure results in localized damage to the cerebellum, motor cortex and the visual cortex.	[95,96]
Ni	Hypoglycemia, asthma, nausea, headache, cancer of nasal cavity and lungs.	[97]
Zn	Tachycardia, vascular shock, dyspeptic nausea, headache, cancer of nasal cavity and lungs, asthma, vomiting, diarrhea, hypoglycemia, pancreatitis and damage of hepatic parenchyma, impairment of growth and reproduction.	[97,98]

Table 2. Toxic effects of HM on bacteria.

Metals	Mechanisms of Action	References
Hg, Pb, Cd	Denaturation of protein	[99]
Hg, Pb, Cd and Zn	Inhibition of cell division	[99,100]
Hg, Pb, Ni, Cu and Cd	Disruption of cell membrane	[100,101]
Hg, Pb, Cd, Cu, Ni and Zn	Inhibition of enzyme activities	[100,102]
Hg, Pb, As and Cd	Damage of Nucleic acid	[99,101]
Hg, Pb, Cd	Inhibition of transcription	[103]

4. Bacterial Interaction with Heavy Metals

Bacteria are the most abundant microorganisms in the soil, with 10^6–10^9 viable cells cm^{-3} of soil. Due to their small size they have a high surface to volume ratio which affords them a large contact area for interaction with their immediate environment. At a higher concentration, metal ions are known to form toxic compounds in bacteria cells [104], and their increasing concentrations in microbial habitats caused by environmental and natural processes, has led to bacteria developing various mechanisms to withstand their presence. Bacteria are known to possess the ability to convert toxic HM into insoluble substances which enhance easy mobility and dissolution in dump-sites [105]. They accumulate HM from the environment as a result of the negative net charge of their cell envelope through a metabolism-independent passive or a metabolism-dependent active process that is determined by absorptivity of the cell envelope and ability to take up HM into the cytosol [106]. This metal accumulating ability can be utilized to remove, concentrate and recover HM from industrial effluents and mine tailings [107]. In mine tailings, the redox potential, physicochemical conditions, metal speciation and co-contaminants limit bacteria-metal interactions and bacterial activity. Despite this limitation, sulphate reducing bacteria such as *Syntrophobacter sulfatireducens*, *Syntrophus gentianae*, *Desulfobacca acetoxidans*, *Desulfosporosinus* sp. and *Desulfotomaculum* sp., have been reported in both acid base-metal tailings and pH neutral gold mine tailings where they assist in natural bioremediation of mine tailings by precipitating toxic HM and increasing pH [108,109]. The level of tolerance shown by bacteria found in various gold mine tailings contaminated environments is determined by the concentration of the HM present in such environments. Several researchers have reported bacterial interactions with metals in various HM contaminated mining sites. Anderson and Cook [31], isolated 6 members of the genera *Exiguobacterium*, *Aeromonas*, *Bacillus*, *Pseudomonas*, *Escherichia*, and *Acinetobacter* resistant to arsenate from two sites contaminated with gold mine tailings in New Zealand and observed that two of the isolates, *Exiguobacterium* strain WK6 and *Pseudomonas* strain CA1 are well adapted and gained metabolic energy from the utilization of 50 mM and 30 mM of the arsenate which increased their total cell yield two fold. Similarly, Chang et al. [32], evaluated bacterial interaction with arsenic from arsenic-contaminated gold-silver mines in the Republic of Korea and discovered 15 isolates that were able to oxidize and reduce two different species of arsenic As(V) and As(III). Two of the isolates, *Pseudomonas putida* strains OS-3 and OS-18 completely oxidize 1 mM of arsenite III to V within 35–40 h of growth, while two of the four arsenate reducers obtained *P. putida* strains RS-4 and RS-5 were able to grow and efficiently utilized 66.7 mM of arsenate V. Bacterial interaction with Hg was also investigated by Ball et al. [110] in tailing ponds located in gold mining area of El Callao, Venezuela. High rates of resistance to both inorganic Hg and organomercurials were detected among the bacterial isolates. The minimal inhibitory concentrations (MIC) determined showed a broad range of resistance levels. As much as 73.58% of the isolated bacteria strains were able to grow in the presence of 0.1 mM of mercury and when grown in the presence of 0.01, 0.02, 0.04 and 0.07 mM of MeHg, the percentage resistance were 71.5%, 59.6%, 48.08% and 30.77% respectively. El Baz et al. [111], isolated 59 HM-resistant bacteria from various abandoned mining sites in Morocco that belong to *Amycolaptosis* and *Streptomyces* genera. Their results showed different levels of HM resistance, the MIC recorded in mM was 1.66 for Pb, 0.51 for Cr and 0.53 for both Zn and Cu. Bacterial interactions with metals have several impacts on the environment, they play crucial roles in the biogeochemical cycling of toxic metals as well as in cleaning or remediating metal contaminated sites [9].

4.1. Effects of HM on Bacteria

Microbes are usually the first biota to be affected by HM pollution [112]. Bacterial communities have been reported to be the most affected by high HM concentration as compared to fungal communities [113]. The beneficial or detrimental effect of an HM to microbial cells is a function of its concentration and the form in which it exists in the environment. The essential metals help in building the structure of an organism or assist in metabolic functions as a component of enzymes [114]. The Presence of HMs like Zn, Cu, Ni, Co and Fe at low concentrations is fundamental for numerous microbial activities, they aid in the metabolism and redox processes [114]. Exposure to high HM concentration results in selection pressure on the microbial community leading to the establishment of HM resistant microbial populations with reduced diversity when compared to unpolluted environment. The community profile is affected by reducing the number, biomass, alteration of morphological structure and loss of activity in microbially assisted soil processes such as nitrification, denitrification and decomposition of organic matter. The decrease in diversity can also result in soil erosion due to reduced soil aggregation and poor soil structure. Heavy metals also interfere with the life cycle of microbes and causes decrease in pigmentation of microbial cells [8]. Smejkalova et al. [48], studied the effect of three HM (Zn, Cd and Pb) on colony forming unit (CFU), enzymatic activities and microbial biomass carbon: oxidisable carbon content (C-biomass: Cox ratio) of a soil's microorganisms. They discovered that all the measured parameters were significantly affected by the HM concentrations. Considerable reduction was observed on CFU which was most significant in the spore-forming and oligotrophic bacteria. Major inhibition of C-biomass was observed in these soils and the C-biomass: ox ratio decreased with increasing soil pollution.

4.2. Mechanisms of Bacterial Resistance to Some Selected HM

Many bacteria are able to resist and survive HM-induced stress. When the acceptable limits of HM a bacterial cell can withstand are exceeded, mechanisms of resistance are triggered in order to survive in the adverse environment [115,116]. Heavy metal tolerant bacteria have been isolated from metal laden environments with some able to survive while others are endemic to their environment and the prevailing environmental conditions may have favored their selection [117]. The ability to survive in these extreme conditions depends on acquired biochemical and structural attributes, physiological, and/or genetic adaptation such as changes of cell, morphological and environmental alterations of metal speciation [118]. Bacteria have developed several types of resistance mechanisms which aid in maintenance of intracellular homeostasis of the vital HM and normalize resistance against toxic HM which is the principle governing bioremediation processes.

4.2.1. Bioaccumulation

This is an energy-dependent HM transport system that involves the retention and concentration of HM by living cells. Metals present outside bacterial cell are transported into the cytoplasm through the cell membrane and the metal is later sequestered [119] intracellularly by metal binding metallothioneins (MTs) which form complexes with the metal. Metallothioneins are small cysteine rich metal binding proteins that are induced by HM stress conditions in bacteria. They play an important role in protecting bacterial metabolic processes catalyzed by enzymes which immobilize toxic HM. Studies have shown the presence of MTs in many cyanobacterial and bacterial strains. Metallothioneins from *Synechococcus* sp. strain PCC 6301 and *Synechococcus* sp. strain PCC 7942 (SmtA) and *Pseudomonas putida* (BmtA), *Oscillatoria brevis* (BmtA), *Anabaena* PCC 7120 (SmtA), *Pseudomonas aeruginosa* (BmtA) have been described by Blindauer et al. [120]. The *smt* locus consists of two divergently transcribed genes, SmtA and SmtB which confers resistance to Zn and Cd in *Synechococcus* spp. [121]. This mechanism is subject to environmental modification, availability and toxicity of the metal, intrinsic biochemical and structural properties as well as genetic and physiological adaptation. It includes ion pumps, ion channels, carrier mediated transport, endocytosis, complex permeation, and lipid permeation. Typical examples of this active mechanism are seen in the transport of Zn, Pb, Cu, Cr and Ni [122]. Bioremediation of metals using growing bacteria cells allow both biosorption and bioaccumulation to occur simultaneously. Several authors have reported metal bioaccumulation by bacterial cells as a promising approach for clean-up of metal polluted sites [111]. Wei et al. [33], reported intracellular accumulation of four HM by bacteria strain CCNWRS33-2 isolated from root nodule of *Lespedeza cuneate* in gold mine tailings in China. This bacterium was found to have 98.9% similarity to *Agrobacterium tumefaciens* LMG 196 by 16SrRNA. The result obtained showed that 0.101 mM of Cu was accumulated after 4 h, while Cd accumulation increased from 0.225 mM at 4 h to 0.353 mM at 12 h and Pb accumulation reached 0.2 mM at 12 h.

Despite the promising results observed from the use of growing bacterial cells for bioremediation in many studies, there are still some significant limitations to the use of this approach in treatment of HM polluted sites. Uptake of metals by bacterial cells encounters significant practical limitations such as sensitivity of the systems to extremes of pH, high salt concentration, the availability of the contaminant to the bacteria, interactions with co-ions and requirement of external metabolic energy [123,124]. Metal interaction is an important factor that needs to be considered as a results of antagonistic and synergistic interactions of metals due to their competition for the same binding sites which determines their uptake in contaminated environments like mine tailings.

4.2.2. Biosorption

This is a non-enzymatic immobilization of HM by dead or living microbial biomass. Dead biomass is better when compared to living biomass, because it is cheaper to obtain as waste, it is not affected by nutritional supply as well as HM toxicity or unfavorable operating conditions. Bio sorption denotes the totality of all passive interactions of metal ions with the cell wall, which include adsorption reactions, surface complexation reactions and ion exchange reactions with the functional groups at the cell surface [125]. In the light of reliance on metabolism, biosorption processes can be divided into metabolism dependent and metabolism independent processes. Depending upon the area where the metal removal takes place, biosorption can be categorized as extracellular accumulation/precipitation, cell surface adsorption/precipitation, and intracellular accumulation. In viable cells, biosorption is dependent on cell metabolism because it is associated with an active defense system of microorganisms, metal is transported across the cell membrane resulting in intracellular accumulation of the metal. Metabolism-independent biosorption using dead biomass occurs due to the physicochemical interaction between the metal and the functional groups (carboxyl, imidazole, sulfhydryl, amino, phosphate, sulfate, thioether, phenol, carbonyl, amide, and hydroxyl moieties) present on the cell surface of the microbial cell. This passive uptake of metal is rapid and reversible and the examples are; physical adsorption, ion exchange, and chemical sorption. Microbial cell walls comprised of polysaccharides, proteins, glucans, chitin, mannans, and phosphomannans, have abundant metal-binding groups such as carboxyl, sulphate, phosphate, and amino groups. These ligands are known to be involved in metal chelation [126,127]. In adsorption, metal ions bind non-specifically to extracellular cell surface associated polysaccharides and proteins [122].

Metal uptake capability by some bacteria has been reported as successful in many studies, Dorian et al. [128], evaluated bio sorption capacity of *Delftia tsuruhatensis* isolated from mine tailings in Mexico. This bacterium showed resistance to 6 mM Pb and 25 mM Zn and maximal absorption for Pb and Zn was observed to be 0.216 mM/g and 0.207 mM/g respectively. Isotherm curves generated from equilibrium batch sorption experiments and effect of process parameters have been extensively researched [125,128,129]. In addition, desorption of adsorbed metals using dilute eluents and cyclic use of regenerated biomass has also been studied [130]. However, research that takes into consideration the physicochemical conditions seen in mine tailings such as cocktail of metals, low nutrient contents of the tailings, salinity and other important factors that dictate the effectiveness of this process for efficient metals removal in mine wastes such as tailings is limited. Also, there are still limitations on most studies carried out on biosorption because information on absorbent characterizations which is an important prerequisite for repeatability of the results is still missing. Surface characterization of the bio sorbent in terms of surface area, surface morphology, functional group and particle size has now recently been included [131,132]. Also, there is a need for more research on characterizations as well as final disposal of the bio sorbent used in order to develop a reliable biosorption process

4.2.3. Biotransformation

Bacteria are able to interact with HM and alter the metal structure through mechanical and biochemical mechanisms which affect the speciation and mobility of the metal [133]. Chemical transformations of HM are brought about through many processes such as oxidation, reduction, methylation, and demethylation which are sometimes by-products of normal metabolism of the bacteria [134]. Biological transformation of metals is a significant detoxification mechanism that is carried out by different bacterial species. The biological action of bacteria on HM result in changes in valency and/or conversion of HM into organometallic compounds that are volatile or less toxic [9]. In an oxidation-reduction reaction, bacteria mobilize or immobilize metal ions, metalloid and organometallic compounds, thus promoting redox processes. Heavy metal reduction by bacteria leads to HM solubility which enhances efficient mobilization of the metal. Mobilization reduces the HM to a lower oxidation state which gives rise to metallic elements (load zero) thereby reducing the metal toxicity. For example, the oxidation of arsenite As(III) to arsenate(V) and the reduction of mercury ions to metallic mercury (Hg^{2+} to Hg^{0}) greatly increases the volatility of Hg and may contribute to its transport away from the microorganism's immediate environment. In bio methylation, the transformation of HM such as Hg, As, Cd and Pb leads to their increased mobility and suitability for involvement in processes that lead to the reduction in their toxicities. It is an enzymatic mechanism that involves the transfer of methyl group (CH_3) to metals and metalloids. The resulting methylated compounds formed differ in solubility, volatility and toxicity compared to the original metal [135]. For example, the inorganic forms of Hg are more toxic when compared to methyl and dimethyl mercury and also the inorganic forms of As are more toxic than methylated species (acids and methyl-As dimethyl-As) [136]. Numerous studies have reported the conversion of HM by bacterial cells. Govarthanan et al. [137], reported the conversion of lead nitrate $Pb(NO_3)_2$ to lead sulphide (PbS) and lead silicon oxide ($PbSiO_3$) by *Bacillus* species isolated from mine tailings. In addition to this is the extracellular conversion of Pb ions to PbS by phototrophic *Rhodobacter sphaeroides* reported by Bai and Zhang [138].

4.3. Genetic Determinant of Metal Resistance

Genetic determinants responsible for resistance to HM are found in several bacterial strains. These resistance determinants are mediated by the chromosomal genome, plasmids or transposons and involve many operons like czcD, nccA, pco, cop, mer, ars, etc. [139]. The resistance-encoding genes seem to be plasmid mediated mainly and these findings have led to suggestions that these plasmids are most likely to be spread by horizontal transfer [140].

Zinc resistance is mediated by two efflux mechanisms which are P-type ATPase efflux and resistance nodulation cell division (RND) driven transporter system [141]. Efflux system is the most studied of all mechanisms of metal resistance in bacteria and involves an active system of transport that actively pumps back toxic ions that entered the cell via an ATPase pump or diffusion (a chemiosmotic ion or proton pump). This mechanism is mediated by plasmids and involves the P-type ATPase which catalyzes the reactions of ATP hydrolysis forming a phosphorylated intermediate [142]. Metal is transported from the cytoplasm to the periplasmic space by the energy released from ATP hydrolysis. This mechanism is one of the pathways responsible for metal resistance in Gram-negative bacteria. Xiong et al. [143], isolated a novel and multiple metalloid resistant strain, *Comamonas testosteroni* S44 having up to 10 mM resistance to zinc. Whole genome sequencing of this bacterium, revealed 9 putative Zn^{2+} transporters (4 znt operons encoding putative 4 znt operons which encode Zn^{2+} translocating P-type ATPases and 5 czc operons encoding putative RND family protein). The RND is a family of proteins that are involved in HM transport. It pumps metal from the cytoplasm directly to the extracellular space and is powered by the proton gradient across the cell wall in Gram-negative bacteria [104,141].

Cupriavidus metallidurans strain CH34 that was isolated from various HM laden environments is a good example of a bacterium to describe plasmid-borne determinants. This type strain possesses two large plasmids pMOL28 and pMOL30 that contain the different types of HM resistant genes. Plasmid-borne czc confers resistance to Cd, Zn, Co, ncc to Ni, Co and Cd and cnr to Co and Ni cation efflux metal resistance operons [144]. The czc locus is located on pMOL30 which is approximately 250 kb in size while the ncc and cnr were reported to be located on pMOL28 (180 kb) [145]. The *cnr*YXHCBA operon of *R. eutropha* CH34 plasmid is the most well studied of the determinants that facilitate medium levels of (up to 10 mM) of Ni and Co resistance [144]. The mechanism of resistance mediated by cnr is inducible which as a result of an energy-dependent efflux system driven by a chemo-osmotic proton-antiporter system [146]. Another Pb resistance operon found in *Cupriavidus metallidurans* strain CH34 is the pbr, which functions in uptake, efflux and accumulation of Pb(II). These resistance loci are made of five structural resistance genes which are: (i) pbrT, which coding for Pb(II) uptake protein; (ii) pbrA, coding for a P-type Pb(II) efflux ATPase; (iii) pbrB, coding for a predicted integral membrane protein whose function is unknown; (iv) pbrC, codes for a predicted prolipoprotein signal peptidase; and (v) pbrD gene, that codes for a Pb(II)-binding protein, was identified in a region of DNA, which was essential for functional Pb sequestration [147].

The pco and cop operon comprises of four structural genes ABCD and an additional one pcoE with two regulatory trans-acting genes pcoRS and copRS [148]. The arsenic resistance system also comprises of three genes Ars ABC. Arsenite is transported by the arsenic resistance efflux using either a two-component (ArsA and ArsB) ATPase or a single polypeptide (ArsB) which functions as a chemiosmotic transporter. The *arsC*, encodes an enzyme that converts intracellular arsenate [As(V)] to arsenite [As(III)], the substrate of the efflux system [149].

The mer operon on the other hand allows bacteria to detoxify Hg^{2+} into volatile metallic mercury through enzymatic reduction. This operon varies in structure and is made up of genes that encode the functional proteins for regulation (merR) and transport (merC, merE, merF, merG, merT) of Hg^{2+} to the cytoplasm where it is reduced by merA. The merB is also found downstream of merA, a periplasmic scavenging protein (merP) and an additional one or two regulatory proteins (MerR, MerD) [150]. The genetic determinant responsible for multiple HM (As, Pb, Cd, Hg, Ni, Co and Cu) resistance patterns observed in 45 Gram positive and Gram negative bacteria isolated from the rhizosphere of *Alyssum murale* and Ni rich soil was examined by Abou-Shanab et al. [118] using polymerase chain reaction in combination with DNA sequencing. The genes responsible for this resistance (ncc, czcD, mer, and chr) were discovered to be present in these bacteria.

4.4. Alteration of Cell Morphology

Another mechanism that bacteria adopt to withstand HM stress is the alteration of cell morphology. This was observed in phototropic bacteria *Pseudomonas putida* and *Enterobacter* sp. on exposure to metalloid oxyanions [151] in the presence of noxious organic compounds [152]. It was also reported that high temperature brought about morphological changes in *E. coli* [153] and *Pseudomonas pseudoalcaligenes* [154]. Exposure of bacteria to unfavorable environmental conditions encountered in polluted sites such as mine tailings with toxic HM/metalloids, highly acidic or alkaline pH and the high and low temperature observed typically induced a stress response which gives rise to characteristic changes in cell shape and arrangement. These responses assist in protection of vital processes, restoration of cellular homeostasis and increase in cellular resistance against subsequent stress challenges [155]. Chakravarty et al. [156], reported the effect of four HM (Cd, Cu, Ni and Zn) on acidophilic heterotrophic *Acidocella* strain GS19h that was isolated from a copper mine. This bacterium by passes the noxious effect of the HM by reducing its surface area in relation to volume ratio. This change was due to alteration of cell morphology as a result of the penicillin binding proteins present on the bacterial cell envelope which give shape to the bacteria cell. The divalent metals structurally resemble the calcium cation and it was proposed that the metals bind in place of calcium to the binding sites as a result of their similar ligand specificities.

5. Future Prospects

Considering the extreme conditions that are found in gold mine tailings, future work may look at how the resistant bacteria interact with HM in this environment. To develop an efficient bioremediation approach for gold mine tailings, better understanding of bacterial interactions with metals in this environment is required.

6. Conclusions

Gold mining has played a tremendous role in the growth and sustenance of the economies of many countries with a huge price to pay in the form of generation and release of toxic waste products which have profound impacts on the ecosystem. Although some HM are required for normal functioning of life processes, elevated concentrations of these metals like those found in mining environments today can be toxic to bacteria that are responsible for biogeochemical cycling of nutrients which are therefore beneficial to human health. Bacterial interactions with metals in contaminated environments have important environmental and health implications, these interactions could result in clean-up of metal-contaminated sites. Most studies on bioaccumulation have focused on accumulation of individual HM ions when exposed to test organisms. Only a limited number of studies utilized growing bacterial cells with multiple mechanisms of metal sequestration and thus may hold greater metal uptake capacities. Nevertheless, such challenges can be overcome by strain selection and supply of nutrients to support the bacteria growth. The screening and selection of metal resistant strains peculiar to contaminated environments is paramount to overcome the limitation of utilizing living cell systems. Resistant cells are anticipated to bind substantial amounts of metals which will greatly enhanced bio precipitation/intracellular accumulation and development of an efficient bioremediation process. Understanding the various ways bacteria interact with these metals can elucidate on the ability of the bacteria to remove noxious ions from the environment.

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Stibnite Gold Project

Fisheries and Aquatic Habitat (Including Threatened, Endangered, Proposed, and Sensitive Species) Report

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Payette National Forest

for:
Payette and Boise National Forests

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List of Acronyms

°C	degrees Celsius
µg/L	micrograms per liter
%	percent
ASAOC	Administrative Settlement Agreement and Order on Consent
BA	Biological Assessment
BF	bankfull
BMP	best management practices
BNF	Boise National Forest
Boise Forest Plan	Boise National Forest Land and Resource Management
CFR	Code of Federal Regulations
cfs	cubic feet per second
CR	County Road
DA	drainage area
dB	decibel
DEM	Digital Elevation Model

DPS	distinct population segment
East Fork SFSR	East Fork South Fork Salmon River
eDNA	environmental DNA
EFH	Essential fish habitat
EFMC	East Fork Meadow Creek
ESA	Endangered Species Act
ESS	Ecosystem Sciences
FA	Functioning Appropriately
FP	Forest Plan
FR	Functioning at Risk
FSH	Forest Service Handbook
ft	foot
FUR	Functioning at Unacceptable Risk
GIS	Geographic Information System
HUC	hydrologic unit code
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
IP	intrinsic potential
ips	inches per second
IRA	inventoried roadless area
LiDAR	Light Detection and Ranging
km	kilometer
kV	kilovolt
m	meter
mg/L	milligrams per liter
MMP	Modified Mine Plan
MPG	major population group
MWMT	maximum weekly maximum temperature
N/A	not applicable
NFS	National Forest System
ng/l	nanograms per liter
NHD	National Hydrography Dataset
NMFS	National Marine Fisheries Service
NP	not present
NPDES	National Pollutant Discharge Elimination System

NTU	Nephelometric Turbidity unit
OM	Occupancy Model
OP	occupancy potential
OSV	over-snow vehicle
RCA	Riparian Conservation Area
Payette Forest Plan	Payette National Forest Land and Resource Management Plan
Perpetua	Perpetua Resources Idaho Inc.
PHABSIM	Physical Habitat Simulation
PIBO	Pacific Anadromous Fish Strategy/Inland Fish Strategy Biological Opinion
PNF	Payette National Forest
PPV	peak particle velocity
RCA	Riparian Conservation Area
ROW	right-of-way
SFSR	South Fork Salmon River
SGLF	Stibnite Gold Logistics Facility
SGP	Stibnite Gold Project
SH	state highway
SODA	spent ore disposal area
SPCC	Spill Prevention, Control, and Countermeasure
SPLNT	Stream and Pit Lake Network Temperature
SWPPP	Stormwater Pollution Prevention Plan
TEPC	Threatened, Endangered, Proposed or Candidate
TSF	tailings storage facility
TSS	total suspended solids
U.S.	United States
USACE	U.S. Army Corps of Engineers
USC	United States Code
USDOT	United States Department of Transportation
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
VBET	valley bottom extraction tool
VBW	valley bottom width
VWR	valley width ratio
WCI	Watershed Condition Indicators
WSC	Westslope cutthroat trout
WUA	weighted usable area
WW	wetted width
YPP	Yellow Pine Pit

1.0 Introduction

The United States (U.S.) Department of Agriculture Forest Service (Forest Service) received the Stibnite Gold Project (SGP) Plan of Restoration and Operations, (Midas Gold Idaho, Inc. 2016) for review and approval in accordance with regulations at 36 Code of Federal Regulations (CFR) 228 Subpart A for the proposed SGP in central Idaho. A revised Plan, also known as ModPRO,[1] was submitted to the Forest Service in 2019 (Brown and Caldwell 2019a). A further modified Plan, also known as ModPRO2,[2] was then submitted in October of 2021 (Perpetua 2021a). Midas Gold changed their name to Perpetua Resources Idaho Inc. (Perpetua[3]) in February 2021. The SGP proposes mine operations on federal, state, and private lands located in Valley County, Idaho.

The SGP would consist of mine operations, including an open pit hard rock mine and associated processing facilities, located within Valley County in central Idaho on federal, state, and private lands (**Figure 1-1**). The SGP would produce gold and silver doré, and antimony concentrate, for commercial sale by Perpetua. The SGP would have a life (construction, operation, closure, and reclamation), not including post-reclamation monitoring, of approximately 20 years, with active mining and ore processing occurring over approximately 15 years.

This specialist report describes the fish resources and fish habitats in the analysis area of the SGP under existing (baseline) physical, chemical, and environmental conditions. While all fish species are of management interest, four special status salmonids (i.e., fish in the family Salmonidae, which includes salmon, trout, and whitefish) are of particular resource management interest because of their status as federally listed fish or fish of management concern to the Forest Service or State of Idaho. Of the four fish species, three are federally listed as threatened species under the Endangered Species Act (ESA): summer Chinook salmon, Snake River Basin steelhead, and Columbia River bull trout. Also, the Payette National Forest Land and Resource Management Plan (Payette Forest Plan) (Forest Service 2003) has designated bull trout as a Management Indicator Species. The Forest Service defines Management Indicators as plant and animal species, communities, or special habitats selected for emphasis in planning, and which are monitored during forest plan implementation in order to assess the effects of management activities on their populations and the populations of other species with similar habitat needs which they may represent (Forest Service Manual 2620.5-1 1991). In addition, the Forest Service (Intermountain Regional Forester) has identified the westslope cutthroat trout as a Forest Service sensitive species.

This report describes the existing (baseline) conditions (Affected Environment) relevant to fisheries and aquatic resources and supporting habitats that have the potential to be affected by the SGP and also evaluates the potential effects (Environmental Consequences) that the SGP could have on these species and their habitat.

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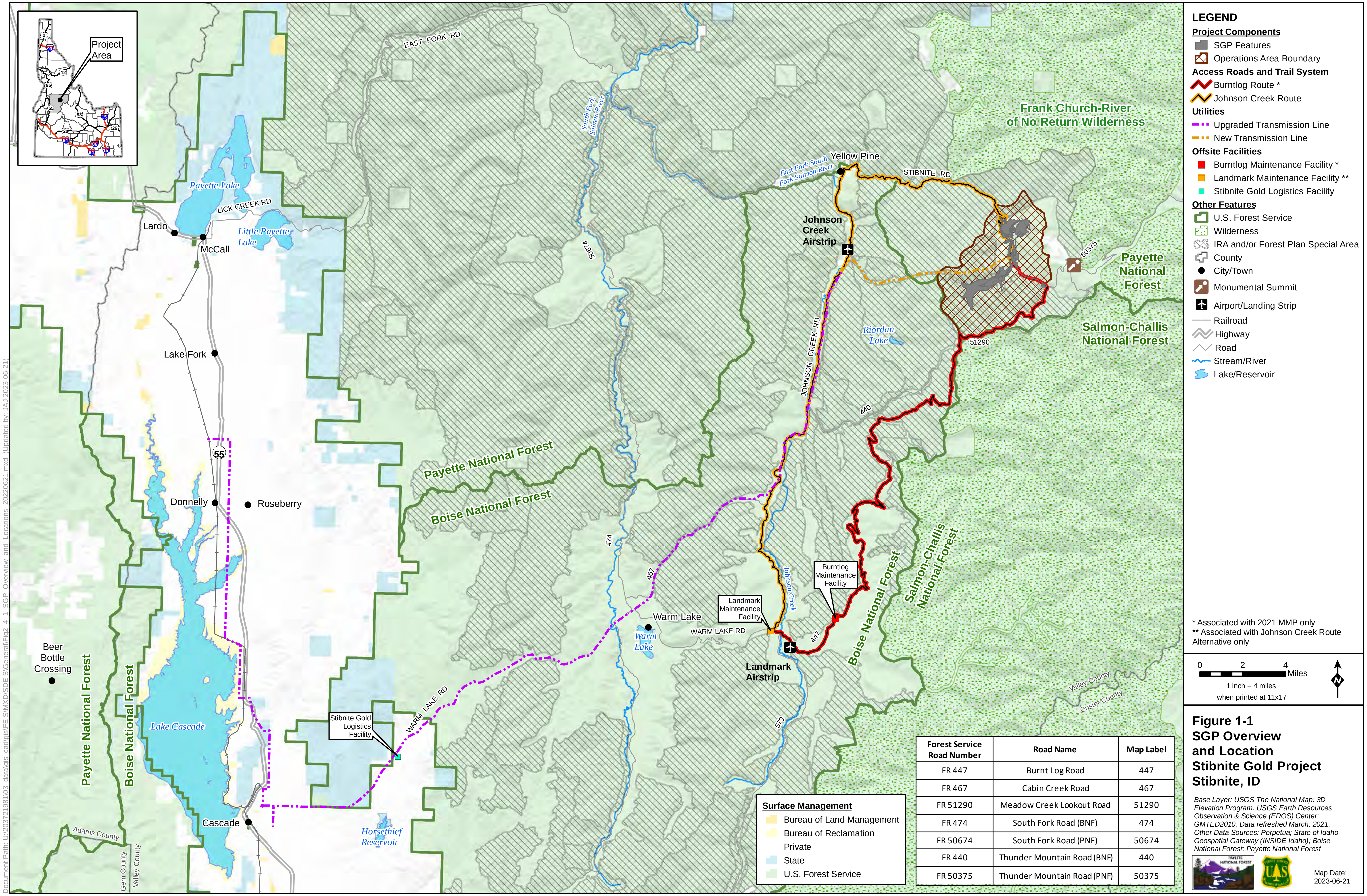
[1] Associated project documents may reference the Revised Plan as the ModPRO.

[2] Associated project documents may reference the Modified Plan as the ModPRO2.

[3] Documents provided by Perpetua prior to the February 2021 name change will still be cited and referenced as Midas Gold.



Forest Service Road Number	Road Name	Map Label
FR 447	Burnt Log Road	447
FR 467	Cabin Creek Road	467
FR 51290	Meadow Creek Lookout Road	51290
FR 474	South Fork Road (BNF)	474
FR 50674	South Fork Road (PNF)	50674
FR 440	Thunder Mountain Road (BNF)	440
FR 50375	Thunder Mountain Road (PNF)	50375

Figure 1-1
SGP Overview and Location
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 2023-06-21

2.0 Alternatives, Including the Proposed Action

The SGP 2021 Modified Mine Plan (MMP) Alternatives Report (Forest Service 2023a) contains the details of the alternatives that are being considered and fully analyzed in this report. For reader usability, the alternatives are briefly summarized here.

2.1 No Action Alternative

Under the No Action Alternative, the 2021 MMP would not be approved and no mining, ore processing, or related activities would occur, including removal of legacy materials (i.e., SODA and Hecla heap leach), restoration of stream channels, and enhanced riparian plantings included in the 2021 MMP. Previously approved activities (i.e., approved exploration activities and associated reclamation obligations) would continue. In a reasonably foreseeable future action, certain legacy and existing mining impacts would be addressed as directed in the 2021 Administrative Settlement Agreement and Order on Consent, including installation of stream diversion ditches designed to avoid contact of water with sources of contamination and removal of approximately 325,000 tons of development rock and tailings that are currently impacting water quality. These CERCLA response actions would occur under all alternatives considered in this analysis. However, other existing legacy disturbances such as the SODA and Hecla heap leach would continue to impact the environment. Under the No Action Alternative, Perpetua would not be precluded from subsequently submitting another plan of operations pursuant to the Mining Law to the Forest Service for subsequent evaluation.

2.2 2021 Modified Mine Plan

The 2021 MMP is based upon Perpetua's Revised Plan (ModPRO2) and is considered the Proposed Action. Mine operations would occur on patented mining claims owned or controlled by Perpetua and on unpatented mining claims and other areas of federal lands comprised of NFS lands that are administered by the PNF. Supporting infrastructure corridors (access and transmission line) are located on the BNF, IDL, Bureau of Reclamation (BOR), and non-federal lands. 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 Operations Area Boundary (**Figure 2-1**). The Operations Area Boundary is defined as the ambient air boundary and encompasses 14,221 acres, of which 13,441 acres are NFS lands and 780 acres are private. The Operations Area Boundary is where hazardous activities would occur, such as explosives handling, blasting, drilling, and heavy equipment operation which require strict safety protocols and controlled access.

The following mine components would be common to the action alternatives:

- Mine pit locations, areal extents, and mining and backfilling methods
- Transportation management on existing and proposed roads
- Pit dewatering, surface water management, and water treatment
- Ore processing
- Lime generation
- Tailings Storage Facility (TSF) construction and operation
- TSF Buttress construction methods
- Water supply needs and uses

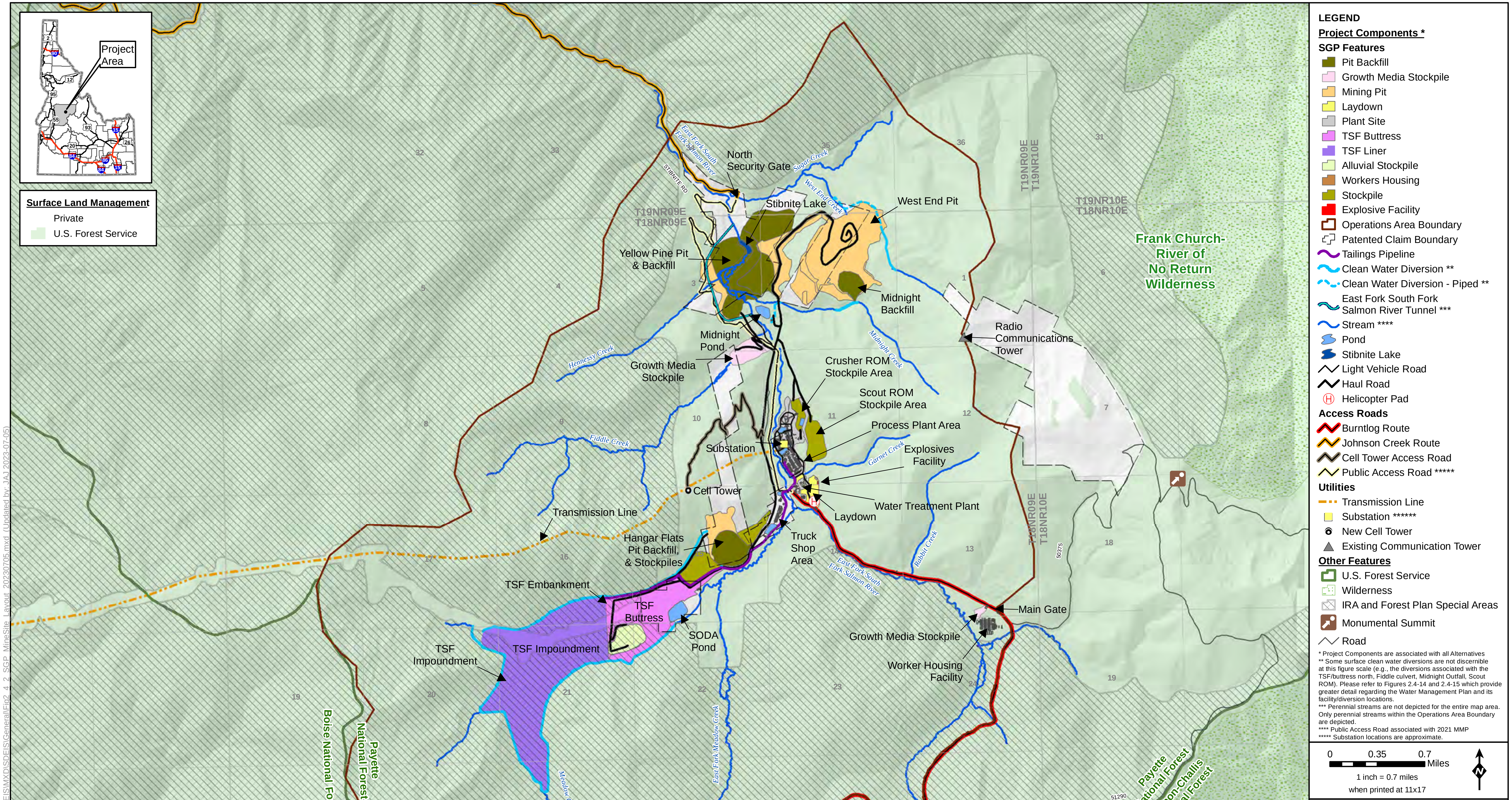


Figure 2-1
Mine Site Layout
Stibnite Gold Project
Stibnite, ID

Base Layer: Hillshade derived from LiDAR supplied by Midas Gold
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 2023-07-05

- Management of mine impacted water and stormwater runoff
- Electrical transmission lines
- Stibnite Gold Logistics Facility (SGLF)
- A road maintenance facility (location different depending on alternative)
- Surface and underground exploration
- Stibnite Gold Project worker housing facility

For access, the 2021 MMP would utilize Warm Lake Road, Johnson Creek Road, and Stibnite Road during construction of the proposed Burntlog Route; then once constructed, the Burntlog Route would be utilized during operations and reclamation. The actions proposed under the 2021 MMP would take place over a period of approximately 20 years, not including the long-term, post-closure environmental monitoring or potential long-term water treatment.

2.3 Johnson Creek Route Alternative

The Johnson Creek Route Alternative was developed to evaluate potential reductions in impacts to various resources. The mining portion of this alternative would be the same as under the 2021 MMP. Therefore, the primary focus of the Johnson Creek Route Alternative would be using an existing road for mine access through operations and reclamation instead of the Burntlog Route that under the 2021 MMP requires new road construction in Idaho Roadless Areas (IRAs). The Johnson Creek Route Alternative would require extensive upgrades to both Johnson Creek Road and Stibnite Road. The construction schedule for upgrading the roads and construction of the SGP would increase from 3 years to 5 years.

The action alternatives are summarized in **Table 2-1**.

Table 2-1 Action Alternatives Summary

SGP Phase	Component/ Subcomponent	2021 MMP	Johnson Creek Route Alternative
All Phases	SGP timeline	• Construction: Approximately3 years. • Operations: Approximately 15 years. • Exploration: Approximately 17 years (during construction and operations). • Reclamation: Approximately 5 years (except for the TSF which would require an additional 9 years for tailings dewatering and consolidation). • Closure/Post-Closure Water Treatment: Approximately through Mine Year 40. • Environmental Monitoring: As long as needed.	Same as 2021 MMP except: • Construction: Approximately 5 years (upgrading the existing Johnson Creek and Stibnite Roads to provide permanent mine access).

SGP Phase	Component/ Subcomponent	2021 MMP	Johnson Creek Route Alternative
All Phases	Access Roads	Construction/Operations: • Warm lake road from State Highway (SH) 55 to Johnson Creek Route intersection (34 miles). • Johnson Creek Route for SGP access during early construction with minor improvements within the road prism. • Burntlog Route (38 miles) for SGP access during last year of construction, mining and ore processing operations, and closure and reclamation. Includes improvements of existing segments (23 miles) and road construction for new segments (15 miles). • Up to eight borrow areas developed along Burntlog Route for materials needed for road improvements and maintenance. • Access route around the Yellow Pine pit for public access. Closure and Reclamation: • New sections of Burntlog Route to be reclaimed after the closure and reclamation period.	Construction/Operations: • Warm lake road from SH 55 to Johnson Creek Route intersection (34 miles). • Johnson Creek Route (39 miles: Johnson Creek Road 25 miles, Stibnite Road 14 miles) upgraded and used for access throughout life of mine (LOM) instead of the Burntlog Route. • Access route around the Yellow Pine pit for public access, employee access, and deliveries of supplies and equipment to the processing, warehouse, worker housing facility, and administration areas. • No improvements or construction of new segments for Burntlog Route. • Up to seven borrow sources developed along the Johnson Creek Route for materials needed for road improvements and maintenance. Closure and Reclamation: • Improved Johnson Creek and Stibnite roads would not be reclaimed to pre-existing conditions.

SGP Phase	Component/ Subcomponent	2021 MMP	Johnson Creek Route Alternative
All Phases	Public Access	Construction: • Temporary groomed over-snow vehicle (OSV) trail on the west side of Johnson Creek from Trout Creek to Landmark while Burntlog Route is constructed (8 miles). • OSV trail on Johnson Creek Road from Wapiti Meadows to Trout Creek campground closed during construction (9 miles). • OSV trail from Warm Lake to Landmark closed during construction through reclamation and closure (8.5 miles). • Cabin Creek Road Groomed OSV trail (11 miles). • Public roads remain open through the Operations Area Boundary with temporary closures as needed to accommodate construction. Operations: • Groomed OSV trail moves from west side of Johnson Creek Road to Johnson Creek Road from Landmark to Wapiti Meadows (16.7 miles). • Stibnite Road (County Road [CR] 50-412) / Thunder Mountain Road (FR 50375) closed through the Operations Area Boundary. • Seasonal public access through the Operations Area Boundary provided by constructing new road through Yellow Pine pit and below mine haul road to link Stibnite Road (FR 50412) to Thunder Mountain Road (FR 50375). • Public access allowed on Burntlog Route to Thunder Mountain Road (FR 50375). • Closure and Reclamation: • New road constructed over the Yellow Pine Backfill (backfilled Yellow Pine pit) connecting Stibnite Road (FR 50412) to Thunder Mountain Road (FR 50375).	Construction and Operations: Same as 2021 MMP except: • OSV trail on the west side of Johnson Creek from Wapiti Meadows to Trout Creek campground would be closed from construction through mine closure (9 miles). • Groomed OSV trail on the west side of Johnson Creek from Trout Creek to Landmark lasting from construction through mine closure. Closure and Reclamation: Same as 2021 MMP.

SGP Phase	Component/ Subcomponent	2021 MMP	Johnson Creek Route Alternative
Operations	Utilities – Transmission Lines	• Upgrade approximately 63 miles of the existing 12.5 kilovolt (kV) and 69 kV transmission lines. • New approximate 9-mile, 138 kV line would be constructed from the Johnson Creek substation to a new substation at the mine site. • Upgrade the substations located at Oxbow Dam, Horse Flat, McCall, Lake Fork, and Warm Lake. • Reroute approximately 5.4 miles of transmission line to avoid the Thunder Mountain Estates subdivision. • Reroute approximately 0.9 miles of transmission line between Cascade and Donnelly to use an old railroad grade on private property. • Installation of approximately 3 miles of new underground distribution line along Johnson Creek Road from the Johnson Creek substation south to Wapiti Meadows.	Same as 2021 MMP.
Operations	Utilities - Communication Towers and Repeater Sites	• One cell tower located north of the Hangar Flats pit. • Locations along Burntlog Route for very high frequency (VHF) repeater sites. • Use existing access roads to repeater site locations along Burntlog Route. • Communication site at the SGLF. • Upgrades to existing communication site.	Same as 2021 MMP except: • Cell tower sites constructed and maintained using helicopter (instead of constructing access roads) for sites within IRAs managed for Backcountry/Restoration. • Locations along Johnson Creek route for repeater sites.
Operations	Off-site Maintenance Facility	• SGLF located along Warm Lake Road. • Burntlog Maintenance Facility located at one of the borrow source locations 4.4 miles east of the junction of Johnson Creek Road and Warm Lake Road along the proposed Burntlog Route.	• SGLF same as 2021 MMP • Landmark Maintenance Facility located at junction of Warm Lake Road at Johnson Creek Road.
Closure and Reclamation	Access road segments	• Removal and reclamation of new road segments constructed for Burntlog Route. • Return of previously existing road segments to pre-construction width and condition.	• No removal or reclamation of pre-existing access routes.

2.4 Environmental Design Features

The SGP must comply with all laws and regulations that apply to the proposed activities with prominent requirements relative to the impact analysis (Forest Service 2023a). Standards and guidelines in the Payette and Boise National Forest Land and Resource Management Plans (Forest Service 2003, 2010a) that are designed to reduce or prevent undesirable impacts resulting from proposed management activities are incorporated into the action alternatives by reference. In addition, best management practices outlined in the Best Management Practices for Mining in Idaho (Idaho Department of Lands (IDL) 1992) would be implemented where appropriate and applicable for operations to minimize site disturbance from mining and drilling activities.

In the design of the 2021 MMP, Perpetua has already considered many of the potential environmental impacts that might be caused by the SGP. This has led to an internal evaluation of project design features and operational characteristics that may have the effect of reducing and/or eliminating potential environmental impacts of the SGP. Such project-specific measures intended by a proponent to inherently reduce and/or avoid potential environmental impacts of a proposed action are referred to as environmental "design features."

Based on the application of permits and regulatory compliance requirements (Forest Service 2023a) to the project, regulatory requirements, standards and guidelines, best management practices, and likely permit conditions are listed in **Table 2-2**. The environmental design features that have been proposed and committed to by the proponent are listed in **Table 2-3**. All of these environmental design measures have been assumed to be effective in conducting the environmental analysis presented in **Section 7.0**.

Table 2-2 Prominent Regulatory and Forest Service Requirements for Fisheries and Aquatic Habitat

Description	Type	Reference
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
When taking water from TEPC 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 NMFS and/or USFWS.	FP Component	BNF and PNF: FRST01, TEST32
Employees and staff will receive training and direction to avoid spawning adult Chinook salmon, bull trout and steelhead.	Design Feature	
Surface water withdrawal intake hoses will be situated so as to prevent generation of turbidity in bottom sediments during pumping.	Design Feature	
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 IDEQ, Forest Service, USFWS, and NMFS 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 SPCC plan), and initiate emergency consultation.	Regulatory Requirement	50 CFR 402.05

Description	Type	Reference
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 percent, the selected locations would be reviewed fand approved by Forest Service specialists.	FP Component	BNF and PNF: SWGU03 Refer to the Implementation Guide for Management on Landslide and Landslide Prone Areas, located in Appendix B (Forest Service 2003, 2010a).
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: a) Analyze waste material using the best conventional methods and analytic techniques to determine its chemical and physical stability characteristics. b) 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 would result in exceedance of established water quality standards or would degrade surface resources, prohibit such facilities in RCAs. c) 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. d) 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. e) 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

Description	Type	Reference
An SPCC plan 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 would 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 would be inspected at each refueling and periodically between refueling for leakage or spillage. • Pilot and emergency spill response vehicles would carry appropriate containment and first aid equipment. • All fuel containers would be marked with contents, owner's name and contact information. • Material Safety and Data Sheets for all products would be posted and available on site with the SPCC plan. • Intake pumps would not be situated within the active stream/ditch channel and would 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 would be used. • Following large storm events, the intake pumps would 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 would be placed at the intake pump site and would consist of absorbent pads and/or boom (which would be sufficient length for a worst-case discharge), drip pan, a shovel, and a fire extinguisher. • Spare fuel for the water intake pump would 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 would 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 National Forest System lands. This includes, but is not limited to, empty fuel and lubricant containers. Food and garbage would be stored either indoors, in vehicles, or if outside, in wildlife-proof containers. No garbage would be burned.	FP Component and Design Features	Design Feature developed for compliance with BNF and PNF: MIGU04

Description	Type	Reference
Fuel will be stored in sealed 55-gallon steel drums, approved double-walled fuel tanks, or in approved single-walled tanks within secondary containment. Fuel will be managed, tanks would be inspected, and any oil release would be responded to in accordance with the SPCC plan.	FP Component	BNF and PNF: SWGU11 49 CFR 171
Should any oil or chemical discharges or spills occur, the release would be reported to IDEQ, and other appropriate agencies as required by applicable federal and state regulations 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.	Design Feature	
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
Annual spill awareness/response training will be required for on-site personnel and suppliers/providers.	Design Feature	
Fuel containment sites, engines and other equipment with fuel or lubricants will be periodically checked for leakage or spillage and in accordance with the SPCC plan.	Design Feature	
A copy of the SPCC plan will be kept at an appropriate onsite facility. 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. Appropriate warning signs will be placed around fuel storage facilities.	Design Feature	
Measures such as, but not limited to, segregating and stockpiling topsoil, implementing stormwater and sediment BMPs, backfilling, revegetation and concurrent reclamation would 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.	Design Feature	Design Feature developed for compliance with BNF and PNF: SWST03, SWGU05
Handling of road waste material (e.g., slough, rocks) will avoid or minimize delivery of waste material to streams that would result in degradation of soil, water, riparian and aquatic resources.	FP Component	Design Feature developed for compliance with BNF and PNF: FRST05
To minimize the degradation of watershed resource conditions, prior to expected water runoff, water management features would 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.	Design Feature	Design Feature developed for compliance with BNF and PNF: SWST01 and SWST04

Description	Type	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.	FP Component	BNF and PNF: FRST02
To minimize sediment runoff from the temporary roads and roadbeds, water management features would 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 would 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 would be installed in strategic downslope areas and in RCAs, where and when appropriate.	Design Feature	Design Feature developed for compliance with BNF and PNF: SWGU06
Snow removal will be accomplished in accordance with the following standards of performance: • All debris, except snow and ice, which 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	

Description	Type	Reference
Road rutting from operations, outside the mine site, would 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 for compliance with BNF and PNF: SWST02 SWST03
Perpetua would 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 unless there are no other alternatives. 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
New facilities for storage of fuels and other toxicants would be located outside of occupied TEPC plant habitat.	FP Component	BNF and PNF: TEST11
Dust abatement chemicals would 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 would be available during chemical dust abatement application. Where the road surface is within 25 feet (slope distance) of surface water, dust abatement would only be applied to a 10-foot swath down the centerline of the road. The rate and quantity of application would be regulated to insure all of the chemical is absorbed before leaving the road surface.	Design Feature	
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
Perpetua would monitor stormwater runoff and stormwater BMPs as per the SWPPP. Stormwater monitoring, inspections, and reporting would be conducted in accordance with the NPDES Multi-Sector General Permit and the SWPPP.	Permitting Requirement	NPDES Multi-Sector General Permit and the SWPPP
Pumps will be turned off when not in use and water conservation practices will be implemented.	Design Feature	Design Feature developed for compliance with BNF and PNF: WIST03, WIST04 TEST29
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	

BMP = Best Management Practice; FP = Forest Plan; IDAPA = Idaho Administrative Procedures Act; IDEQ = Idaho Department of Environmental Quality; NDPES = National Pollutant Discharge Elimination System; NMFS = National Marine Fisheries Service; RCA = Riparian Conservation Area; SPCC = Spill Prevention, Control and Countermeasure; SWPPP = Stormwater Pollution Prevention Plan; TEPC = Threatened, Endangered, Proposed or Candidate; USFWS = U.S. Fish and Wildlife Service

Table 2-3 Proponent Proposed Environmental Design Features for Fisheries and Aquatic Habitat

Description
Proper dust control would be employed along transportation corridors and active mining areas using aquatic safe dust suppression chemicals and methods.
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 to isolate the lake from upstream movement into the lake and salvage and release fish. The Fish Salvage and Release Plan would be refined in coordination with federal, state, and tribal agencies. Perpetua would, in consultation with the USFWS and the NMFS, 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 would be designed to minimize the number of fish in the YPP lake, particularly larger bull trout . Fish captured in the YPP lake would be immediately released downstream from the upstream fish movement barrier or in another location determined by the appropriate regulatory agencies. The YPP lake would be partially drained to recover the remaining fish and relocate them prior to final draining of the pit lake.
A fishway has been designed and would be operated within the East Fork South Fork Salmon River (East Fork SFSR) diversion tunnel to provide upstream and downstream connectivity fish passage throughout mine operations. The East Fork SFSR diversion tunnel would be approximately 0.9 miles long and 15 feet high by 15 feet wide. The diversion tunnel would include a parallel accessway to allow equipment and personnel access for monitoring, inspection, and maintenance. The accessway would 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.
As an alternative to the fishway in the East Fork SFSR diversion tunnel Perpetua would 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 would be switched to trap and haul operations.
Low-energy lighting would be provided in the fishway to determine if it aids in fish passage and to provide light for diversion tunnel and fishway inspections. The system would 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.
Fish salvage and relocation operations would be conducted any time the facility needs repair within the fishway, potentially during sediment removal, and potentially when stream flows recede from the accessway.
Post mining, the East Fork SFSR stream channel would be reestablished across the backfilled YPP with a channel design that would provide for upstream and downstream fish passage.
Perpetua would reestablish fish passage through the existing box culvert on the East Fork SFSR just downstream from the confluence with Meadow Creek at the McCall-Stibnite Road (County Road [CR] CR 50-412) crossing.
Perpetua would improve fish passage along the Burntlog Route within the 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.
Perpetua would 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.
Perpetua would employ blasting setback distances and other controlled blasting techniques following industry best management practices (modifying blasting variables including charge size, and vibration and overpressure monitoring) to minimize impacts to fish from blasting. Perpetua would 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.
Dewatering would generally be conducted during low-flow periods to facilitate stream segment isolation and fish salvage. When practicable, dewatering also would be timed to avoid or minimize impacts during known spawning periods for Chinook salmon, steelhead, and bull trout.

Description
To protect fish, Perpetua would 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.
The fishway operations and management plan (FOMP) defines the monitoring and evaluation plan elements and describes how the hydraulic conditions, fish use, and performance of the diversion tunnel fishway would be measured and evaluated, and the design of the adaptive management component of the plan including the option of using trap and haul.
Access and mine site haul road crossings of fish bearing streams would be designed such that structures installed or constructed allow fish passage.
Perpetua would 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 infiltrating groundwater that is extracted for pit dewatering into infiltration basins. Maintain instream flows for fish species and other aquatic resources: flows within natural stream channels affected by SGP operations would be maintained to meet seasonally appropriate and stream-specific low-flow needs to the maximum extent practicable. Perpetua would 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.
Following permanent cessation of mining activities at the YPP, Perpetua would backfill the pit and route the East Fork SFSR 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 would include side-channels and other off-channel features and would be revegetated to restore wetland and riparian habitat providing long-term shade/cover favorable to fish.
The Meadow Creek channel would be routed over the final tailings storage facility (TSF) and the TSF Buttress, resulting in a long, relatively flat surface and a short, steep face. On top of the TSF/TSF Buttress surface, Meadow Creek would be contained within a broad floodplain corridor bound laterally by erosion-resistant terraces and vertically by a subsurface armor layer over an impermeable stream liner.
Perpetua would stabilize and restore East Fork Meadow Creek. East Fork Meadow Creek wetland restoration would consist of restoring and enhancing palustrine aquatic bed , palustrine emergent , palustrine scrub-scrub wetlands that were impacted when a historical dam failed on East Fork Meadow Creek. 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 East Fork Meadow Creek as well as recharge the shallow groundwater system and reduce stream headcutting. A coarse rock drain would be constructed within the chute downstream from the failed dam to isolate the flow of East Fork Meadow Creek 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 would 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.
Perpetua would lead annual site visits for U.S. Army Corps of Engineers (USACE), 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 would be subject to permit conditions; however, at a minimum, it is anticipated that monitoring reports would be prepared by Perpetua annually and submitted to USACE Walla Walla District, EPA, IDFG, Idaho Department of Lands (IDL), NMFS, USFWS, the Forest Service, and other interested agencies, SGP partners, and stakeholders.
Perpetua would repair and rehabilitate habitats adversely affected by historical mining impacts in the SGP area.
Minor surface improvements (e.g., ditch and culvert repair, adding gravel, winter snow removal, and summer dust suppression) would occur on the Johnson Creek Route to reduce sediment runoff and dust generation.
Personnel transporting, handling, or using any hazardous chemicals (including sodium cyanide) would be trained to ensure the safe use of such materials. Perpetua would design, construct, and manage facilities to conform to International Cyanide Management Institute code.

Description
Fuel and other petroleum products at the site would be stored in above ground containment structures, with appropriate secondary containment measures.
Perpetua would 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.
Crushed rock would be placed on SGP access roads as needed to provide a durable surface and limit sediment transport.
Road surfaces throughout the SGP would 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.
Runoff generated from direct precipitation on the TSF would be retained in the TSF water pool for reclaim to the ore processing circuit.
During the Burntlog Route and mine site haul road construction and use, Perpetua would 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.
Placing sub-base material and surfacing with gravel and localized sections of road with binders to provide a stable long-term roadway and reduce sediment runoff
During winter road maintenance, Perpetua would remove snow from the Burntlog Route and haul roads at the mine site and the temporary construction access Johnson Creek Route. Perpetua would avoid disposal of snow in riparian areas, wetlands, or areas where snowmelt might cause road damage or erosion during spring melt. Care would 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.
Perpetua would use coarse sand for winter sanding of the main access road and mine site haul roads in combination with gravel as needed.

In addition to the design features listed in **Table 2-3**, Perpetua has proposed additional environmental measures for the SGP as described in the following documents:

- Fisheries and Aquatic Resources Mitigation Plan (Brown and Caldwell, Rio Applied Science and Engineering, and BioAnalysts, Inc. 2021);
- Fishway Operations and Management Plan (Brown and Caldwell, McMillen Jacobs Associates, and BioAnalysts 2021a); and
- Compensatory Stream and Wetland Mitigation Plan (Tetra Tech 2023).

3.0 Relevant Laws, Regulations, and Policy

The following section provides descriptions of the relevant laws, regulations and policies that may affect fisheries and aquatic resources.

3.1 Land and Resource Management Plan

Physical, social, and biological resources on National Forest System (NFS) lands are managed to achieve a desired condition that supports a broad range of biodiversity and social and economic opportunity. National Forest Land and Resource Management Plans embody the provisions of the National Forest Management Act and guide natural resource management activities on NFS land. In the SGP area, the Payette National Forest Land and Resource Management Plan (Payette Forest Plan; Forest Service 2003), and the Boise National Forest Land and Resource Management Plan (Boise Forest Plan; Forest Service 2010a) provide management prescriptions designed to realize goals for achieving desired conditions for wildlife and wildlife habitat and include various objectives, guidelines, and standards for this purpose.

Portions of the BNF are administratively managed by the PNF due to location. Forest Service regulations and the Forest Plans (Forest Service 2003, 2010a) provide guidance on resource management on NFS lands. The SGP is located in PNF Management Area 13 (Big Creek/Stibnite) and in BNF Management Areas 17 (North Fork Payette River), 19 (Warm Lake), 20 (Upper Johnson Creek), and 21 (Lower Johnson Creek), which are described in the respective Forest Plans. In addition, Appendix B of both the Payette and Boise Forest Plans provides National Environmental Policy Act guidance with respect to evaluating the ecological functionality of aquatic resources in the analysis area using Watershed Condition Indicators (WCI) under existing baseline conditions because they may be affected by the SGP.

3.2 Federal Laws, Regulations, and Policy

3.2.1 U.S. Army Corps of Engineers 404 Permit

Under Section 404 of the Clean Water Act (33 United States Code [USC] 1344), a Department of the Army, U.S. Army Corps of Engineers (USACE) permit is required for the discharge of dredged and/or fill material into “waters of the United States”. This would include discharges of dredge and/or fill material associated with activities, such as the construction of road crossings, water diversions, waste rock disposal in a stream, and other facilities associated with the SGP’s construction, operation, and closure and reclamation. See the SGP Wetlands and Riparian Resources Specialist Report (Forest Service 2023b) for additional detail regarding the Clean Water Act.

3.2.2 Endangered Species Act Section 7 Consultation

The ESA (16 USC 35 1531 et seq. 1988) provides for the protection and conservation of threatened and endangered species and their Critical Habitats.

Section 7 of the ESA (16 USC 1531 et seq.) requires all federal agencies to consult with the USFWS and/or the NMFS, collectively known as “the Services”, which share regulatory authority for implementing the ESA. Federal agencies must submit a consultation package for proposed actions that may affect ESA-listed species, species proposed for listing, or designated Critical Habitat for such species. The USFWS generally manages ESA-listed terrestrial and freshwater plant and animal species, while NMFS is responsible for marine species, including anadromous fish.

“Critical habitat” is defined by the ESA as specific areas within the geographical area occupied by listed species at the time of listing that contains the physical or biological features essential to conservation of the species and that may require special management considerations or protection (50 CFR 424). Critical habitat also may include specific areas outside the geographical area occupied by the species if the agency determines that the outside area itself is essential for conservation of the species.

The first step in the consultation process is an "informal" consultation with one or both of the Services to initially determine if the proposed action is likely to affect any listed species, species proposed for listing, or designated Critical Habitat in the analysis area. The federal agency taking the action or the "action agency" (i.e., the Forest Service and the USACE in the case of the SGP) may prepare a Biological Assessment (BA) (or designate a non-federal representative to prepare the BA acceptable to the agency under federal regulation) to aid in determining a project's effects on listed or proposed species or designated Critical Habitat. If the action agency determines that the action is likely to adversely affect ESA-listed or proposed species or designated Critical Habitat, then the action agency enters into "formal" consultation (or "conference" for species proposed for listing). The USFWS and/or NMFS then prepare(s) a Biological Opinion and determines whether the action is likely to jeopardize the continued existence of the species or adversely modify designated Critical Habitat. If there is any anticipated "incidental take" (see 50 CFR 402.02 [defining "take"]) of a species, one or both of the Services must issue an Incidental Take Statement that includes terms and conditions and reasonable and prudent measures that must be followed to eliminate or minimize impacts to the species or its designated Critical Habitat.

3.2.3 Sustainable Fisheries Act (Essential Fish Habitat)

In response to growing concern about the status of fisheries in the U.S., Congress passed the Sustainable Fisheries Act of 1996 (Public Law 104 297) to amend the Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265), the primary law governing marine fisheries management in the federal waters of the U.S. NMFS is responsible for protecting habitats important to federally managed marine species, which include anadromous Pacific salmon that occur in the SGP analysis area. Federal agencies must consult with NMFS concerning any action that may adversely affect "Essential Fish Habitat" (EFH) pursuant to the amended Magnuson-Stevens Fishery Conservation and Management Act and its regulations (50 CFR 600). The Act defines EFH as habitats necessary to a species for spawning, breeding, feeding, or growth to maturity, which includes marine and riverine migratory corridors, spawning grounds, and rearing areas of Pacific salmon species. Given the SGP's geographic location, Chinook salmon (Oncorhynchus tshawytscha) is the only species that has designated EFH within the SGP analysis area. As defined by the regulations, EFH includes "all streams, estuaries, marine waters, and other waterbodies occupied or historically accessible to Chinook salmon in Washington, Oregon, Idaho, and California" (50 CFR 660.412(a)). EFH is coincident with designated critical habit for Chinook salmon within the analysis area.

3.2.4 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act generally requires that federal agencies consult with the USFWS, the NMFS, and State wildlife agencies for activities that control or modify waters of any stream or bodies of water, in order to minimize the adverse impacts of such actions on fish and wildlife resources and habitat. This consultation is generally incorporated into the process of complying with National Environmental Policy Act, Section 404 of the Clean Water Act, or other federal permit, license, or review requirements. The Fish and Wildlife Coordination Act provides that wildlife conservation shall receive equal consideration and be coordinated with other features of a project.

The term "wildlife resources" is explicitly defined to include "birds, fishes, mammals, and all other classes of wild animals and types of aquatic and land vegetation upon which wildlife is dependent" (16 USC 666 (b)). Further, the Fish and Wildlife Coordination Act states that reports determining the possible damage to wildlife resources and an estimation of wildlife loss shall be made an integral part of any report prepared or submitted by the action agency with permitting authority (16 USC 662 (b), (f)).

3.3 State and Local Policy

3.3.1 Idaho Department of Water Resources – Stream Channel Protection Program

The Idaho Stream Channel Protection Act (Idaho Code Title 42, Chapter 38) requires that the stream channels of the state and their environments be protected against alteration for the protection of fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, and water quality. The Idaho Stream Channel Protection Act applies to any type of alteration work done inside the ordinary high-water mark of a continuously flowing stream and requires a stream channel alteration permit from Idaho Department of Water Resources (IDWR) before commencing any work that would alter the stream channel. This means that the IDWR must approve, in advance, any work that is conducted within the beds and banks of continuously flowing streams (i.e., perennial streams). Stream channel alteration permitting requires a joint-permit application process with IDWR, the IDL, and the USACE.

3.3.2 Idaho Department of Fish and Game – Scientific Collection Permit and Fish Transport Permit

The IDFG requires a Scientific Collection Permit for any handling of fish that is not related to sportfishing with a state fishing license. The salvage and transport of fish by vehicle between capture and release sites for the proposed SGP is expected to require a fish transport permit.

4.0 Issues and Resource Indicators

4.1 Significant Issues

Construction and operation of mine infrastructure may impact the quality and quantity of water, and habitat for steelhead, salmon, and bull trout. Project activities may also affect fish behavior and reproductive success and may result in injury or mortality of steelhead, salmon, and bull trout in the analysis area.

4.2 Resource Issues and Indicators

The analysis of effects on fish resources and fish habitat includes the following identified issues and indicators:

Issue: The SGP may cause changes in fish habitat in the analysis area that may affect aquatic species, including federally listed fish species and aquatic habitat (e.g., designated Critical Habitat) and Management Indicator Species within and downstream from the SGP area.

Indicators:

- Changes in water chemistry.
- Change in stream flow.
- Change in length of stream and lake habitat directly impacted by channel removal.
- Changes in water temperature (degrees Celsius [°C]).
- Change in amount of total useable Chinook salmon Intrinsic Potential (IP) habitat.
- Loss of Chinook salmon Critical Habitat.

- Change in total useable steelhead IP habitat.
- Change in length of bull trout habitat.
- Change in bull trout occupancy probability.
- Change in access to bull trout lake habitat.
- Loss of bull trout Critical Habitat.
- Change in length of westslope cutthroat trout habitat (km)
- Change in westslope cutthroat trout occupancy probability
- Changes in stream peak and baseflow (cubic feet per second [cfs]).

5.0 Methodology

5.1 Analysis Area

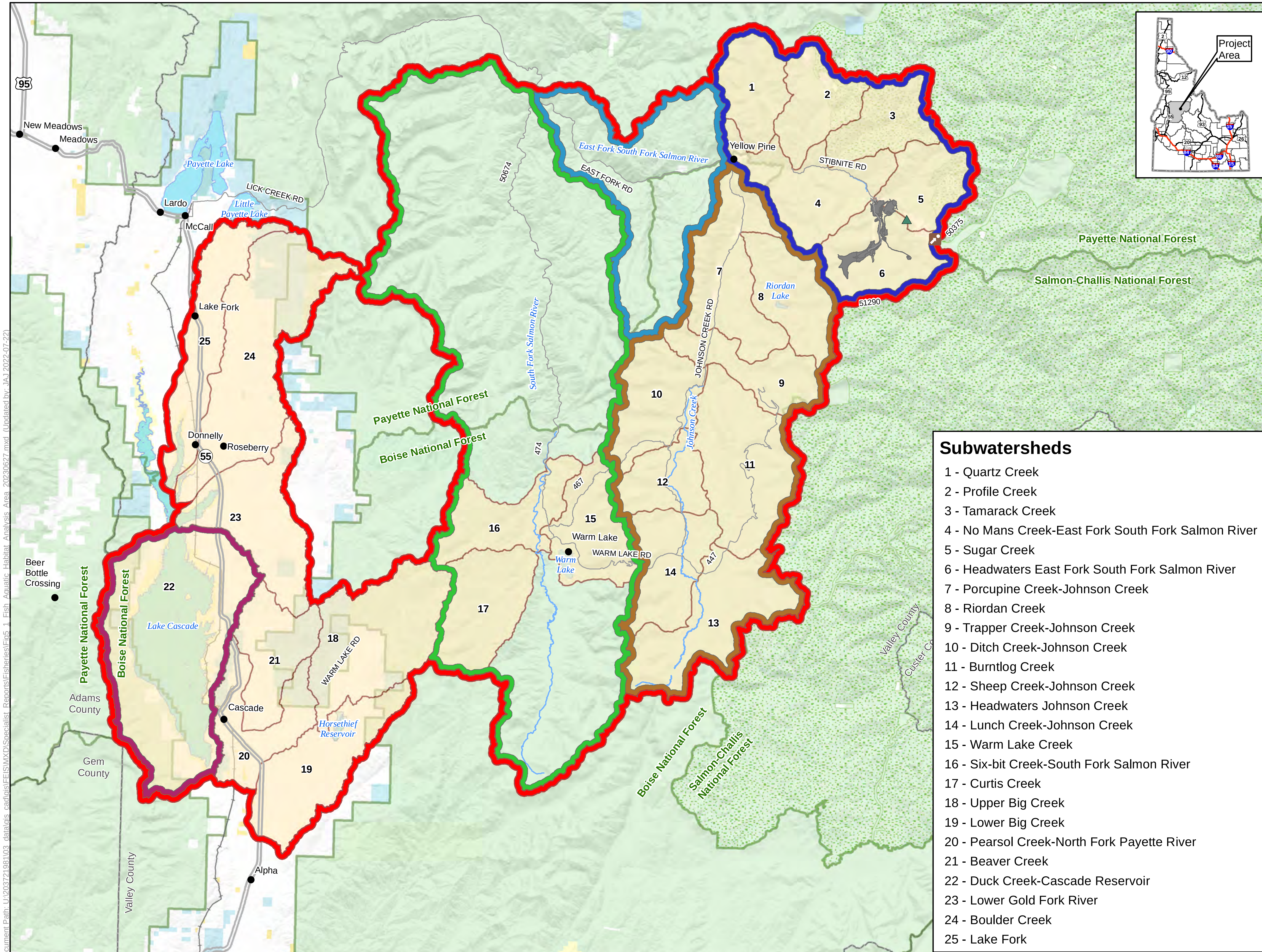
The analysis area for fish and fish habitat includes the area where effects (direct / indirect and cumulative) may be caused by the proposed activities (Forest Service Handbook [FSH] 1909.15, 15.2a). The analysis area encompasses all areas in which fish resources and fish habitat may be affected directly or indirectly by the SGP, and not merely the immediate area involved. The analysis area is located in the South Fork Salmon River hydrological subbasin and the North Fork Payette River hydrological subbasin (**Figure 5-1**). The analysis area for fish resources also includes all of the watercourses (i.e., streams and rivers) and waterbodies (i.e., lakes, reservoirs) in the 12-digit HUC subwatersheds that overlap the SGP area.

Hydrologic unit codes (HUC) are used to identify all of the drainage basins in the United States in a nested (hierarchical) arrangement from the largest to smallest drainage basins. In the SGP analysis area the hydrologic units of relevance are, from largest to smallest:

- Salmon River “Basin” (HUC 170602) and Middle Snake-Boise “Basin” (HUC 170501);
- South Fork Salmon River “Subbasin” (HUC 17060208) and North Fork Payette River “Subbasin” (HUC 17050123);
- Numerous “Watersheds” within each subbasin (i.e., Upper East Fork Salmon River Watershed (HUC 1706020804); and
- Numerous “Subwatersheds” within each watershed (i.e., Headwaters East Fork South Fork Salmon River Subwatershed (HUC 170602080201). Subwatersheds are sometimes referenced as “6th field” or “HUC 12” due to the 12-digit numerical code assigned to each.

The physical footprint of the SGP where mining is proposed (i.e., the proposed “mine site” footprint) occurs within two subwatersheds: Sugar Creek and Headwaters East Fork South Fork Salmon River (**Figure 5-2**), labeled numbers 5 and 6 on **Figure 5-1**. SGP-related facilities potentially located within these two subbasins would include buildings, tailings and waste rock storage facilities, access roads, electrical substations, transmission lines, and mining operational areas. Immediately downstream from these two subwatersheds is the adjacent No Mans Creek-East Fork SFSR subwatershed that also is discussed in this section (hydrologic unit code [HUC] 170602080206), which is labeled number 4 on **Figure 5-1**. This latter subwatershed is within the analysis area, but not within the proposed mine site.

The analysis area for fish resources also includes all of the watercourses (i.e., streams and rivers) and waterbodies (i.e., lakes, reservoirs) in the 12-digit HUC subwatersheds that overlap the SGP area. Because the majority of the activities and disturbance would occur at the mine site, which is located in the



LEGEND

- Analysis Area
- Subwatershed (see table)

Watershed

- Cascade Reservoir
- Johnson Creek
- Lower East Fork South Fork Salmon River
- Upper East Fork South Fork Salmon River
- Upper South Fork Salmon River

Project Components *

- SGP Features

Utilities

- Existing Communication Tower

Other Features

- U.S. Forest Service
- Wilderness
- County
- City/Town
- Monumental Summit
- Railroad
- Highway
- Road
- Stream/River
- Lake/Reservoir

Surface Management Agency

- Bureau of Land Management
- Bureau of Reclamation
- Private
- State
- State Fish and Game
- State Parks and Recreation
- U.S. Forest Service

* Project Components are associated with 2021 MMP

0 2.5 5 Miles

1 inch = 5 miles when printed at 11x17

Subwatersheds

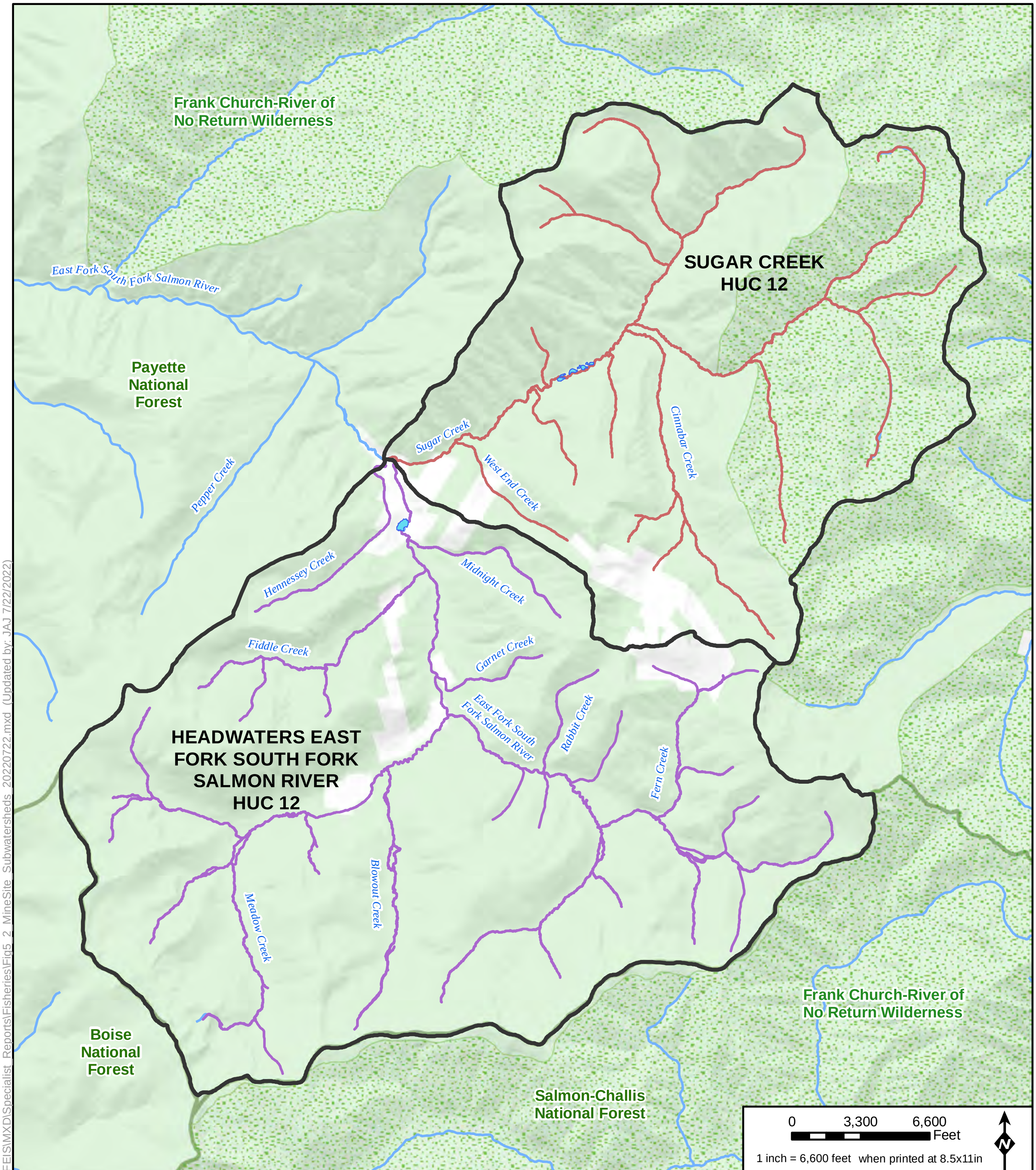
1 - Quartz Creek
2 - Profile Creek
3 - Tamarack Creek
4 - No Mans Creek-East Fork South Fork Salmon River
5 - Sugar Creek
6 - Headwaters East Fork South Fork Salmon River
7 - Porcupine Creek-Johnson Creek
8 - Riordan Creek
9 - Trapper Creek-Johnson Creek
10 - Ditch Creek-Johnson Creek
11 - Burntlog Creek
12 - Sheep Creek-Johnson Creek
13 - Headwaters Johnson Creek
14 - Lunch Creek-Johnson Creek
15 - Warm Lake Creek
16 - Six-bit Creek-South Fork Salmon River
17 - Curtis Creek
18 - Upper Big Creek
19 - Lower Big Creek
20 - Pearsol Creek-North Fork Payette River
21 - Beaver Creek
22 - Duck Creek-Cascade Reservoir
23 - Lower Gold Fork River
24 - Boulder Creek
25 - Lake Fork

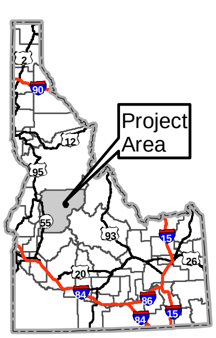
Figure 5-1
Analysis Area for Fish and Aquatic Habitat
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021.
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 2023-06-27

Document Path: U:\203721981\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig5_1_Fish_Aquatic_Habitat_Analysis_Area_20230627.mxd (Updated by: JAJ 2022-07-22)





LEGEND

- Subwatershed (HUC 12)
- Headwaters East Fork South Fork Salmon River Drainages
- Sugar Creek Drainages

Other Features

- U.S. Forest Service
- Wilderness
- County
- Stream/River
- Lake/Reservoir

Surface Management

- Private
- U.S. Forest Service

Figure 5-2
Mine Site Subwatersheds
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI World Terrain Basemap
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Ecosystem Sciences; Boise National Forest; Payette National Forest

Map Date:
7/22/2022

Document Path: U:\2037219\81\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig5_2_MineSite_Subwatersheds_20220722.mxd (Updated by: JAJ 7/22/2022)

South Fork Salmon River (SFSR) subbasin, greater emphasis is placed on describing the affected environment within this subbasin. However, relevant habitat conditions in other subbasins, watersheds, and subwatersheds that may be impacted by SGP activities also are described, as appropriate.

Where appropriate, the impact analysis discusses effects to other areas of the analysis area, particularly with respect to road construction and traffic effects. Effects of direct mining activities are discussed in the context of the mine site area. Mining effects generally do not affect conditions outside the mine site area where effects are primarily associated with road usage.

5.2 Methodology

The analysis area for fish and aquatic habitat includes the area where effects (direct/indirect and cumulative) may be caused by the proposed activities (FSH.1909.15, 15.2a). Alternative components include the mine site, all associated mine support infrastructure, all access and haul roads (proposed and existing), all utility infrastructure (proposed and upgraded), and off-site facilities.

5.2.1 Information Sources

A summary of the available data was compiled for specific watersheds/subwatersheds and individual species (Chinook salmon, steelhead, bull trout, and westslope cutthroat trout). Data was obtained and modeled using various sources and consisted of different metrics, such WCIs. The information used to describe the existing condition of fish and fish habitat in the analysis area was gathered from numerous sources, including federal and state resource agencies, the Nez Perce Tribe, and Perpetua. AECOM (2020a) provides a list of fish and stream habitat data collected in the analysis area between 1991 and 2019 (**Table 5-1**).

To further describe the existing condition of habitat in the analysis area for special status fish species, additional modeling was performed and the studies and outcomes are described in technical memoranda (Ecoysystem Sciences (ESS) 2019a, 2019b, 2022a, 2022b, 2022c, 2022d, 2022e, 2022f, 2022g; AECOM 2020a, 2020b).

In addition, various other data sources were used to describe the existing conditions. For instance, fisheries distribution and environmental DNA (eDNA) data were obtained from the Forest Service; stream gage data were obtained from the U.S. Geological Survey (USGS); water quality information was provided by the IDEQ; and the IDFG provided fisheries technical reports, management plans, and historical supplementation (i.e., fish translocation) records.

5.2.2 Aquatic Resources Baseline Data Collection

Perpetua funded aquatic resources baseline studies from 2012 to 2020 specifically for the SGP within the mine site area and along the Burntlog Route area (AECOM 2020a). Fish data was collected through snorkel surveys, electrofishing, videography, and eDNA sampling (MWH 2017; Stantec 2018, 2019). **Figures 5-3a** and **5-3b** show the location of these surveys. In 2015, fish tissue was collected to check for metal concentrations and DNA analysis.

Field investigations to characterize existing aquatic physical habitat in the mine site area and along the Burntlog Route area were performed between 2012 and 2020 (Great Ecology 2018; HDR 2016; Rio ASE 2019; MWH 2017; Stantec 2018, 2019, 2020; Watershed Solutions Inc. 2021) (**Figure 5-4**). These investigations collected information on aquatic habitat parameters, such as water temperature, substrate size, substrate embeddedness, surface fines, channel geometry and physical attributes, large woody debris, and pool frequency. Stream habitat condition surveys, following the Pacific Anadromous Fish Strategy/Inland Fish Strategy Biological Opinion (PIBO) protocols, collected information on bankfull width, wetted width, bank stability, sediment size, stream gradient, pool dimensions, and large woody debris.

Table 5-1 Fisheries and Stream Habitat Data Collected Within and Near the Analysis Area, 1991-2019

Data Source	Project/ Study	Location	Data Years	Available Data	Data Collection Methods	Species Information	Reference
Boise National Forest	Boise National Forest Aquatic Database	Analysis area and vicinity	1991-2016	Habitat, fish community	Electrofishing, snorkel, eDNA, PIBO and other stream habitat surveys	Chinook salmon, bull trout, westslope cutthroat trout, *Oncorhynchus mykiss*	Forest Service 2017
Brown and Caldwell	Yellow Pine Pit Fish Monitoring Summary	Yellow Pine Pit	2018-2019	Fish community	Seining and hook-and-line angling.	Chinook salmon, bull trout, westslope cutthroat trout, rainbow trout, whitefish	Brown and Caldwell 2019b, 2020
GeoEngineers	Aquatic Resources 2016 Baseline Study Addendum Report	Mine site Study Area	2015	Fish community, population estimates	Electrofishing/mark-recapture surveys	Chinook salmon, bull trout, westslope cutthroat trout, *Oncorhynchus mykiss*	GeoEngineers 2017
Great Ecology	Supplemental Stream and Wetland Baseline Data Report for the Stibnite Gold Project	Mine site Study Area, as well as access roads	2018	Habitat	Stream habitat surveys	Habitat data only	Great Ecology 2018
HDR	Stream Functional Assessment	Mine site Study Area	2015-2016	Habitat	Stream habitat surveys	N/A	HDR 2016
MWH	Aquatic Resources 2016 Baseline Study	Mine site Study Area	2012-2016	Habitat, fish community, macroinvertebrates, fish tissue	Electrofishing, snorkel, eDNA, PIBO and substrate surveys, water temperature monitoring	Chinook salmon, bull trout, westslope cutthroat trout, *Oncorhynchus mykiss*	MWH 2017

Data Source	Project/ Study	Location	Data Years	Available Data	Data Collection Methods	Species Information	Reference
Nez Perce Tribe	Status and Monitoring of Natural and Supplemented Chinook Salmon	Johnson Creek, Burntlog Creek, East Fork SFSR (tributaries, including Meadow Creek)	2005-2017	Adult and smolt data; redd counts	Weir counts and spawning ground survey	Chinook salmon	Rabe and Nelson 2007, 2008, 2009, 2010, 2014 Rabe et al. 2016, 2017, 2018a
Nez Perce Tribe	Chinook and Bull Trout Redd Count Data	Johnson Creek, Burntlog Creek, East Fork SFSR, and tributaries, including Meadow Creek	1998-2018	GIS data on redd counts	Spawning ground survey	Chinook salmon and bull trout	Nez Perce Tribe 2018
Stantec	Aquatic Resources Baseline Study Tech Memos	Mine site Study Area, as well as access roads and control sites	2017-2019	Habitat and fish community	Substrate, PIBO, floodplain monitoring, and eDNA surveys, water temperature monitoring	Chinook salmon, bull trout, westslope cutthroat trout, *Oncorhynchus mykiss*	Stantec 2018, 2019, 2020
Watershed Solutions	Aquatic Resources Baseline Study	Mine site Study Area, as well as access roads and control sites	2020	Habitat	Substrate and PIBO surveys, water temperature monitoring	N/A	Watershed Solutions 2021

[1] Available data: stream habitat (e.g., habitat unit, riparian habitat, PIBO methodology, substrate type, water temperature, water velocity), fish community (e.g., eDNA, presence/absence, redd counts, juvenile density), tissue residues (metals), population estimates, etc.

[2] Data collection methods applied (e.g., fish surveys, weir counts, spawning ground surveys, stream habitat surveys (e.g., PIBO).

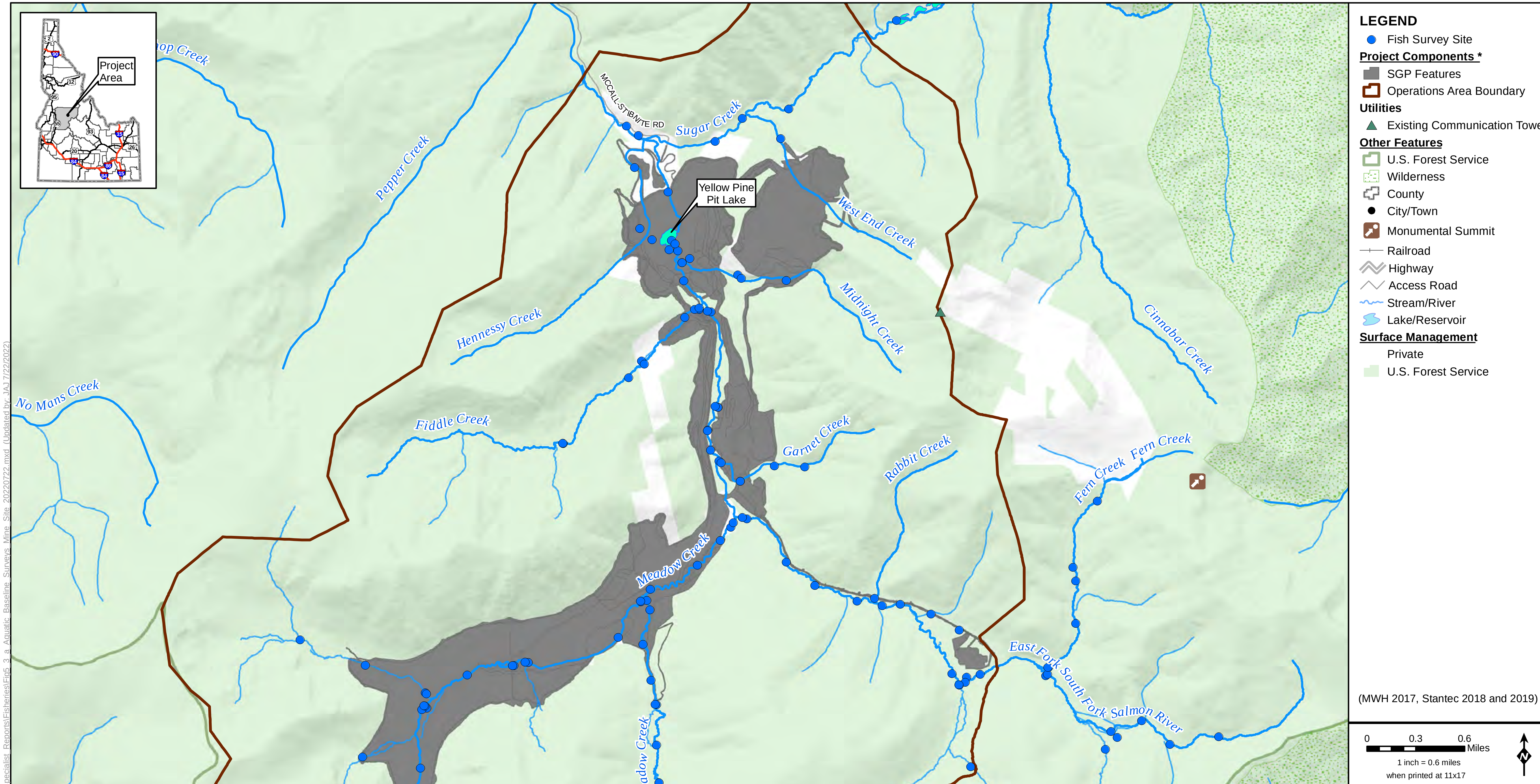
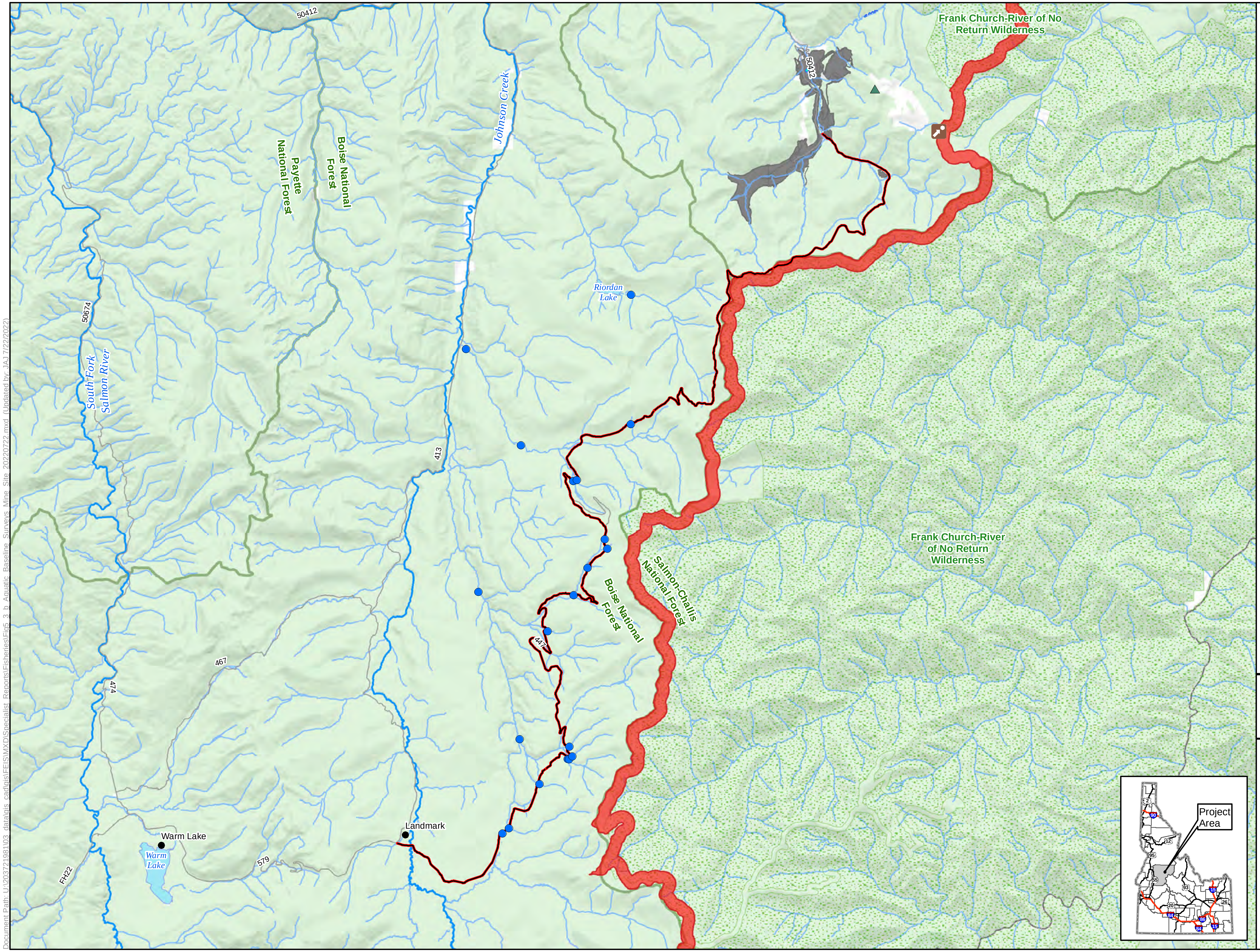


Figure 5-3a
Aquatic Baseline
Fish Survey Locations
at the Mine Site
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest, MWH and Stantec

Map Date: 7/22/2022

Document Path: U:\203721981\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig5_3_a_Aquatic_Baseline_Surveys_Mine_Site_20220722.mxd (Updated by: JAJ 7/22/2022)



LEGEND

- Fish Survey Sites
- Analysis Area

Project Components *

- SGP Features
- Burntlog Route

Utilities

- Existing Communication Tower

Other Features

- U.S. Forest Service
- Wilderness
- County
- City/Town
- Monumental Summit
- Railroad
- Highway
- Road
- Lake/Reservoir

Surface Management

- Private
- U.S. Forest Service

(Stantec 2018 and 2019)

0 1.125 2.25 Miles

1 inch = 2.25 miles when printed at 11x17

Figure 5-3b Aquatic Baseline Fish Survey Locations Along Burntlog Route Stibnite Gold Project Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Document Path: U:\203721981\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig5_3_b_Aquatic_Baseline_Surveys_Mine_Site_20220722.mxd (Updated by: JAJ 7/22/2022)

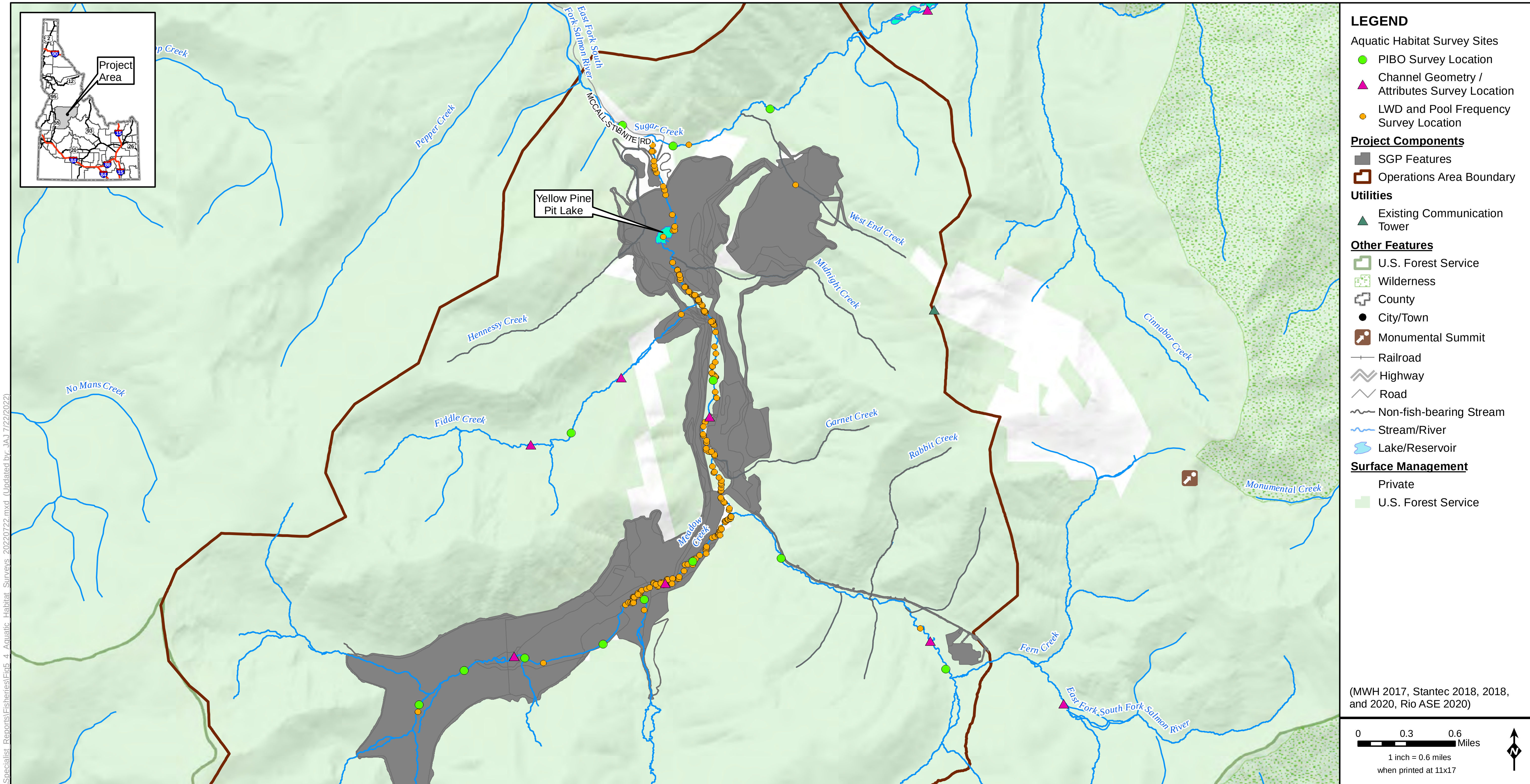


Figure 5-4
Aquatic Habitat Survey Locations
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest, MWH, Stantec, and RIO

Map Date: 7/22/2022

Document Path: U:\203721981\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig5_4_Aquatic_Habitat_Surveys_20220722.mxd (Updated by: JAJ 7/22/2022)

6.0 Affected Environment

General descriptions of fish and aquatic habitat in the analysis area, including descriptions are presented in **Section 6.1**. The following subsections describe the existing conditions of fish species, particularly Chinook salmon, steelhead, bull trout, and westslope cutthroat trout, and their habitat, as well as an overview of fish densities and watershed condition indicators (WCIs). Modeling tools are utilized to characterize fish usage and habitat based on application of threshold criteria to available data for the site or other Idaho streams. In general, modeling tools are limited by the assumptions and data they employ and may not match field observations precisely. However, the modeling tools are utilized to form a basis for consistent comparisons between habitat criteria, existing conditions, and forecasts of future conditions. A summary of the streams within the mine site area and the WCIs under baseline conditions is provided in **Section 6.3**.

6.1 Watershed Condition Indicators

This section summarizes the existing data describing the baseline aquatic habitat conditions that may be affected by the SGP within the analysis area. It includes brief descriptions of the streams that may be affected by the SGP both outside and within the mine site. The WCIs are used as a metric to compare baseline conditions to estimated changes that might be caused by projects or other events. 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 Nez Perce Tribe), as well as private entities (e.g., Perpetua).

Table 6-1 and **Table 6-2** summarize the WCI data currently available along with fish species occurrence information for each watershed and subwatershed (shown in **Figure 5-1**). Only one subwatershed (Upper Big Creek) in the Cascade Reservoir Watershed had any WCI data available for the local fish community. More WCI data are available for most of the subwatersheds in the Upper SFSR, Johnson Creek, Lower East Fork SFSR, and Upper East Fork SFSR watersheds.

The Southwest Idaho Ecogroup Matrix of Pathways and Watershed Condition Indicators (WCIs or “The Matrix”) (Forest Service 2003, 2010a) have been applied to describe and evaluate the baseline environment for fish and aquatic resources in the analysis area. The WCI matrix was developed specifically for application in the PNF and BNF (Forest Service 2003, 2010a) to assist in project design and analysis during National Environmental Policy Act (NEPA) assessments of proposed projects. The WCI matrix evaluates watershed ecological functions by measuring elements that reflect water quality, habitat access, channel conditions and dynamics, flow and hydrology, and other watershed conditions. Furthermore, the WCI matrix comprises a series of “pathways” by which mining, reclamation, or restoration activities can have potential effects on native and desired non-native fish species, their habitats, and associated ecological functions. This ecological functionality is broken down into three separate categories: “functioning appropriately,” “functioning at risk,” and “functioning at unacceptable risk.” Where possible, quantitative values are applied to determine the functionality. The same description of the pathways and WCIs can be found in Table B-1, Appendix B of each Forest Plan (Forest Service 2003, 2010a).

6.1.1 North Fork Payette River Subbasin Baseline

The Cascade Reservoir Watershed is the only HUC 5th Field watershed in this subbasin (**Figure 5-1**; **Table 6-1**). Eight subwatersheds occur in this watershed that could be impacted by the SGP. Only one subwatershed, Upper Big Creek, has had a WCI analysis completed. Many of the other subwatersheds are on private land and do not have WCIs completed.

Table 6-1 Baseline Watershed Condition Indicators for Potentially Impacted Subwatersheds in the Analysis Area for the Cascade Reservoir and Upper South Fork Salmon River Watersheds

Watershed Condition Indicator	Cascade Reservoir Watershed (HUC 5th Field)								Upper South Fork Salmon River Watershed (HUC 5th Field)		
	Subwatersheds (HUC 6th Field)										
	Lake Fork	Boulder Creek	Lower Gold Fork River	Duck Creek	Beaver Creek	Pearsol Creek	Lower Big Creek	Upper Big Creek	Curtis Creek	Six-bit Creek	Warm Lake Creek
Bull Trout Local Population Characteristics within Core Area											
Local Population Size	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	FR	No Data	FR
Growth and Survival	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Life History Diversity and Isolation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Persistence and Genetic Integrity	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Water Quality											
Temperature – Steelhead, Chinook salmon	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present	FR	Steelhead Present. No Data	FUR
Temperature – Bull trout	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FUR
Temperature – Other fish species	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present. FA for other species	WSC Present. No Data	WSC Present. No Data	WSC Present. No Data
Sediment/Turbidity – Steelhead, Chinook salmon	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Sediment/Turbidity – Bull trout	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Sediment/Turbidity – Other fish species, i.e., westslope cutthroat trout	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present	WSC Not Present. FUR for other species	No Data	No Data	No Data
Chemical Contamination / Nutrients	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FR	No Data	FR
Habitat Access											
Physical Barriers	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FUR	FA	No Data	FR
Habitat Elements											
Substrate Embeddedness (Bull trout rearing areas)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FUR
Large Woody Debris	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FA	FA	No Data	FA
Pool Frequency and Quality	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FA	No Data	FR
Large Pools/Pool Quality (all fish species in adult holding, juvenile rearing, and over wintering reaches)	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FUR	FA	No Data	FR
Off-Channel Habitat	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FA	FA	No Data	FR
Refugia (Steelhead, Chinook salmon)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FR	No Data	FR
Channel Conditions and Dynamics											
Average Wetted Width/Maximum Depth Ratio	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FA	No Data	FR
Streambank Condition	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FA	FA	No Data	FR
Floodplain Connectivity	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FUR	No Data	FUR
Flow/Hydrology											
Change in Peak/Base Flows	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FA	FA	No Data	FUR
Change in Drainage Network	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FUR	FUR	No Data	FUR

Watershed Condition Indicator	Cascade Reservoir Watershed (HUC 5th Field)								Upper South Fork Salmon River Watershed (HUC 5th Field)		
	Subwatersheds (HUC 6th Field)										
	Lake Fork	Boulder Creek	Lower Gold Fork River	Duck Creek	Beaver Creek	Pearsol Creek	Lower Big Creek	Upper Big Creek	Curtis Creek	Six-bit Creek	Warm Lake Creek
Watershed Conditions											
Road Density/Location	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FUR	FUR	No Data	FR
Disturbance History	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FUR	No Data	FUR
Riparian Conservation Areas	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FR	No Data	FUR
Disturbance Regime	No Data	No Data	No Data	No Data	No Data	No Data	No Data	FR	FR	No Data	FR
Integration of Pathways											
Integration of Pathways (Steelhead, Chinook salmon)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FUR	FR	No Data	FUR
Integration of Pathways (Bull trout)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	FUR	FR	No Data	FUR
Integration of Pathways (Other fish species, i.e., westslope cutthroat trout)	No Data	No Data	No Data	No Data	No Data	No Data	No Data	WSC not Present. FUR for other species	FR	No Data	FUR

Source: Forest Service 2003; Forest Service 2012; Foust and Nalder 2010; StreamNet 2020
Subwatersheds are at the HUC 6th Field.
FA = Functioning Appropriately; FR = Functioning at Risk; FUR = Functioning at Unacceptable Risk; HUC = hydrologic unit code; N/A = Not Applicable; WSC = westslope cutthroat trout

Table 6-2 Baseline Watershed Condition Indicators for Potentially Impacted Subwatersheds in the Analysis Area for the Johnson Creek, Lower East Fork South Fork Salmon River, and Upper East Fork South Fork Salmon River Watersheds

Watershed Condition Indicator	South Fork Salmon River Subbasins															
	Johnson Creek Watershed (HUC 5th Field)									East Fork SFSR Watershed (HUC 5th Field)	Upper East Fork SFSR Watershed (HUC 5th Field)					
	Subwatersheds (HUC 6th Field															
	Lunch Creek	Headwaters Johnson Creek	Sheep Creek	Burnt Log Creek	Dutch/Ditch Creek	Trapper Creek	Upper Indian Creek	Riordan Creek	Porcupine Creek	Lower East Fork SFSR	Quartz Creek[1]	Profile Creek[1]	Tamarack Creek[1]	No Mans Creek[1]	Sugar Creek[2]	Headwaters East Fork SFSR[2]
Bull Trout Local Population Characteristics within Core Area																
Local Population Size	FUR	FUR	FUR	FA	Bull Trout Present No Data	FA	Bull Trout Present No Data	FR	FR	FR	Bull Trout Present No Data	Bull Trout Present No Data	Bull Trout Present No Data	Bull Trout Present. No Data	FR	FR
Growth and Survival	FR	FR	FR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	No Data	No Data	FR	FR
Life History Diversity and Isolation	FR	FR	FR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	No Data	No Data	FR	FR
Persistence and Genetic Integrity	FR	FR	FR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	No Data	No Data	FR	FR
Water Quality																
Temperature (Steelhead, Chinook salmon)	FUR	FUR	FUR	FR	Steelhead Present. No Data	FA	Steelhead and Chinook Present No Data	FUR	Species Not Present	FR	Steelhead Present. No Data	Chinook Present. No Data	FR	Species Not Present	FR	FR
Temperature (Bull trout)	FUR	FUR	FUR	FR	No Data	FA	No Data	FUR	FUR	FR	No Data	FR	FR	No Data	FR	FR
Temperature (Other fish species, i.e., westslope cutthroat trout)	No WSC. No Data for other species	WSC Present. No Data	No WSC. No Data for other species	WSC Present. No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	WSC Present No Data	FR
Sediment/Turbidity (Steelhead, Chinook salmon)	FUR	FUR	FA	FA	Steelhead Present. No Data	FA	No Data	FUR	N/A	No Data	No Data	No Data	No Data	N/A	FUR	FUR
Sediment/Turbidity (Bull trout)	FUR	FUR	FA	FA	No Data	FA	No Data	FUR	FR	FR	No Data	No Data	No Data	No Data	FUR	FUR
Chemical Contaminants/ Nutrients	No Data	No Data	No Data	FA	No Data	FA	No Data	FA	No Data	FUR	No Data	No Data	No Data	No Data	FUR	FUR
Habitat Access																
Physical Barriers	FUR	FA	FUR	FA	No Data	FUR	No Data	FA	FUR	FR	No Data	No Data	No Data	No Data	FA	FUR
Habitat Elements																
Substrate Embeddedness (Bull trout rearing areas)	FUR	FUR	FA	FA	No Data	FA	No Data	FUR	FR	FR	No Data	FA	FUR	No Data	FA	FA
Large Woody Debris	FA	FA	FA	FA	No Data	FA	No Data	FA	FUR	FUR	No Data	No Data	No Data	No Data	FA	FA

Watershed Condition Indicator	South Fork Salmon River Subbasins															
	Johnson Creek Watershed (HUC 5th Field)									East Fork SFSR Watershed (HUC 5th Field)	Upper East Fork SFSR Watershed (HUC 5th Field)					
	Subwatersheds (HUC 6th Field															
	Lunch Creek	Headwaters Johnson Creek	Sheep Creek	Burnt Log Creek	Dutch/Ditch Creek	Trapper Creek	Upper Indian Creek	Riordan Creek	Porcupine Creek	Lower East Fork SFSR	Quartz Creek[1]	Profile Creek[1]	Tamarack Creek[1]	No Mans Creek[1]	Sugar Creek[2]	Headwaters East Fork SFSR[2]
Pool Frequency and Quality	FA	FA	FA	FA	No Data	FA	No Data	FA	FUR	FR	No Data	No Data	No Data	No Data	FR	FR
Large Pools/Pool Quality (all fish species in adult holding, juvenile rearing, and over wintering reaches)	FUR	FUR	FUR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	No Data	No Data	FUR	FUR
Off-Channel Habitat	FA	FA	FA	FA	No Data	FA	No Data	FA	FA	FR	No Data	No Data	No Data	No Data	FR	FR
Refugia (Steelhead, Chinook salmon)	FR	FR	FR	FR	No Data	FR	No Data	FR	No Data	FR	No Data	No Data	No Data	N/A	FR	FR
Refugia (Bull trout)	FR	FR	FR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	FA	No Data	FR	FR
Channel Conditions and Dynamics																
Average Wetted Width/Maximum Depth Ratio	FA	FR	FA	FA	No Data	FA	No Data	FA	FR	FR	FA	No Data	No Data	FA	FA	FA
Streambank Condition	FUR	FR	FA	FA	No Data	FA	No Data	FA	FR	FR	No Data	No Data	No Data	No Data	FA	FA
Floodplain Connectivity	FR	FR	FR	FR	No Data	FR	No Data	FA	FR	FR	FR	FR	No WCI	No WCI	FR	FR
Flow/Hydrology																
Change in Peak/Base Flows	FR	FUR	FA	FUR	No Data	FUR	No Data	FUR	FUR	FR	No Data	FR	No Data	No Data	FA	FA
Change in Drainage Network	FR	FR	FR	FR	No Data	FR	No Data	FA	FR	FUR	No Data	No Data	No Data	No Data	FA	FA
Watershed Conditions																
Road Density/Location	FR	FR	FR	FR	No Data	FR	No Data	FA	FR	FR	No Data	No Data	No Data	No Data	FUR	FUR
Disturbance History	FUR	FUR	FA	FUR	No Data	FUR	No Data	FUR	FUR	FUR	No Data	No Data	No Data	No Data	FR	FR
Riparian Conservation Areas	FR	FA	FR	FR	No Data	FR	No Data	FR	FR	FUR	FUR	FUR	No Data	No Data	FA	FUR
Disturbance Regime	FR	FR	FR	FR	No Data	FR	No Data	FR	FR	FR	FUR	FUR	No WCI	No WCI	FR	FR
Integration of Pathways																
Integration of Pathways (Steelhead, Chinook salmon)	FUR	FUR	FUR	FR	No Data	FR	No Data	FR	NA	FR	No Data	No Data	No Data	N/A	FR	FR
Integration of Pathways (Bull trout)	FUR	FUR	FUR	FR	No Data	FR	No Data	FR	FR	FR	No Data	No Data	No Data	No Data	FR	FR
Integration of Pathways (other fish species, i.e., westslope cutthroat trout)	No WSC	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data

Source: Forest Service 2010b: Johnson Creek Watershed Improvement Project-Boise NF: Attachment B, Subwatersheds Baselines; Forest Service 2012; Foust and Nalder 2010; StreamNet 2020; MWH 2017; Stantec 2018, 2019, 2020

[1] Outside of the Mine Site

[2] Within the Mine Site

FA = Functioning Appropriately; FR = Functioning at Risk; FUR = Functioning at Unacceptable Risk; HUC = hydrologic unit code; WCT = westslope cutthroat trout

6.1.2 South Fork Salmon River Subbasin Baseline

Baseline conditions for WCIs were developed per the guidance in Appendix B of the Forest Plans (Forest Service 2003, 2010a) to describe the existing conditions in the SFSR subbasin. **Table 6-2** summarizes the baseline WCI information for the SFSR subbasin for those watersheds and subwatersheds that may be directly impacted by SGP activities.

6.1.2.1 East Fork South Fork Salmon River Watershed Baseline

The East Fork SFSR 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 Forest Service 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 village 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 East Fork SFSR watershed. The Forest Service and mine operators have since undertaken restoration work. However, habitat for migratory salmonids in the East Fork SFSR upstream from the YPP lake is inaccessible because historical mining excavation of the stream channel has created a gradient barrier (YPP lake cascade). Although there has been a reduction in human influences since about 1950, there are still significant legacy effects that continue to impact channel conditions and fish populations. Kuzis (1997) describes the Upper East Fork SFSR watershed as follows:

> *"The most significant geophysical processes affecting channels in the East Fork SFSR are mass wasting and erosion. The most obvious impacts to stream channels are located at the Yellow Pine pit lake, Meadow Creek, East Fork Meadow Creek, and the Cinnabar Mine area."*

The East Fork SFSR drainage has the lowest quality habitat for sensitive and protected fish in the SFSR subbasin (Northwest Power Conservation Council 2004). Primary habitat limitations in the East Fork SFSR 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 large woody debris, water quality degradation, and fish passage barriers resulting from legacy mining in the area (Northwest Power Conservation Council 2004).

All IDEQ-inventoried waterbodies at the proposed mine site (except for West End Creek) are listed under Section 303(d) of the federal Clean Water Act as "impaired" due to water quality. 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 aquatic life," "salmonid spawning," and "primary contact recreation," and all (except Sugar Creek) have designated beneficial uses of "domestic water supply."

Wildfires have eliminated much of the tree canopy at the SGP mine site and vicinity. Although much of the understory vegetation in burned areas has started to regenerate, substantial erosion still occurs (HDR 2013). In addition, the failure of a dam on the East Fork Meadow Creek (also referred to as Blowout Creek) 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 East Fork SFSR. 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.

East Fork South Fork Salmon River

The East Fork SFSR is a tributary to the SFSR. The East Fork SFSR between its confluence with Sugar Creek upstream to the YPP lake is 1.2 km, upstream to the confluence with Meadow Creek is 6.1 km. This stream reach includes the YPP lake, immediately upstream from which is a long cascade (22 percent gradient) that presents a complete upstream passage barrier for all fish species including migrating Chinook salmon and steelhead. Despite the migratory barrier at the YPP lake, bull trout and westslope cutthroat trout are known to occur upstream from the YPP lake. Chinook salmon also spawn and rear in the stream reach upstream from the lake because they have been introduced there by the IDFG. Downstream from the YPP lake, this stream reach is accessible to all four special status salmonid species.

Between Meadow Creek and the YPP lake, the East Fork SFSR widens and has larger streambed material (including abundant cobble and boulders), relative to the upper East Fork SFSR. 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 East Fork SFSR 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 (2019), there are more and deeper pools upstream from the YPP lake. The East Fork SFSR 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 East Fork SFSR in this reach 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 East Fork SFSR channel, dam construction across the East Fork SFSR main channel, and other legacy impacts (Midas Gold 2016).

Hennessy Creek

Hennessy Creek historically flowed into the East Fork SFSR downstream from the YPP lake, but it has been diverted to flow into the East Fork SFSR downstream from Sugar Creek. It is a narrow, low-flow stream that flows in a constructed ditch alongside McCall-Stibnite Road (CR 50-412), and then through a subterranean section under an adjacent waste rock dump before passing through a very high-gradient reach into the East Fork SFSR. The creek is not expected to support upstream fish passage because of an average channel gradient of 37 percent at its mouth (HDR 2016). Hennessy Creek is densely vegetated and shallow. The lower portion of Hennessy Creek has been significantly impacted by legacy mine-related activities, including stream diversion, road construction that buried the stream channel, and mining infrastructure (Midas Gold 2016).

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 East Fork SFSR was diverted through the Bradley Tunnel to Sugar Creek (Hogen 2002). After mining ceased in 1952, the East Fork SFSR was allowed to flow through the abandoned mine pit. The pit currently has a maximum depth of approximately 11 meters. Diverting the East Fork SFSR back into the stream channel and pit created a long cascade with a high (22 percent) gradient 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 2019b and 2020a) and it supports a healthy benthic macroinvertebrate community (MWH 2017, IDEQ 2002). Bull trout found in the YPP lake may be either resident (Brown and Caldwell 2020a) and/or an adfluvial life history population that use the YPP lake for overwintering, with downstream migration to tributaries for spawning (Hogen and Scarnecchia 2006).

The YPP lake is the largest feature that affects flow rates in the East Fork SFSR; 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), but resuspension of sediments due to turnover is not expected. The bottom velocities necessary for turnover would not be high enough for resuspension (IDEQ 2002). Fish sampling in the YPP lake was not included in the habitat-related aquatic baseline studies conducted by HDR (2016) or MWH (2017).

Midnight Creek

Midnight Creek is a small tributary of the East Fork SFSR. The lower portion of the creek is characterized as a narrow channel with extremely high gradient (approximately 90 percent) and dense overhanging vegetation. The high gradient presents a complete fish passage barrier to fish (HDR 2016). Midnight Creek has been impacted by legacy mining activities, including open-pit mining, waste rock dumps, and road construction (Midas Gold 2016).

Midnight Creek was not included in the preliminary baseline study due to restricted access, but it was surveyed by Great Ecology (2018) in the supplemental assessment. There is no baseline fish use noted for Midnight Creek (MWH 2017).

Fiddle Creek

Fiddle Creek is a small tributary of the East Fork SFSR just upstream from Midnight Creek. Habitat conditions in the creek have been adversely impacted from legacy mine operations, road construction, and culvert installation (Midas Gold 2016). The lower portion of Fiddle Creek also was the site of a former water storage reservoir, the construction and operation of which degraded portions of the stream.

The lower reach of Fiddle Creek has an approximate 37 percent gradient where it flows into the East Fork SFSR, creating a complete barrier to upstream fish passage (HDR 2016). Upstream from this barrier, Fiddle Creek retains a relatively high gradient in a relatively narrow channel, with side channels (HDR 2016). The lower portion of the creek has a thick tall-shrub overstory dominated by gray alder (*Alnus incana*) (HDR 2016). The uppermost section of Fiddle Creek is natural glacial topography, flattens in gradient, and is a slower meandering stream . Large amounts of large woody debris occur throughout the creek, and the dominant streambed substrate consists of boulders, large cobble, and gravel (HDR 2016). Westslope cutthroat trout were the only salmonids observed in Fiddle Creek or detected in eDNA surveys (MWH 2017, Stantec 2018). Near the confluence with the East Fork SFSR, fish that occupy the EFSFSR also likely use the lower portion of Fiddle Creek below the gradient barrier.

Garnet Creek

Garnet Creek is a narrow, shallow, moderate-gradient tributary to East Fork SFSR approximately 0.5 km downstream from the Meadow Creek confluence. The creek has been severely modified over the past 100 years to accommodate mining-related activities. It is still influenced by legacy mining infrastructure that was located across and adjacent to the stream channel, including portions of a town site; and is currently routed through several man-made ditches (Midas Gold 2016). Garnet Creek flows through a 26-m-long corrugated metal pipe culvert near its confluence with the East Fork SFSR that presents a partial barrier to fish (HDR 2016).

Garnet Creek was surveyed by Great Ecology (2018) in a supplemental assessment. Garnet Creek cuts through a formerly burned hillside. Most of the vegetative cover along the creek is composed of grasses; however, shrubs and trees grow alongside its banks, and woody vegetation is found in the channel (MWH 2017). There is no baseline fish use noted for Garnet Creek (MWH 2017).

Lower and Middle Meadow Creek

Meadow Creek is a major tributary to the East Fork SFSR that flows through a flat-bottomed valley surrounded by steep mountains. Elevations range from 1.9 km above sea level in the lower reach to over 2.3 km 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 East Fork Meadow Creek drainage south of the site of the Meadow Creek Mine. 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 spent ore disposal area (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 (BioAnalysts 2021). The channel includes low-gradient riffles, glides (section of the stream coming out of a pool) and runs. There is no side channel development or potential large woody debris recruitment.

Upper Meadow Creek

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 (sequence of runs separated by shorter riffle steps), 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.

East Fork Meadow Creek

The East Fork Meadow Creek (EFMC), also known as “Blowout Creek,” is a tributary to Meadow Creek that has been severely impacted as a result of legacy mining-related activities and the failure of a dam that had been constructed across its stream channel (Midas Gold 2016). The dam was constructed in 1929 to supply hydroelectric power for historical milling operations. The dam failed in 1965 due to record snow melt and runoff rates, depositing large volumes of sediment into Meadow Creek, the East Fork SFSR, and the YPP lake (URS Corporation 2000). This stream is considered to be the largest source of sediment to the East Fork SFSR in the analysis area.

The middle reach of EFMC flows through a lateral glacial moraine that eroded during the dam failure and is still considered unstable as it continues to deposit sediments into Meadow Creek and the East Fork SFSR. Upstream from this middle reach, EFMC has a low-gradient pool-riffle reach flowing through a large meadow. This reach is incised and continues to headcut in response to the dam failure. There are few trees and the banks have abundant grasses. The dominant streambed material is sand and gravel (MWH 2017). The EFMC headwaters are high gradient (4 to 20 percent) with cascades, high-gradient riffle, and plunge-pool habitat.

Immediately downstream from the historical dam location, the creek has a slightly steeper (8 to 20 percent) gradient and is composed of cascade habitat. Near the confluence with Meadow Creek, the EFMC passes through a multi-thread and unconfined alluvial fan with a 4 to 8 percent gradient. Sediment from the unstable slopes immediately upstream may contribute to the formation and maintenance of this alluvial fan.

Headwaters East Fork SFSR

Upstream from the Meadow Creek confluence, the East Fork SFSR is characterized by narrower channels with moderate gradient (2 to 4 percent), transitioning to higher-gradient (4 to 8 percent) step-pool habitat further upstream. Overall substrate size is generally smaller than downstream reaches, with sand, gravel, smaller cobble, and boulders. This reach of the East Fork SFSR has relatively abundant riparian vegetation and large amounts of large woody debris.

Kuzis (1997) found that the Headwaters East Fork SFSR 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.

East Fork SFSR Between Sugar Creek and Profile Creek

The East Fork SFSR downstream from Sugar Creek is adjacent to the SGP mine site in the No Mans-East Fork SFSR subwatershed. The East Fork SFSR 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 large woody debris in the East Fork SFSR 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 East Fork SFSR (Midas Gold 2019b). These events were naturally occurring in burn areas and were related to rain-on-snow events.

Sugar Creek

Sugar Creek, a tributary to the East Fork SFSR, enters the river downstream from the YPP lake. It has a relatively low gradient. An officially closed road closely parallels Sugar Creek for nearly 3.2 km. This road may confine the movement of Sugar Creek, specifically in areas where the banks are bound with riprap rock material. Much of Sugar Creek has large aggregates of large woody debris. The dominant substrates are sand, gravel, and cobble.

This 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 (approximately 76,455 cubic meters) of glacial overburden was removed from the East Fork SFSR channel and placed in both Sugar Creek and other parts of the East Fork SFSR (Kuzis 1997).

Sugar Creek supports spawning and rearing for all four salmonid species and represents one of the most productive fish habitats in the Upper East Fork SFSR watershed. Legacy mining-related impacts include construction of an access road adjacent to and in the stream channel, upstream sources of sediment, and mercury contamination.

6.1.3 Mine Site Watershed Condition Indicators

Baseline WCIs were determined for the stream reaches within the SGP mine site (**Table 6-3**). 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 would not be affected by the SGP, some are not well-established from a quantitative analysis perspective so they cannot be evaluated, and some WCIs are irrelevant to the SGP. For these reasons, five WCIs that have the greatest potential to accurately identify potential impacts due to the SGP were selected for detailed analysis. These WCIs are:

1. Water Temperature
2. Sediment/Turbidity
3. Chemical Contaminants
4. Physical Barriers
5. Change in Peak/Base Flows

A description of each of these WCIs and their current condition is provided in **Table 6-3**.

Table 6-3 Mine Site Stream Reaches Baseline Summary of Watershed Condition Indicators

Watershed Condition Indicator	East Fork SFSR and Tributaries from Sugar Creek to Meadow Creek	Meadow Creek and East Fork Meadow Creek	East Fork SFSR Upstream from Meadow Creek	East Fork SFSR Between Sugar Creek and Profile Creek	Sugar Creek
Bull Trout Local Population Characteristics within Core Area					
Local Population Size	FR	FR	FR	FR	FR
Growth and Survival	FR	FR	FR	FR	FR
Diversity and Isolation	FR	FR	FR	FR	FR
Persistence and Genetic Integrity	FR	FR	FR	FR	FR
Water Quality					
Temperature (Steelhead/Chinook salmon)	FR	FR	FR	FR	FR
Temperature (Bull trout)	FR	FR	FR	FR	FR
Sediment/Turbidity (Steelhead, Chinook salmon)	FUR	FUR	FUR	FUR	FUR
Sediment/Turbidity (Bull trout)	FUR	FUR	FUR	FUR	FUR
Chemical Contaminants	FUR	FR	FUR	FUR	FUR
Habitat Access					
Physical Barriers	FUR	FUR	FA	FA	FA
Substrate Embeddedness (Bull trout rearing areas)	FA	FA	FA	FA	FA
Large Woody Debris	FR	FA	FA	FA	FA
Pool Frequency and Quality	FR	FR	FR	FA	FR
Large Pools/Pool Quality (Bull trout)	FUR	FUR	FUR	FUR	FUR
Off Channel Habitat	FR	FR	FR	FR	FR
Refugia (Steelhead/Chinook salmon)	FR	FR	FR	FR	FR
Refugia (bull trout)	FR	FR	FR	FR	FR

Watershed Condition Indicator	East Fork SFSR and Tributaries from Sugar Creek to Meadow Creek	Meadow Creek and East Fork Meadow Creek	East Fork SFSR Upstream from Meadow Creek	East Fork SFSR Between Sugar Creek and Profile Creek	Sugar Creek
Channel Conditions and Dynamics					
Average Wetted Width/ Maximum Depth Ratio	FA	FA	FA	FA	FA
Streambank Condition	FA	FA	FA	FA	FA
Floodplain Connectivity	FR	FA	FR	FR	FR
Flow/Hydrology					
Change in Peak/Base Flows	FA	FA	FA	FA	FA
Change in Drainage Network	FA	FA	FA	FA	FA
Watershed Condition					
Road Density/Location	FUR	FUR	FUR	FR	FUR
Disturbance History	FR	FR	FR	FUR	FR
Riparian Conservation Areas	FA	FA	FA	FR	FA
Disturbance Regime	FR	FR	FA	FR	FR
Integration of Pathways					
Integration of Species/ Habitat Conditions	FR	FR	FR	FR	FR

Source: Forest Service 2010b; IDEQ 2017; Burns et al. 2005; Kuzis 1997, MWH 2017; USFWS 2015a, Stantec 2018, 2019, 2020 and Integration of Species and Habitat which is derived from professional judgment.
East Fork SFSR; FA = functioning appropriately; FR = functioning at risk; FUR = functioning at unacceptable risk

6.1.3.1 Water Temperature

Baseline water temperatures for the SGP mine area were evaluated using a Stream and Pit Lake Network Temperature (SPLNT) model developed by Brown and Caldwell (2021a). This model evaluated stream water temperatures and YPP lake water temperatures under baseline conditions and then potential changes that may occur as a result of proposed mine operations and subsequent reclamation. The SPLNT 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). 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 (see Water Quality Specialist Report for further details on models).

Results of the SPLNT model describing existing conditions (maximum weekly summer (July) and fall (September) temperatures) are shown in **Table 6-4**.

Table 6-4 SPLNT Modeled Baseline Maximum Weekly Summer and Fall Stream Temperatures for Specific Stream Reaches

SPLNT Model Stream Reaches	Baseline Summer Weekly Maximum Temperature (°C)	Baseline Fall Weekly Maximum Temperature (°C)
Upper East Fork SFSR (upstream from Meadow Creek confluence)	13.4	11.0
Meadow Creek upstream from East Fork Meadow Creek confluence	14.0	12.0
Meadow Creek downstream from East Fork Meadow Creek confluence	19.4	15.9
Middle East Fork SFSR (between Meadow Creek and YPP)	17.3	13.9
Lower East Fork SFSR (between YPP and Sugar Creek)	14.1	11.2
East Fork SFSR downstream from Sugar Creek confluence	14.9	11.9

Note: Temperatures based on distance weighted average of all QUAL2K reaches.
Summer temperatures are represented by July daily temperatures, and Fall temperatures are represented by September weekly maximum temperatures.
°C = degrees Celsius; East Fork SFSR = East Fork South Fork Salmon River; SPLNT = Stream and Pit Lake Network Temperature; YPP = Yellow Pine pit lake barrier

Establishing existing surface water temperature conditions at the SGP mine site was performed as part of the Surface Water Quality Baseline Study (HDR 2017) to provide a baseline dataset for comparing future temperature changes predicted by the SPLNT model.

The SPLNT model did not account for changes to stream temperatures caused by changing climate conditions. This means the model assumed future stream temperatures would be similar to the historic water temperature data without the SGP (Brown and Caldwell 2018). Given ongoing climate changes, modeled temperature results would likely be higher if climate change had been considered in the model. The effects of different air temperature conditions on stream temperatures were evaluated through a sensitivity analysis (Brown and Caldwell 2018) and an uncertainty analysis (Forest Service 2023c).

For air temperatures, the sensitivity of the model to altered air temperatures was evaluated, 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 (Brown and Caldwell 2018b). Stream water temperature modeling uncertainty relates largely to spatially and temporally variable implementation success of closure activities; this combined with broader climate conditions could result in higher than predicted stream temperatures (Forest Service 2023c).

The NorWeST model, produced by the Forest Service Rocky Mountain Research Station, provides a variety of scenario-based parameters that represent future stream temperatures for National Hydrography Dataset (-Plus) reaches across the western U.S. NorWeST-modeled stream temperatures are presented (Isaak et al. 2016) alongside the SPLNT stream temperatures in **Table 6-5** to provide information regarding the possibility of changing climate conditions in the analysis area.

Table 6-5 Comparison of Baseline SPLNT Model Temperatures with NorWeST Model Stream Temperatures for Multiple Timeframes (Mean August Temperatures)

SPLNT Reach	Baseline SPLNT Modeled Stream Temperature (°C)	NorWeST Model Stream Temperature (°C)			
		1930-2011	2015	2030-2059	2070-2099
YPP Lake Headwater	11.9	11.57	12.18	12.86	13.7
Meadow Creek	11.8	10.38	10.99	11.64	12.46
Upper East Fork SFSR at Rabbit Creek	9.5	9.95	10.56	11.2	12.01
Sugar Creek	9.2	10.83	11.43	12.1	12.92

Source: Brown and Caldwell 2018, Isaak et al. 2016

Note: SPLNT existing condition model reach 31 is comparable to NorWeST's YPP Lake Headwater, reach 16 to Meadow Creek, reach 5 to Rabbit Creek, and reach 11 to Sugar Creek

°C = degrees Celsius; East Fork SFSR = East Fork South Fork Salmon River; SPLNT = Stream and Pit Lake Network Temperature; YPP = Yellow Pine pit

Of the NorWeST parameters, modeled stream temperatures for 1993-2011 and 2015 are the most appropriate for comparison to existing condition (baseline) SPLNT modeled stream temperatures because they most closely coincide with the data that was used to represent baseline conditions. The NorWeST data from the above timeframes most closely coincides with the baseline data, which was collected between 2012 and 2019. There are two parameters within the NorWeST dataset that predict stream temperatures based on future scenarios; they are represented by warming trajectories 2040 (2030-2059) and 2080 (2070-2099). The exact year when the SGP would be implemented is unknown; however, if construction were to begin in 2022, then Mine Year 20 would occur in 2045 (3 years construction plus 20 years of operation and closure and reclamation activities), within the NorWeST 2040 (2030-2059) prediction timeframe. Year 112 would be outside of the predicted timeframes the NorWeST models provide, but the predictions through 2099 are representative of the modeled long-term trend applicable to that time period. These factors were considered when interpreting modeled future temperatures, especially the further into the future the modeled water temperatures represent.

These modeling results indicate that, depending on stream reach, climate change would increase water temperatures from baseline estimates to the end of the mine operations (2030-2059) by as much as 0.1° to 2.0°C. Into the future, baseline estimates for water temperatures could increase by as much as an additional degree (2070-2099). Depending on the salmonid species, climate change may have important biological impacts. Climate change was not explicitly incorporated into the base case SPLNT modeling but was assessed via sensitivity analyses that indicated a 5°C increase in air temperature could result in a 0.5°C increase in stream temperature. The WCI criteria for water temperatures are species and life-stage-dependent (Forest Service 2003). The criteria also are defined as the 7-day average of the maximum weekly maximum temperatures (MWMT). The WCI water temperature criteria for Chinook salmon and steelhead spawning and rearing, and bull trout spawning, incubation, and rearing, used in the WCI functional assessment are included in BioAnalysts (2019) and Forest Service (2003).

6.1.3.2 Sediment/Turbidity

All of the stream reaches in the Headwaters East Fork SFSR subwatershed are at unacceptable risk for Chinook salmon, steelhead, and bull trout due to baseline sediment conditions (**Table 6-3**). This is due to a variety of past disturbances at the SGP mine site that are currently affecting streambank stability and erosion, and the proximity to existing roads. The matrix WCIs use surface fines as a proxy to evaluate suspended sediment, turbidity, and salmonid spawning substrate quality.

6.1.3.3 Physical Barriers

Barriers to fish passage can impact the natural movement (e.g., migration) of fish species and fish population dynamics by reducing, or completely blocking, potential habitat during certain life stages. Barriers can impact fish habitat connectivity and disrupt the natural movement of fish and block important habitat for fish during all life cycles, including spawning and rearing. Fish passage barriers were identified and described within the SGP mine site (BioAnalysts 2021). Only the East Fork SFSR downstream from the mine site and Sugar Creek are without artificial (i.e., human-made) barriers (BioAnalysts 2021). Eleven artificial barriers to fish passage and one natural barrier were identified (BioAnalysts 2021). The status of these barriers were 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). Of these eleven artificial barriers, six are located in non-fish bearing streams. The remaining five barriers are shown in **Figure 6-1** and described in more detail in ESS 2022a. **Table 6-6** presents the amount of total potential fish habitat upstream from each barrier.

BioAnalysts (2021) identified three major barriers to fish movement in the SGP mine site area: 1) the high gradient cascade in the East Fork SFSR upstream from the YPP lake; 2) East Fork SFSR box culvert; and 3) the high gradient cascade in Meadow Creek upstream from the confluence with the East Fork Meadow Creek. The high gradient cascade in the East Fork SFSR upstream from the YPP lake is a complete barrier to natural fish passage. The other two major barriers, the East Fork SFSR 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 (i.e., translocated Chinook salmon).

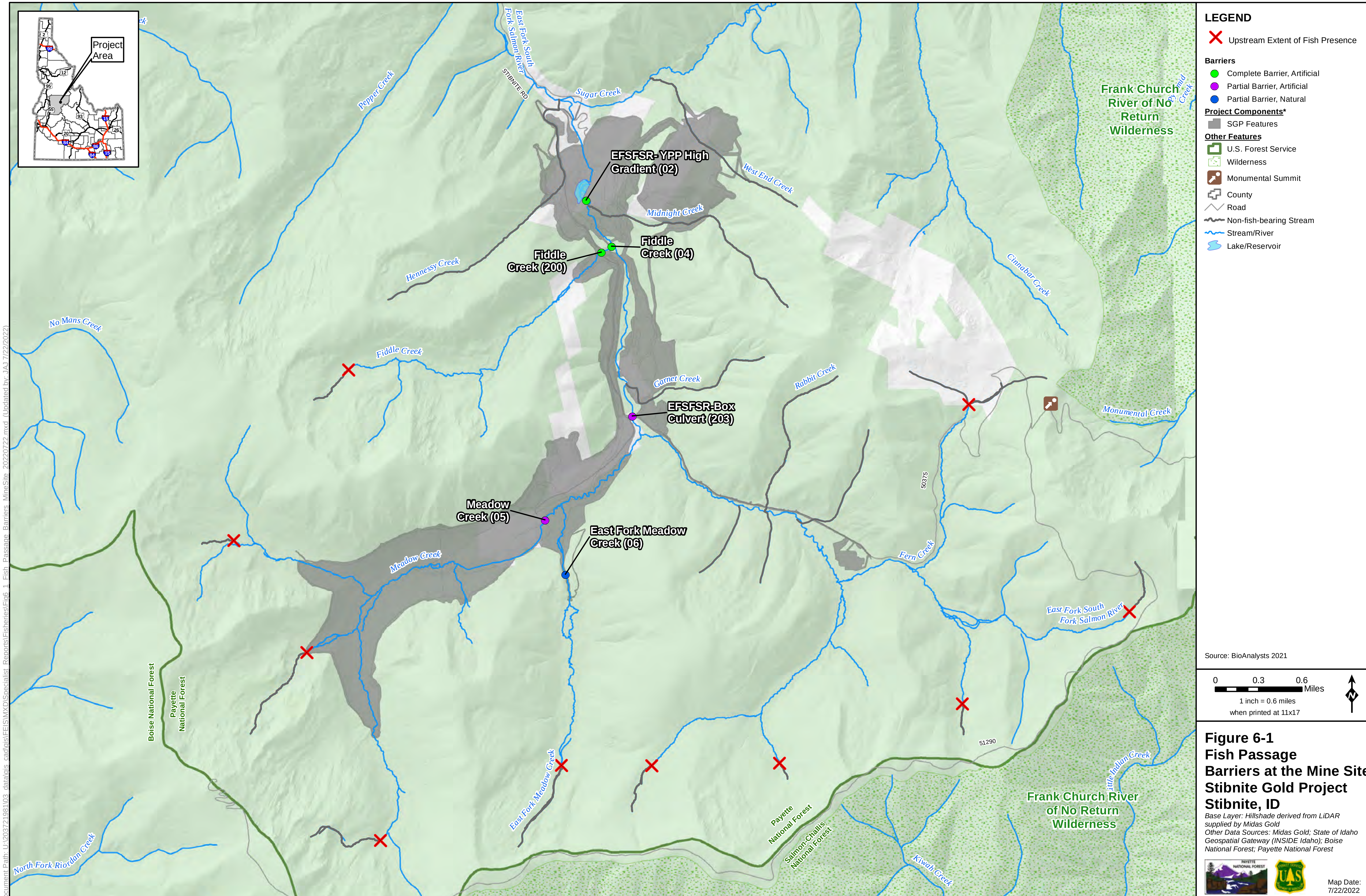


Figure 6-1
Fish Passage Barriers at the Mine Site
Stibnite Gold Project
Stibnite, ID

Base Layer: Hillshade derived from LiDAR supplied by Midas Gold
Other Data Sources: Midas Gold; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Table 6-6 Existing Fish Passage Barriers at the Proposed Mine Site and Potential Fish Habitat Under Baseline Conditions

Barrier	Status	Potential Bull Trout and Cutthroat Trout Habitat (km)		Potential Chinook Habitat (km)		Potential Steelhead Habitat (km)	
		Upstream from Barrier	Total Available[1]	Upstream from Barrier	Total Available[1]	Upstream from Barrier	Total Available[1]
East Fork SFSR above YPP (02) Artificial – Gradient	Complete	32.82[2] 19.54[3]	34.04[2] 22.12[3]	8.87[4] 25.88[3]	11.15[4] 28.16[3]	8.72[4]	10.67[4]
East Fork SFSR (203) Artificial – Box Culvert	Partial	26.43[2] 16.66[3]	34.04[2] 22.12[3]	6.29[4] 23.10[3]	11.15[4] 28.16[3]	6.89[4]	10.67[4]
Fiddle Creek (04) Artificial – Gradient	Complete	3.50[2] 0[3]	34.04[2] 22.12[3]	0[3,4]	11.15[4] 28.16[3]	0[4]	10.67[4]
Fiddle Creek (200) Artificial – Culvert	Complete	3.46[2] 0[3]	34.04[2] 22.12[3]	0[3,4]	11.15[4] 28.16[3]	0[4]	10.67[4]
Meadow Creek (05) Artificial – Gradient	Partial	8.23[2] 6.62[3]	34.04[2] 22.12[3]	1.02[4] 6.81[3]	11.15[4] 28.16[3]	1.69[4]	10.67[4]
East Fork Meadow Creek (06) Natural – Gradient	Partial	2.22[2] 0[3]	34.04[2] 22.12[3]	0[3,4]	11.15[4] 28.16[3]	0[4]	10.67[4]

[1] Not all of the Total Habitat is considered Usable Habitat
[2] Results based on Occupancy Probability for bull trout and cutthroat trout
[3] Results based on Critical Habitat for bull trout or modeled Critical Habitat for Chinook salmon
[4] Results based on usable Intrinsic Potential habitat
km = kilometer; YPP = Yellow Pine pit

6.1.3.4 Chemical Contaminants

This WCI is used to evaluate chemical contamination in surface waters in the analysis area at the mine site. The description of existing conditions relies upon data collected at eight surface water chemistry monitoring locations (**Figure 6-2**) and from information provided in the SGP Water Quality Specialist Report (Forest Service 2023c).

The description of chemical contaminants focuses on five constituents of concern: aluminum, copper, antimony, arsenic, and mercury. These five constituents of concern were selected because certain concentrations within the water or fish tissue can be detrimental to fish (potential effects to fish described in more detail below). **Table 6-7** provides the baseline conditions for these constituents of concern compared to the applicable criteria. Criteria were chosen based on consultation with the USFWS and NMFS. Explanations of the analysis criteria for the five constituents are provided in **Table 6-7** notes.

In sum, for the chemical contaminants WCI, the analysis area is “functioning at risk” or “functioning at unacceptable risk” (**Table 6-3**) due to existing levels of legacy mining contamination. No stream on the SGP mine site is considered functioning acceptably for chemical contaminants. The constituents that are currently exceeding thresholds are arsenic, antimony, copper, and mercury.

Aluminum

Aluminum can accumulate at the surface of the gill, leading to respiratory dysfunction and disruption of salt balance, and can cause mortality (EPA 2018). The aquatic life recommended criteria for aluminum for a site are based on site-specific conditions of pH, total hardness, and dissolved organic carbon. The EPA acute criteria for the same conditions as used in calculating the site-specific copper criteria based on the Biotic Ligand Model (Brown and Caldwell 2020b), range from 930 to 2,500 microgram per liter (µg/L) total recoverable aluminum, and the chronic criteria range from 360 to 1,700 µg/L total recoverable aluminum. The State of Idaho does not currently have a specific water quality standard for aluminum in place for the protection of aquatic life and the EPA criteria have not yet been adopted by the State of Idaho. Nevertheless, they reflect the most current knowledge of potential impacts of aluminum to aquatic life.

None of the assessment nodes show an exceedance of the analysis criteria for aluminum.

Copper

Copper and copper compounds are acutely toxic to fish and other aquatic life at low parts per billion levels (Eisler 1991, 2000; Hamilton and Buhl 1990). Copper is essential to the growth and metabolism of fish and other aquatic life, but it can cause irreversible harm at levels slightly higher than those required for growth and reproduction (Eisler 2000). Exposure to sublethal levels of copper can have a detrimental effect on the behavior of salmonids. McIntyre et al. (2012) evaluated the effects of copper exposure on juvenile Coho salmon (*Oncorhynchus kisutch*) predator avoidance behaviors and found that the exposed juveniles were unresponsive to their chemosensory environment, unprepared to evade nearby predators, and less likely to survive an attack sequence. Salmonids are known to avoid waters with sublethal concentrations of copper, and such concentrations alter other behavior as well.

The Biotic Ligand Model-based copper criteria indicated an exceedance in Sugar Creek at YP-T-1. However, of the 38 dissolved copper values reported for YP-T-1, only one value was higher than 0.00261 milligrams per liter (mg/L); therefore, it is likely that this single anomalous value was the result of a sampling, analytical, or data management error.

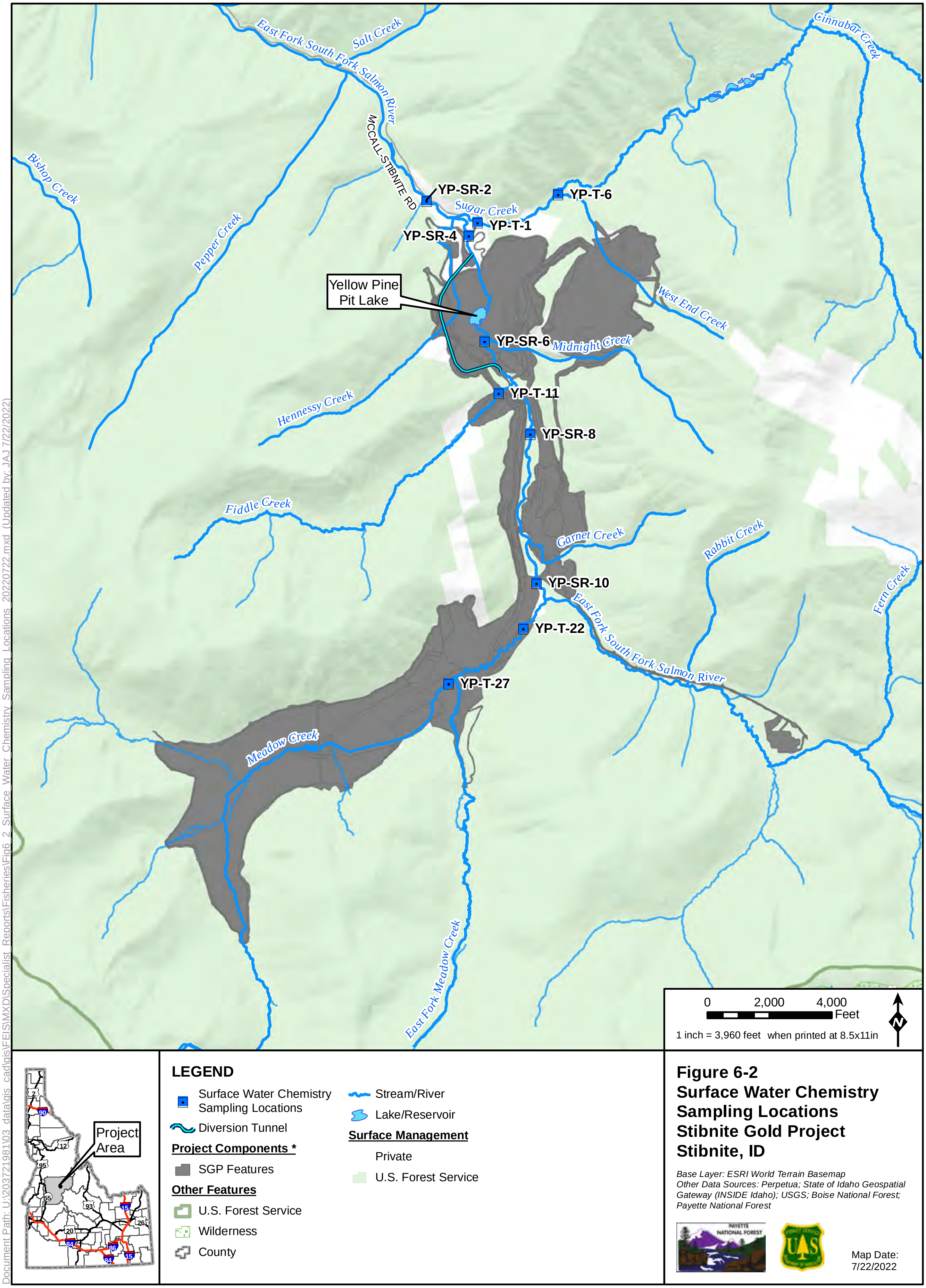


Figure 6-2
Surface Water Chemistry Sampling Locations
Stibnite Gold Project
Stibnite, ID

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Table 6-7 Average Measured Constituent Concentrations at Monitoring Locations

Constituent of Concern		Aluminum[1]	Copper[2]	Antimony[3]	Arsenic[4]	Mercury[5]
Analysis Criteria		38 µg/L	2.4 µg/L	5.2 µg/L	10 µg/L	0.002 µg/L (total mercury)
Node	Stream	Average Measured Baseline (µg/L)				
YP-T-27	Meadow Creek	1.2	0.3	6.1	35	0.0015
YP-T-22	Meadow Creek	1.2	0.3	8.1	34	0.0017
YP-SR-10	East Fork SFSR	9.4	0.2	12	25	0.0025
YP-SR-8	East Fork SFSR	9.4	0.3	17	28	0.0024
YP-SR-6	East Fork SFSR	9.8	0.2	19	31	0.0024
YP-SR-4	East Fork East Fork SFSR	12	0.3	31	63	0.0024
YP-SR-2	East Fork SFSR	14	0.2	22	45	0.0057
YP-T-11	Fiddle Creek	16	0.2	0.6	2	0.0018
YP-T-6	West End Creek	4.0	0.3	10.5	80	0.0042
YP-T-1	Sugar Creek	9.0	8.56[6]	34	13	0.159

Source: Midas Gold 2019a; SRK 2021

Analysis criteria pertain to fish species. Aluminum, arsenic, and mercury criteria are based on total concentrations while copper and antimony are based on dissolved concentrations.

[1] Aluminum: Lowest predicted for the SGP area based on Recommended Aquatic Life Criteria (EPA 2018); The same water quality data as in the Biotic Ligand Model were used (Brown and Caldwell 2020b).

[2] Copper criteria was derived using the Biotic Ligand Model per guidance contained in IDEQ (2017). 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 2020c), preliminary calculations using the Biotic Ligand Model and site-specific data have produced similar values to the standard derived using these regional classifications.

[3] Antimony does not have a specified NMFS or USFWS criteria and is based on EPA's human health chronic criterion for consumption of water and organisms is 0.0056 mg/L.

[4] 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. USFWS (2015b) directed EPA to ensure that the 10 microgram per liter recreational use standard is applied in all Water Quality Based Effluent Limitations (WQBELs) and Reasonable Potential to Exceed Calculations using the human health criteria and the current methodology for developing WQBELs to protect human health.

[5] 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. Where fish tissue is not readily available, then NMFS specified application of a 2.0E-0 µg/L threshold (as total mercury) in the interim. USFWS (2015b) directed EPA to use the 2001 EPA/2005 Idaho human health fish tissue criterion of 0.3 milligram per kilogram wet weight for WQBELs and reasonable potential to exceed criterion calculations using the current methodology for developing WQBELs to protect human health.

[6] Of the 38 dissolved copper values reported for YP-T-1, only one value was higher than 0.00261 mg/L; therefore, it is likely that this single anomalous value was the result of a sampling, analytical, or data management error.

µg/L = micrograms per liter; East Fork SFSR = East Fork South Fork Salmon River

Antimony

Known effects of antimony on aquatic organisms are more limited than for other metals and most available information pre-date the last three decades. Antimony can be toxic to aquatic life and bioaccumulate in tissues but has not consistently shown a tendency to biomagnify within aquatic food webs as other metals (Obiakor et al. 2017). Ambient water quality criteria for the protection of aquatic life have not been established for antimony. Average antimony concentrations currently exceed the analysis criteria at every assessment node except YP-T-11 in Fiddle Creek (**Table 6-6**).

Arsenic

Arsenic criteria are specific to the inorganic form, which is the more toxic form to aquatic life and humans. Arsenic exposure can occur through both waterborne concentrations and through dietary exposure for aquatic life and humans. In the State of Idaho, criteria exist for both the protection of human health and the protection of aquatic life. NMFS directed the human health standard be used until new aquatic life criterion can be promulgated by EPA. Arsenic can concentrate in tissues of fish, but it does not biomagnify. The effects of arsenic on fish health include enzymatic, genetic, and immune system failure (Kumari et al. 2017). Arsenic is a suspected carcinogen in fish and is associated with necrotic and fibrous tissues and cell damage, especially in the liver. Arsenic can result in immediate death through increased mucus production and suffocation. Other effects include anemia and gallbladder inflammation (NMFS 2014).

Arsenic concentrations currently exceed the analysis criteria at all assessment nodes except YP-T-11 in Sugar Creek (**Table 6-6**).

Mercury

Mercury in the environment originates from both natural and anthropogenic (human-caused) sources. However, regionally, the most significant source of mercury in Idaho is air deposition. Methylation is a process by which inorganic mercury is converted to the organic form (methylmercury), which can be present in the water column and is the form that bioaccumulates in tissues of living organisms. Consuming methylmercury that has accumulated in other organisms is the primary form for mercury exposure for humans. Currently, the value of 0.3 milligrams of methylmercury per kilogram of fish tissue wet weight is set at a level to protect the general public from negative effects of mercury during a lifetime of exposure through the consumption of fish. It also is the human health standard of 0.3 milligram per kilogram fish tissue criterion that is protective of aquatic life (IDEQ 2005, 2018). Although the water column-based aquatic life chronic criterion for mercury in Idaho is 0.000012 mg/L (Total), the preferred value used for interpreting risks of mercury contamination to aquatic life is the fish tissue criterion of 0.3 milligram per kilogram wet weight, the same value used for protection of human health (IDEQ 2018).

Predatory species in the food web concentrate the highest amounts of mercury in their tissues, a process called biomagnification. Salmonids in the streams and rivers of Idaho may be the dominant predator species and can concentrate mercury at levels several times that of prey species, such as algae, aquatic insects, and fish that do not feed exclusively on other fish. Generally, piscivorous fish (fish-eating) will bioaccumulate the highest concentration of mercury. Larger fish, which also tend to be older, are expected to bioaccumulate the most methylmercury.

Mercury concentrations currently exceed the 2.0E-6 mg/L analysis criteria at six of the ten nodes including in the East Fork SFSR at nodes YP-SR-10, YP-SR-8, YP-SR-6, YP-SR-4, YP-SR-2, and in West End Creek at node YP-T-6 (**Table 6-6**).

6.1.3.5 Peak/Base Flow

USGS data were used to derive peak flow statistics for the ten major drainages in the analysis area (**Figure 6-3**). Results from the peak flow analysis were summarized in the baseline study (HydroGeo 2012) and are presented in the Water Quantity Specialist Report (Forest Service 2023d). 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 cubic feet per second (cfs) for West End Creek to 237 cfs for the East Fork SFSR, and for a 500-year event they ranged from 13.4 cfs to 931 cfs, respectively. Table 6-5 in the SGP Water Quantity Specialist Report (Forest Service 2023d) provides the maximum flow predicted to occur for various return periods from a 1.5-year event up to a 500-year event.

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. 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 6-6 in the SGP Water Quantity Specialist Report (Forest Service 2023d) provides stream flow statistics derived from baseline measurements collected between 2012 and early 2016. The mean flows calculated from this dataset for the East Fork SFSR ranged from 4.47 cfs at the farthest upstream monitoring location to 31.31 cfs at the most downstream location.

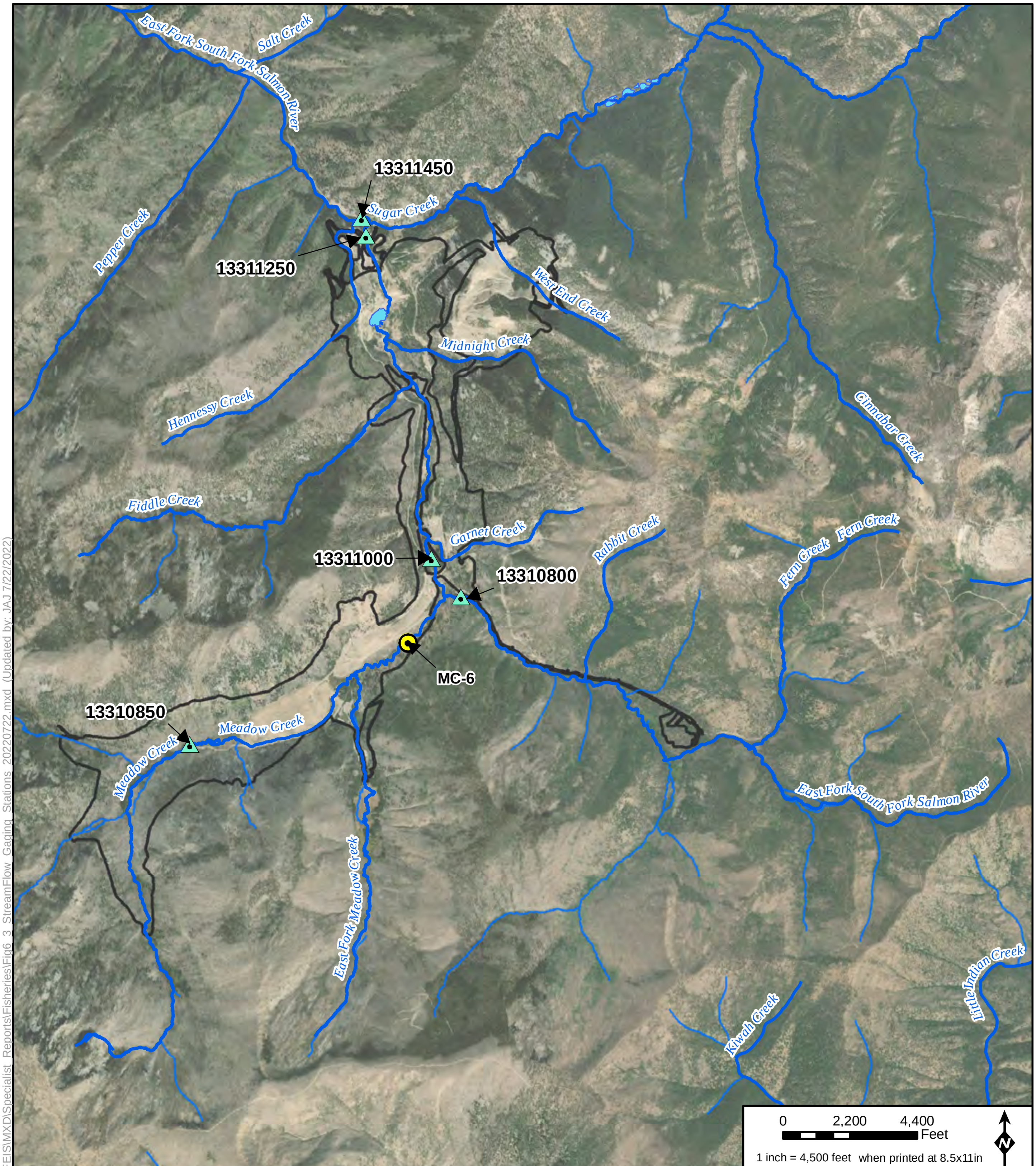
Table 6-8 shows average monthly stream flows during the August to March low flow period at five gaging stations and location in lower Meadow Creek in the SGP mine site streams for the years 1929 to 2017.

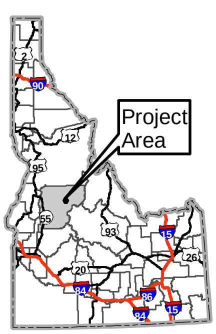
Climate change conditions resulting in increasing air temperatures would potentially transition snow to rain resulting in diminished snowpack and earlier season streamflow along with changes in groundwater recharge to aquifers that discharge to streams. Mean annual streamflow projections suggest a slight increase, but summer low flows are expected to decline (Halofsky et al. 2018).

Table 6-8 Average Monthly Stream Flow During the August-March Low Flow Period for 1929 to 2017 at USGS Gaging Stations and One Meadow Creek Location

Month	East Fork SFSR above Meadow: 13310800 (cfs)	East Fork SFSR at Stibnite: 13311000 (cfs)	East Fork SFSR above Sugar Creek: 13311250 (cfs)	Sugar Creek above East Fork SFSR: 13311450 (cfs)	Meadow Creek: 13310850 (cfs)	Meadow Creek: MC-6 (cfs)
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
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
Average	4.6	10.4	12.1	8.2	2.9	5.3

MC-6 is located in the lower reaches of Meadow Creek
cfs = cubic feet per second; USGS = U.S. Geological Survey.





LEGEND

USGS Active Gaging Station

MC-6

Project Components *

SGP Features

Stream/River

* SGP Features are associated with all Alternatives

Figure 6-3
Stream Flow Gaging Stations at the Mine Site
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI USA Topographic Basemap
Other Data Sources: United States Geological Survey; Perpetua; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

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6.2 Fish Density

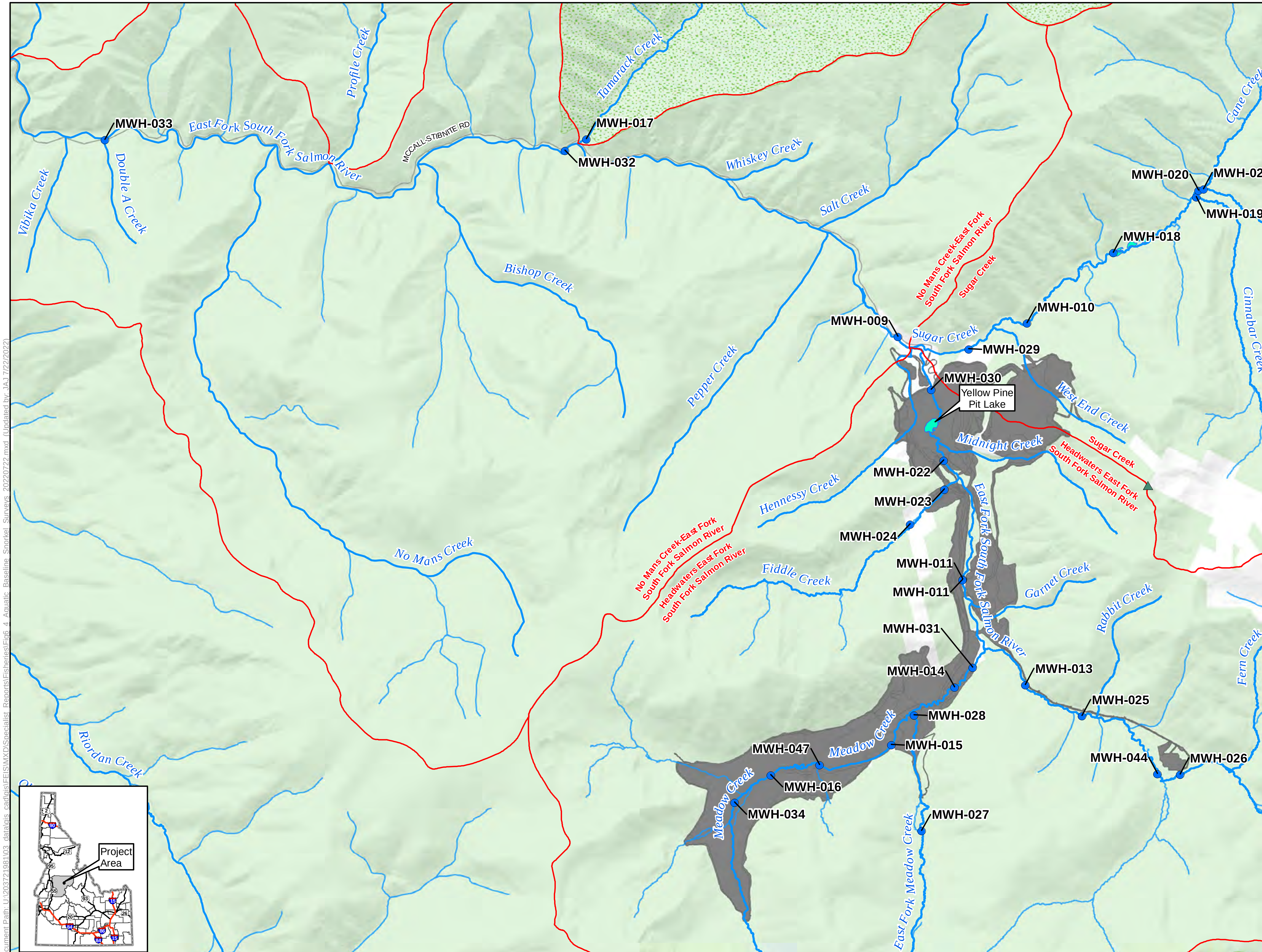
Fish density refers to the number of individuals per unit area (e.g., square meters) or volume (e.g., cubic meters). In this document, the term "linear density" is also discussed. Linear density as used here is the number of fish per linear length of stream, typically per meter. Because the wetted area of streams varies with flow, it is useful to have a metric that is non-flow dependent, (i.e., stream length).

6.2.1 Stream Estimates

Fish abundance data collected during snorkel surveys in the mine site area in 2015 were used in conjunction with fish mark-recapture survey data collected at the same sites at the same time to develop fish relative abundance and density estimates. The objective of comparing snorkeling abundance data to mark-recapture data was to develop a metric that could be applied to the large number of snorkeling sites evaluated from 2012 to 2015. The details of how fish densities were derived are included in AECOM 2020b.

Several approaches to estimating salmonid densities were applied to the mine site subwatersheds and these approaches are described in detail in MWH 2017 and GeoEngineers 2017. In summary, it was determined that fish densities based on the mark-recapture method represent fair to good estimates of the fish density for most stream reaches evaluated (GeoEngineers 2017). Note that this analysis determines fish densities that can be used to estimate the salmonid abundance at a specific stream reach at the time of sampling.

The results adjusting the salmonid species areal and linear densities at snorkel survey sites within and adjacent to the mine site subwatersheds from 2012 to 2015 (**Figure 6-4**) are summarized in **Table 6-9**.



LEGEND

- Fish Survey Site
- Subwatershed (HUC 12)

Project Components *

- SGP Features

Utilities

- Existing Communication Tower
- Wilderness
- County
- City/Town
- Monumental Summit
- Railroad
- Highway
- Access Road
- Stream/River
- Lake/Reservoir

Surface Management

- Private
- U.S. Forest Service

(MWH 2017)

0 0.3 0.6 Miles

1 inch = 0.71 miles when printed at 11x17

N

Figure 6-4
Aquatic Baseline Snorkel Survey Site Locations
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest, MWH and Stantec

Map Date: 7/22/2022

Table 6-9 Adjusted Salmonid Species Areal and Linear Densities at Snorkel Survey Sites Within and Adjacent to the Proposed Mine Site Subwatersheds from 2012 to 2015

Site ID (Downstream to Upstream)	Stream	Location	Year(s) Sampled	Mean Site Length (m) / Width (m)	Mean Fish Density – fish/m² (Mean Fish Linear Density – fish/m)			
					Chinook Salmon	Steelhead/ Rainbow Trout	Bull Trout	Westslope Cutthroat Trout
East Fork South Fork Salmon River Downstream from Sugar Creek and Tributaries, Sugar Creek, and Sugar Creek Tributaries								
MWH-033	East Fork SFSR	Upstream from Johnson Creek	2013	100/14.1	0.121 (1.701)	0.084 (1.174)	0.011 (0.148)	0.036 (0.500)
MWH-032	East Fork SFSR	Downstream from Tamarack Creek	2013, 2014	100/15.9	0.045 (0.675)	0.038 (0.574)	0.011 (0.162)	0.017 (0.250)
MWH-017	Tamarack Creek	Near confluence with East Fork SFSR	2012-2014	97/5.7	0.017 (0.097)	0.034 (0.195)	0.006 (0.032)	0.038 (0.218)
MWH-009	East Fork SFSR	Downstream from Sugar Creek	2012, 2014	95.5/8.4	0.059 (0.495)	0.050 (0.417)	0.022 (0.184)	0.014 (0.120)
MWH-029	Sugar Creek	Lower Reach	2012-2014	97/5.5	0.021 (0.116)	0.019 (0.107)	0.029 (0.162)	0.024 (0.134)
MWH-010	Sugar Creek	Middle Reach	2012-2014	97/5.5	0.023 (0.125)	0.024 (0.130)	0.048 (0.260)	0.022 (0.121)
MWH-018	Sugar Creek	Upper Reach	2012-2015	95.2/5.1	0.003 (0.018)	0.011 (0.057)	0.046 (0.234)	0.005 (0.025)
MWH-020	Sugar Creek	Upstream from Cinnabar Creek	2012-2013	95.5/3.6	0.002 (0.007)	0.006 (0.021)	0.080 (0.283)	NP
MWH-019	Cinnabar Creek	Lower Reach	2012-2015	93/2.8	NP	NP	0.095 (0.236)	0.006 (0.014)
MWH-021	Cane Creek	Lower Reach	2012-2013	55.5/3.0	NP	NP	0.107 (0.316)	NP
East Fork South Fork Salmon River Between Sugar Creek and YPP								
MWH-030	East Fork SFSR	Upstream from Sugar Creek	2012-2014	97/6.4	0.088 (0.561)	0.062 (0.394)	0.015 (0.093)	0.020 (0.125)

Site ID (Downstream to Upstream)	Stream	Location	Year(s) Sampled	Mean Site Length (m) / Width (m)	Mean Fish Density – fish/m² (Mean Fish Linear Density – fish/m)			
					Chinook Salmon	Steelhead/ Rainbow Trout	Bull Trout	Westslope Cutthroat Trout
East Fork South Fork Salmon River Between YPP and Meadow Creek and Tributaries								
MWH-022	East Fork SFSR	Upstream from Midnight Creek	2012-2014	80.3/7.8	0.606 (4.707)	NP	NP	0.009 (0.073)
MWH-011	East Fork SFSR	Near Mining Camp	2012-2015	97.8/5.3	0.397[1] (2.113)	NP	NP	0.027 (0.142)
MWH-023	Fiddle Creek	Lower Reach	2012-2014	97/2.0	NP	NP	NP	0.089 (0.181)
MWH-024	Fiddle Creek	Middle Reach	2012	22/2.0	NP	NP	NP	0.215 (0.430)
East Fork South Fork Salmon River Upstream from Meadow Creek								
MWH-013	East Fork SFSR	Near Meadow Creek Confluence	2012-2014	95.7/4.3	0.014 (0.061)	NP	NP	0.061 (0.263)
MWH-025	East Fork SFSR	Middle Reach	2012-2013, 2015	97/4.4	0.020 (0.088)	NP	NP	0.094 (0.418)
MWH-044	East Fork SFSR	Near Worker Housing	2013	100/3.0	NP	NP	NP	0.202 (0.608)
MWH-026	East Fork SFSR	Near Worker Housing	2012-2015	97.8/3.3	NP	NP	NP	0.044 (0.145)
Meadow Creek								
MWH-031	Meadow Creek	Near East Fork SFSR Confluence	2012	91/4.0	1.852[1] (7.407)	NP	0.004 (0.015)	0.067 (0.267)
MWH-014	Meadow Creek	Downstream from East Fork Meadow Creek Confluence	2013-2015	100/5.1	0.783[1] (4.020)	NP	NP	0.018 (0.090)
MWH-015	Meadow Creek	Downstream from TSF Buttress	2012-2014	97/4.8	0.005 (0.023)	NP	0.006 (0.028)	0.035 (0.167)
MWH-047	Meadow Creek	TSF Buttress	2013-2015	100/4.3	0.017 (0.072)	NP	0.002 (0.009)	0.044 (0.189)

Site ID (Downstream to Upstream)	Stream	Location	Year(s) Sampled	Mean Site Length (m) / Width (m)	Mean Fish Density – fish/m^2 (Mean Fish Linear Density – fish/m)			
					Chinook Salmon	Steelhead/ Rainbow Trout	Bull Trout	Westslope Cutthroat Trout
MWH-016	Meadow Creek	Along the TSF	2012, 2014-2015	97/3.9	NP	NP	0.005 (0.018)	0.168 (0.654)
MWH-034	Meadow Creek	Upper Reach	2013, 2015	100/3.2	NP	NP	0.004 (0.013)	0.075 (0.236)
East Fork Meadow Creek								
MWH-028	East Fork Meadow Creek	Near Confluence	2012-2014	97/2.4	2.573[1] (6.175)	NP	NP	0.041 (0.097)
MWH-027	East Fork Meadow Creek	In Meadow	2012-2014	97/1.6	NP	NP	NP	0.027 (0.044)

Source: MWH 2017

[1] Chinook salmon densities at these locations are higher than would naturally occur, as they were from translocated adults that spawned in a small, localized area.

Site IDs consisted of reaches ranging in length from 22 to 100 meters in length with most reaches set at 100 meters.

Daytime surveys only-all fish size classes combined

East Fork SFSR = East Fork South Fork Salmon River; m = meter; m^2 = square meter; NP = not present

6.2.2 Yellow Pine Pit Lake Estimates

Mark-recapture studies were undertaken at the YPP lake in 2018 and 2019 to evaluate movements of salmonids and to estimate population abundances (Brown and Caldwell 2019b, 2020a). **Table 6-10** summarizes the abundance estimate results. Detailed discussions are included in Brown and Caldwell (2019b, 2020a). No estimates were made for steelhead/rainbow trout due to the low numbers captured (i.e., five in 2018 and nine in 2019). In addition to bull trout, cutthroat trout, Chinook salmon and steelhead/rainbow trout, mountain whitefish were captured, but no abundance estimates were made.

The results indicate limited abundance of these salmonids in the YPP lake. Brown and Caldwell (2019b) notes that several hundred whitefish also were captured suggesting the lake can support a large number of fish given suitable habitat.

Table 6-10 Salmonid Population Abundance Estimates for the Yellow Pine Pit Lake in 2018 and 2019

Species	Abundance Estimate by Month and Year					
	May 2018	July 2018	September 2018	July 2019	August 2019	September 2019
Bull Trout	57	104	82	104	45	47
Westslope Cutthroat Trout	48	48	33	67	80	101
Chinook Salmon	No Tagged Juvenile Fish Returned					

Source: Brown and Caldwell 2019b and 2020a
Four rainbow trout were tagged but the sample size was too small for an abundance estimate.

6.3 Fish Species

The four federally listed or Forest Service sensitive fish species (i.e., special status fish species) known to be present in the analysis area are Chinook salmon, steelhead trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and westslope cutthroat trout (*Oncorhynchus clarkia lewisi*). Chinook salmon, steelhead, and bull trout are all federally listed as threatened under the ESA, and westslope cutthroat trout is a Forest Service sensitive species. Bull trout is also a Forest Service Management Indicator Species on the PNF and the BNF and is among the most sensitive to changes in environmental variables, such as water temperature, sediment, or contaminants.

Other native fish species found within the analysis area include mottled sculpin (*Cottus bairdii*), longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*), redside shiner (*Richardsonius balteatus*), mountain whitefish (*Prosopium williamsoni*), Pacific lamprey (*Entosphenus tridentatus*), and mountain sucker (*Catostomus platyrhynchus*). It is important to note that while Pacific lamprey may occur in the South Fork Salmon River, no observations of these fish have been made in snorkel surveys and electrofishing surveys, and eDNA studies conducted did not detect any lamprey DNA within or downstream from the project area.

AECOM 2020a includes a list of every fish species documented in the analysis area, including non-native fish introduced to the area.

6.3.1 Chinook Salmon

6.3.1.1 Status

The Snake River spring/summer-run Chinook Salmon Evolutionary Significant Unit was listed as threatened under the ESA in 1992 (57 Federal Register 14653). Most Chinook salmon in the analysis area are considered “summer-run” fish (NMFS 2017). These fish are found throughout the analysis area, including naturally in the SFSR subbasin and the East Fork SFSR drainage upstream to the YPP lake within the mine site and upstream from the YPP when transplanted as discussed below.

A cascade with a current slope of 22 percent, caused by historic mining activities, located upstream from YPP lake is a barrier to further upstream natural migration for adult Chinook salmon. Juvenile fish, however, can move downstream through the cascade because adult Chinook salmon have been reintroduced upstream from the YPP lake by the IDFG. Spawning-ready adult Chinook salmon are periodically translocated from the SFSR to upstream from the barrier with support from the Nez Perce Tribe.

Historically, the Snake River was considered the Columbia River Basin’s most productive drainage for salmon, supporting more than 40 percent of all Columbia River spring/summer Chinook salmon (Fulton 1968; NMFS 1995 in NMFS 2017). Strong runs of Chinook salmon returned each year to spawn and rear in the mainstem and tributary reaches of the Snake River extending upstream to Shoshone Falls near Twin Falls, Idaho. The fish also ranged into most Snake River tributaries stretching across portions of the states of Oregon, Washington, Idaho, and Nevada.

Currently, the stock has been severely depleted from a variety of activities, including hydropower systems, hatcheries, harvest, fish passage, and pathogens/predation/competition. Chinook salmon remain at risk of becoming endangered within 100 years (NMFS 2017). Multiple threats across their life cycle contribute to their current status and need to be addressed to ensure that Snake River spring/summer Chinook salmon populations can be self-sustaining in the wild over the long term (NMFS 2017).

The proposed status for the East Fork SFSR population is considered “maintained,” indicating there is a moderate (25 percent or less) risk of extinction over 100 years (NMFS 2017).

6.3.1.2 Critical Habitat and Essential Fish Habitat

Critical habitat for Chinook salmon was originally designated in 1993 (58 Federal Register 68543) and re-designated in 1999 (64 Federal Register 57399). As defined, designated Critical Habitat includes all “river reaches presently or historically accessible (except reaches above impassible natural barriers (including Napias Creek Falls [Napias Creek tributary to the Salmon River]) and Dworshak and Hells Canyon Dams)” (64 Federal Register 57403). Thus, designated Critical Habitat includes all presently and historically accessible rivers and streams within the analysis area, except for the Payette River drainage. The Payette River drainage historically supported anadromous fish but is excluded by rule from being designated as Critical Habitat because it is now upstream from the Hells Canyon Dam Complex.

Given the very broad definition of Critical Habitat for Chinook salmon, a more refined description of the affected environment for the SGP was needed. Two different sets of information were used to address this need. First, data on the distribution of Chinook salmon occurrences (fish observations and spawning redd counts) were compiled for 1985 to 2011 to determine the actual locations occupied by Chinook salmon (Isaak et al. 2017). The premise was that such locations with species presence demonstrated empirical evidence of Chinook salmon Critical Habitat.

Second, available Geographic Information System data was used to model what likely is Critical Habitat for Chinook salmon within the mine site area upstream from the YPP (ESS 2019a). This approach identified a 12 percent maximum gradient (percent slope) within occupied NHD lines (Isaak et al. 2017), meaning Chinook salmon can migrate upstream through stream reaches that have a less than 12 percent gradient. Within the SGP mine site, stream segments below the gradient cut-off point were modeled as Critical Habitat, (i.e., areas with steeper slopes were not identified as modeled Critical Habitat) (ESS 2019a). Currently, there is an estimated 26 km of modeled Chinook salmon Critical Habitat upstream from the YPP lake barrier (**Figure 6-5**).

The EFH characteristics important for anadromous salmon for freshwater spawning and rearing include water quality, water quantity, substrate, floodplain connectivity, forage, natural cover, and reaches free of artificial obstructions for freshwater migration (NMFS 2017). EFH has been designated for Chinook salmon within all streams and other waterbodies occupied or historically accessible to Chinook salmon (67 Federal Register 2343, 2002).

6.3.1.3 Physical and Biological Features and Recovery Plan

NMFS (2017) designated the following sites and essential physical and biological features as primary constituent elements for anadromous salmon and steelhead in freshwater:

- Freshwater spawning (water quality, water quantity, and substrate);
- Freshwater rearing (water quantity and floodplain connectivity, water quality and forage, and natural cover);
- Freshwater migration (free of artificial obstruction, water quality and quantity, and natural cover).

These physical and biological features have been designated because of their potential to develop or improve and eventually provide the needed ecological functions to support species recovery (NMFS 2017). The 2017 NMFS Recovery Plan identified recovery strategies for Snake River spring/summer Chinook salmon for the Lower East Fork SFSR and Upper East Fork SFSR 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.

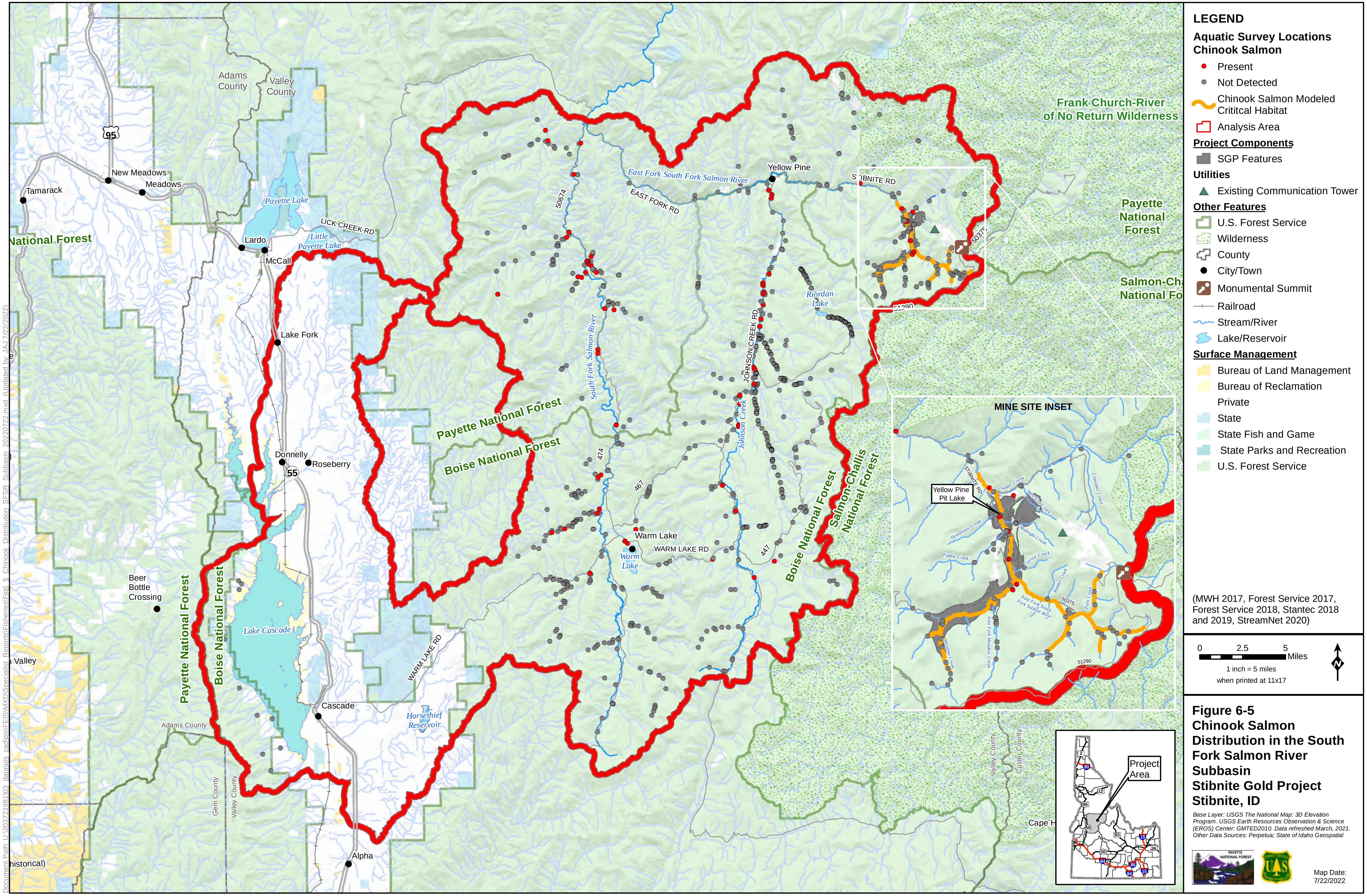


Figure 6-5
Chinook Salmon Distribution in the South Fork Salmon River Subbasin
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial

Map Date: 7/22/2022

6.3.1.4 Temperature Requirements and Baseline Conditions

Chinook salmon have different temperature requirements or limitations for their various life stages. Exceeding thresholds could impact various life-stages and could cause fish to avoid areas or even mortality. The periodicity (i.e., recurring intervals) of each life stage and the accepted stream temperature threshold ranges for various temperature considerations for each species were compiled from regulatory standards and other relevant literature into ESS 2022b, a condensed version of which is presented in **Table 6-11**.

Using the QUAL2K predicted monthly MWMT stream values, and stream segment lengths from the SPLNT Model Refined Modified Proposed Action (ModPRO2) report (Brown and Caldwell 2021a), the length of proposed mine site streams within the temperature thresholds identified in **Table 6-11** was estimated. The QUAL2K stream segments that contain the segments in which there was modeled habitat with Intrinsic Potential (IP) (see **Section 6.3.1.1**) were evaluated for thermally suitable habitat (based on MWMT) for all life stages except juvenile rearing. However, it is important to note, the IP model applied more refined spatial scale (i.e., shorter reaches) than were applied in the SPLNT model. Hence, the stream segments evaluated for temperature could have lengths that extended beyond the ends of the segments evaluated for IP. Therefore, the stream lengths are not identical, meaning the length of stream habitat meeting the temperature thresholds may be longer than the length of stream habitat with IP.

For juvenile rearing, the QUAL2K stream segments that contain segments in which there was modeled Critical Habitat (see **Section 6.3.1.2**) were evaluated for thermally suitable habitat. Modeled Critical Habitat extends to a much larger area than IP because the criteria defining Critical Habitat is based on a 12 percent gradient cut-off, whereas IP criteria are based on channel conditions, gradient, and valley bottom conditions (see **Section 6.3.1.1**). It is assumed that juvenile Chinook salmon are able to access a larger range of habitat conditions than the other life stages, and therefore, less restrictive habitat conditions were applied in the analysis.

The East Fork SFSR from 0.89 kilometer (km) downstream from the confluence with Sugar Creek to around 3.4 km upstream from the confluence with Meadow Creek (total of 8.59 km), and around 4.35 km of Meadow Creek were evaluated for the temperature thresholds. **Table 6-11** shows that of the entire 12.93 km of potential habitat is within the temperature thresholds for adult spawning and juvenile rearing; however, only 9.49 km (73.4 percent) and 3.44 km (26.6 percent) is within the water temperature threshold for adult migration and incubation and emergence based on comparison to summer and fall MWMT. Of these total lengths, 10.92 km of suitable conditions for spawning and rearing, and all of the suitable conditions for migration and incubation and emergence are upstream from the YPP lake cascade barrier.

It is important to note that they do experience significant diurnal variations, and that for mobile life stages (i.e., adults and juveniles), if MWMT are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges.

Table 6-11 Chinook Salmon Optimal Temperature Thresholds and Modeled Length of Stream Within the Water Temperature Thresholds in July and September

Life Stage / Season[1]	Range of Optimal Temperature Thresholds (°C)	Total Stream Length Above YPP / Below YPP	Stream Length Within Optimal Temperature Threshold (km)		
			Above YPP	Below YPP	Total
Adult Migration/ May – September[2]	12-19	10.92 / 2.01	7.48	2.01	9.49 (73.4%)[3]
Adult Spawning/ July – September[4]	4-14	10.92 / 2.01	10.92	2.01	12.93 (100%)[3]
Incubation/Emergence/ July – April[4]	6-10	10.92 / 2.01	3.44	0	3.44 (26.6%)[3]
Juvenile Rearing/ Year-round[2]	10-20	17.51 / 2.01	17.51	2.01	19.53 (100%)[5]

Source: EPA 2003, Poole et al. 2001, IDAPA 58.01.02
[1] The months in the life stage are not applicable for comparison to the SPLNT model results.
[2] Analysis based Summer Maximum (July) 7 Day Average of the Daily Maximum.
[3] Percent of stream length within the modeled usable Intrinsic Potential habitat.
[4] Analysis based on Fall Maximum (September) 7 Day Average of the Daily Maximum.
[5] Percent of stream length within the modeled Critical Habitat.
% = Percent; °C = degrees Celsius; km = kilometers; YPP = Yellow Pine pit

6.3.1.5 Distribution

Chinook salmon are distributed throughout the analysis area (**Figure 6-5**); however, this section focuses on the mine site area and the travel corridor on Johnson Creek Road and the Burntlog Route. The East Fork SFSR population was historically a large population, with spawning areas throughout the East Fork SFSR mainstem and Johnson Creek (NMFS 2017). Anadromous fish passage in the East Fork SFSR upstream from the YPP lake was blocked in 1938 when activities for mining diverted the East Fork SFSR in surface ditches and later into a bypass tunnel (constructed in 1943). The East Fork SFSR was routed back through the YPP after mining ceased, but the remaining 22 percent gradient cascade, just upstream from the YPP lake, prevents Chinook from traveling upstream. There is a supplementation program to spawning habitat in Meadow Creek above the YPP, discussed below.

Chinook salmon occurrence in the analysis area varies by life stage. Adult migration occurs between May and mid-September, with most reaching the upper East Fork SFSR watershed by late July and August. Spawning occurs from mid-July to September, with peak spawning in August, particularly in the mine site, where spawning is not typically observed before mid-August. Egg incubation begins after spawning, and emergence of larval fish occurs between January and April. Juvenile rearing occurs year-round and juvenile outmigration to the ocean occurs between mid-March to November (ESS 2022b).

Surplus Supplementation

The Nez Perce Tribe began the Johnson Creek Artificial Propagation Enhancement Project in 1998 in response to critically low numbers of returning adult Chinook salmon to Johnson Creek (Columbia River Inter-Tribal Fish Commission 2012). The program uses only natural-origin returns for broodstock, and currently has an annual target release level of 100,000 yearling smolts into Johnson Creek (NMFS 2016).

The Nez Perce Tribe and IDFG translocated adult Chinook salmon from the SFSR to Meadow Creek (upstream from the YPP), but not as part of the Johnson Creek Artificial Propagation Enhancement Project. This out-planting program has been highlighted in the IDFG Fisheries Management Plan (IDFG

2019a). Between 2008 and 2017 (excluding 2014), Chinook salmon spawners were released into Meadow Creek when there are surplus adults from the McCall Fish Hatchery South Fork Salmon River Chinook Salmon Mitigation Program. It should be noted that any juvenile Chinook salmon upstream from the YPP lake cascade barrier were entirely human assisted; w there is currently no volitional passage of Chinook salmon upstream from the YPP lake barrier.

Redd Surveys

A redd is defined as a depression or hollow that a salmon creates in the stream substrate (i.e., bed) to deposit eggs. The Nez Perce Tribe has conducted redd surveys for Chinook salmon upstream from the YPP lake in the East Fork SFSR, Meadow Creek, and in other SFSR subbasin streams (e.g., Lower East Fork SFSR, Burntlog Creek, Johnson Creek, Sugar Creek, and Tamarack Creek) since 2008 (Nez Perce Tribe unpublished data 2018; Rabe et al. 2018). **Table 6-12** shows the number of redd counts between 2008 and 2018 in the East Fork SFSR and tributaries within or near the mine site and those that might be affected by the travel corridor on Johnson Creek Road and the Burntlog Route.

Redds observed upstream from the YPP cascade barrier are all from translocated Chinook salmon. During years when adults were translocated into Meadow Creek, redd counts varied from 24 (2017) to 128 (2016). In general, lower numbers of Chinook salmon redds were found in the East Fork SFSR, likely because Chinook salmon are translocated to Meadow Creek and tend to spawn in close proximity to their introduction sites and the fact that the fish are ready to spawn at the time of release. Chinook salmon redds documented in the East Fork SFSR (between the YPP lake and Meadow Creek) have ranged from 1 (2013) to 13 (2011), with an average of 5 redds per year over 11 years. The number of Chinook salmon translocated and the number of redds observed demonstrate a clear, positive relationship. As the number of adults translocated increased so did the number of redds.

Johnson Creek, a tributary of the East Fork SFSR downstream from the mine site, had the highest numbers of Chinook salmon redd counts in the Upper East Fork SFSR watershed, ranging from 193 (2008, 2011) to 376 (2014), with an average count of 207 redds per year.

Flow-Productivity

The effects of streamflow changes on Chinook salmon productivity within the mine site area were based upon a SGP flow-productivity model that was developed using the flow-productivity modeling approach for the Big Creek Water Diversion Project (NMFS 2013). Productivity (also referred to as adult or whole life cycle productivity) is estimated as the ratio of the number of returning adults to the total number of fish allowed to spawn naturally during the brood year (Morrow 2018). Therefore, productivity is a unitless measure of the adult escapement. The SGP flow-productivity model then regresses productivity against flow metrics using simple linear regression to output flow-productivity (ESS 2022c).

Table 6-12 Chinook Salmon Redd Counts in Upper East Fork South Fork Salmon River and Johnson Creek Watersheds Between 2008 and 2021

Year	Streams from Upstream to Downstream							
	Meadow Creek - Proposed TSF to Confluence (1.7 km)	East Fork SFSR - Between Meadow Creek and Fiddle Creek (2.4 km)	East Fork SFSR – YPP Lake to Sugar Creek (1.1 km)	Sugar Creek -Cinnabar Creek to Confluence (4.3 km)	East Fork SFSR – Sugar Creek to Quartz Creek (15 km)	East Fork SFSR -Town of Yellow Pine to Confluence (0.8 km)	Johnson Creek -Upper Johnson Creek to Confluence (45.5 km)	Burntlog Creek – East Fork Burntlog Creek to Confluence (8.5 km)
2008	0	0	0	3	2	0	193	30
2009	41	10	10	40	46	2	235	16
2010	74	81	3	43	3	0	345	52
2011	89	131	0	10	73	3	194	41
2012	50	7	10	17	47	0	234	63
2013	40	1	3	11	46	0	201	34
2014	0	0	7	17	42	2	376	41
2015	64	3	3	5	43	0	257	20
2016	128	7	18	13	55	0	253	28
2017	24	0	3	2	16	ND	ND	ND
2018	0	0	0	11	18	ND	ND	ND
2019	0	0	1	0	18	0	68	10
2020	0	0	1	0	11	0	107	6
2021	0	0	0	0	16	0	101	6

Source: Nez Perce Tribe unpublished data; Rabe et al 2018, Rabe 2021
East Fork SFSR = East Fork South Fork Salmon River; km = kilometers; ND = No Data; TSF= tailings storage facility; YPP = Yellow Pine pit

The SGP flow-productivity model uses proxy data from nearby Johnson Creek and assumes that the physical and biological conditions in Johnson Creek are relatable to the mine site streams. However, there are many physical differences between upper East Fork SFSR and Johnson Creek, including drainage size, flow regime, and Chinook populations. Also, the SGP flow-productivity model assumes a fixed number of Chinook salmon spawners each year that occurred in Johnson Creek to occur across all of the mine site streams (ESS 2022c). Therefore, these flow-productivity estimates provide a rough approximation of changes in productivity due to flow within the mine site. Additionally, the differences in streamflow regimes, physical habitat characteristics, population sizes, and other differences between Johnson Creek and the mine site streams creates uncertainty that cannot be addressed with the available data.

The flow-productivity analysis predicts changes in productivity based solely on streamflow changes and it does not factor in additional habitat changes that would also occur in the analysis area (e.g., direct loss of habitat, water temperature changes, etc.) The model outputs help to show the relative effects of flow modifications on Chinook salmon productivity at the reach level. Chinook salmon productivity was assessed in four stream reaches (East Fork SFSR above Meadow Creek, East Fork SFSR at Stibnite, East Fork SFSR above Sugar Creek, and lower Meadow Creek). The lower Meadow Creek site (MC-6) was set up to supplement the system of USGS gages. MC-6 specifically examines conditions in the portion of Meadow Creek that is routed through a constructed channel to divert the stream away from historical mine waste.

The flow-productivity model outputs productivity values that are compared to baseline productivity values to calculate the predicted annual percent change in Chinook salmon productivity from baseline productivity. The baseline Chinook salmon productivity of 1.06 was derived from productivity data collected on Johnson Creek (Morrow 2018). Again, the interpretation of the predicted annual percent change in productivity is based upon the baseline productivity calculated with Johnson Creek data because data is not available within the mine site. Because the productivity value is greater than 1.0, if Johnson Creek were unimpaired, there would be slightly more returning adults than the spawning brood year.

Intrinsic Potential

To assist with describing the existing conditions and predicted potential changes in Chinook salmon habitat at the mine site, a site-specific IP model was developed to derive a predictive metric for streams in the mine site that could potentially support spawning through early-rearing habitat for the Chinook salmon. In general, the IP is the underlying capacity (i.e., potential) of a stream to provide habitat based on channel slope and dimensions. The IP model was used to estimate the potential for spawning, incubation, and rearing habitat in the headwaters of the East Fork SFSR subwatershed (**Figure 6-6**). This subwatershed encompasses the mine site where mining-related activities are proposed; which includes the East Fork SFSR and tributaries upstream from YPP, Meadow Creek and East Fork Meadow Creek, East Fork SFSR and tributaries between YPP and Sugar Creek, and East Fork SFSR downstream from Sugar Creek. Flow reductions attributable to the project would typically be less than 1 percent with a maximum monthly difference of 3 percent. Flow differences of this magnitude would have little influence on the wetted width, bankfull width, gradient, valley bottom width, and valley width ration parameters used to assess IP. However, Chinook salmon are known to occupy Sugar Creek under its existing IP condition which would not be measurably modified by the project.

The output from the IP model provides a classification that varies from “negligible” (minimal IP to support habitat) to “high” (likely to provide habitat) with low and medium classifications in between. See Intrinsic Potential Model Chinook Salmon and Steelhead Technical Memorandum (ESS 2022d) for a detailed description and discussion of the model and results.

The methodology followed the IP approach developed by Cooney and Holzer (2006) for the Interior Columbia Basin but was refined for the mine site using site-specific data (i.e., Light Detection and Ranging (LiDAR) topography and field data). The IP modeling used key landscape characteristics of gradient, channel characteristics, and valley confinement (i.e., valley bottom) at a local SGP-specific scale (i.e., the mine site) to estimate the linear potential within the subwatershed to support spawning and early-rearing habitat for Chinook salmon. Field data (wetted width and bankfull width) and modeled parameters were used as inputs to the IP model. Other important information for the model included the following:

- Modeling was performed at a 30-meter linear reach-scale; and
- The IP model analysis identified Chinook salmon spawning and early-rearing habitat potential for waters upstream from the YPP cascade barrier; however, this area is not currently accessible by natural upstream migration of adult fish.

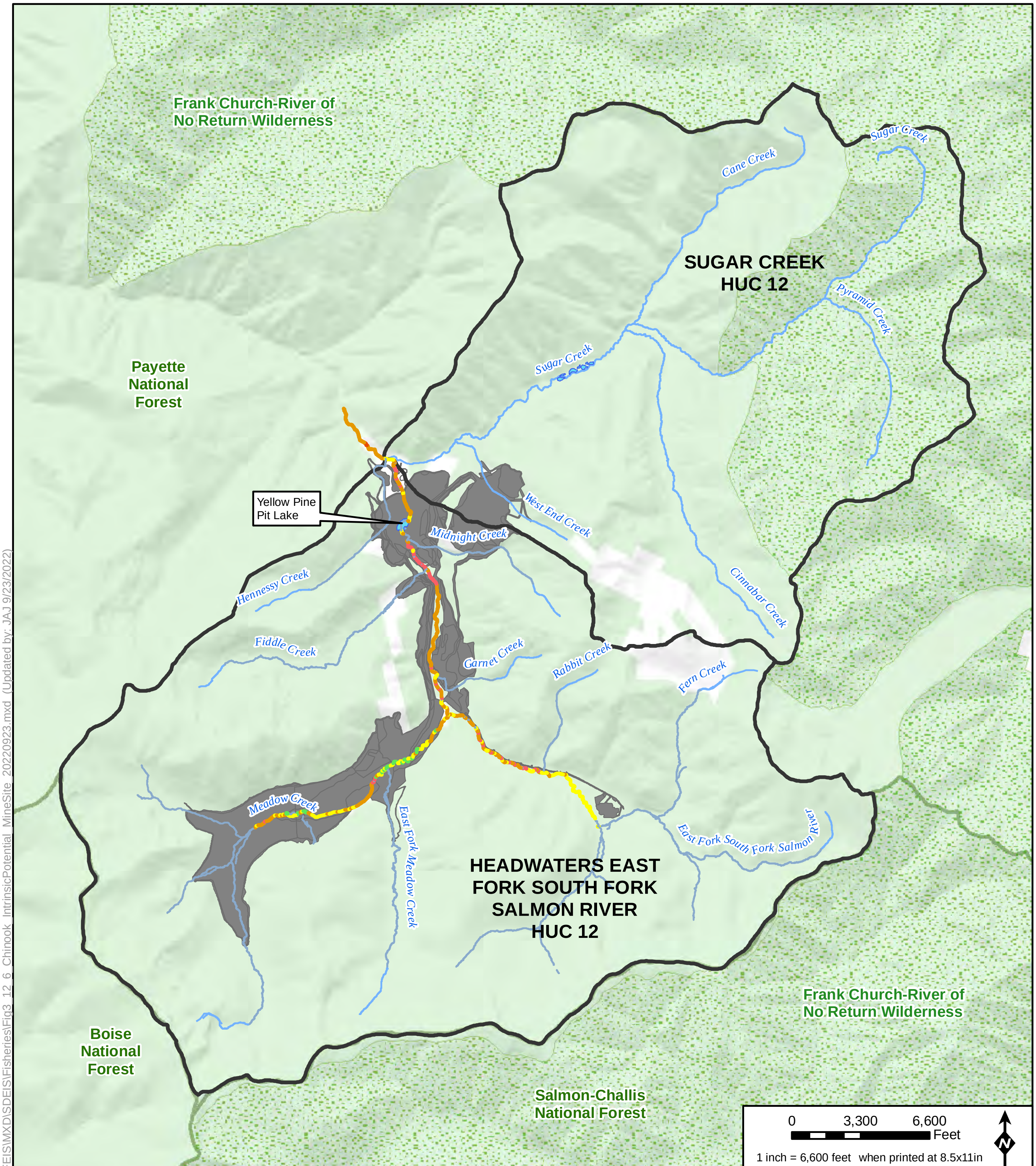
Table 6-13 shows the input Chinook and steelhead IP model parameters and their source(s).

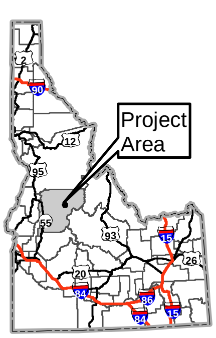
The IP model was used to evaluate over 51 km of stream habitat. Under baseline conditions, modeled IP stream length shows only 11.1 km of the 51 km have potential spawning, incubation, and early-rearing habitat for Chinook salmon (**Figure 6-6** and **Table 6-14**) The majority of the IP habitat is rated as low potential, followed by medium and negligible, with high potential having the least amount available (**Table 6-14**).

Table 6-13 Data and Parameters Used in the Intrinsic Potential Model for Chinook Salmon and Steelhead

Parameter	Chinook	Steelhead	Source
Wetted Width (WW)	≥3.6 m	N/A	PIBO and Rio ASE field data Rio ASE wetted width (WW) calculation: WW = BF * 0.799
Bankfull Width (BF)	N/A	≥3.8 m	PIBO and Rio ASE field data Rio ASE BF calculation based on drainage area (DA) and then converted to meters: BF (ft)[1] = 6.868 * $DA^{0.407}$
Gradient (% slope)	<7%	<7%	Derived in ESRI ArcGIS based on LiDAR data and streamline segment
Valley Bottom Width (VBW)	Stream Reach Dependent	Stream Reach Dependent	Derived in ESRI ArcGIS using the Valley Bottom Extraction Tool (VBET)
Valley Width Ratio (VWR)	VBW / BF	VBW / BF	Derived in ESRI ArcGIS by dividing the VBW by its corresponding segments bankfull width (VWR = VBW/BF)

Source: ESS 2022d
[1] The equation used to calculate the wetted width uses feet (ft), the total is then the BF is converted to meters (m)
< = less than; ≥ = greater than or equal to; % = percent; DA = drainage area; ft = foot; LiDAR = light detection and ranging; m = meter; N/A = not applicable; PIBO = Pacific Anadromous Fish Strategy/Inland Fish Strategy Biological Opinion





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LEGEND

Subwatershed (HUC 12)

Chinook Salmon Intrinsic Potential
- High
- Medium
- Low
- Negligible
- None

Project Components
- Mine Site Components

Other Features
- U.S. Forest Service
- Wilderness
- County
- Stream/River
- Lake/Reservoir

Surface Management
- Private
- U.S. Forest Service

Figure 6-6
Chinook Salmon Intrinsic Potential Habitat Within the Mine Site Subwatershed
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI World Terrain Basemap
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Ecosystem Sciences; Boise National Forest; Payette National Forest

Table 6-14 Chinook Salmon Intrinsic Potential Habitat Under Baseline Conditions

Chinook Salmon IP[1]	East Fork SFSR and Tributaries Upstream from YPP Lake[2]		Meadow Creek and East Fork Meadow Creek		East Fork SFSR and Tributaries between YPP Lake and Sugar Creek		East Fork SFSR Downstream from Sugar Creek		Total IP Habitat in Mine Site Area (km)[3]
	Length (km)	Percent Total Length	Length (km)	Percent Total Length	Length (km)	Percent Total Length	Length (km)	Percent Total Length	
High	0	0	0.66	3.9	0	0	0	0	0.66
Medium	0.66	2.3	0.90	5.3	0.18	4.5	0.03	2.7	1.76
Low	4.29	14.8	1.21	7.1	0.84	19.4	1.02	91.9	7.36
Negligible	1.05	3.6	0.10	0.6	0.15	3.5	0.06	5.4	1.36
Total IP Habitat	6.00	20.7	2.86	16.97	1.17	27.0	1.11	100.0	11.1 (22%)[4]
Total Length Evaluated	29.01	-	16.93	-	4.34	-	1.11	-	51.39

[1] Results are presented in the table as the length (kilometers) of stream with usable IP. For Chinook salmon the IP is rated as high, medium, low, and negligible. “Useable” habitat is defined as all of these classes combined (usable = high + medium + low + negligible).

[2] Does not include the East Fork SFSR tributaries Meadow Creek and East Fork Meadow Creek.

[3] Does not include Sugar Creek.

[4] Total percent of IP habitat within the total length of streams evaluated.

% = percent; East Fork SFSR = East Fork South Fork Salmon River; IP = Intrinsic Potential; km = kilometer; YPP = Yellow Pine pit

6.3.2 Steelhead

6.3.2.1 Status

The Snake River Basin Steelhead Distinct Population Segment (DPS) is found in the East Fork SFSR drainage and its tributaries downstream from the YPP lake. Steelhead were initially listed as federally threatened under the ESA in August 1997 (62 Federal Register 43937) with the geographic listing area including all natural-origin populations of steelhead in the Snake River Basin. In 2006, Snake River steelhead were subsequently reclassified as a threatened DPS (71 Federal Register 834).

The Interior Columbia Technical Recovery Team (ICTRT) identified five extant major population groups (MPGs) in the Snake River Basin steelhead DPS, which includes the Salmon River Steelhead MPG (ICTRT 2008 as cited in NMFS 2017). The Salmon River Steelhead MPG consists of 12 demographically different steelhead populations all of which are presently considered non-viable (NMFS 2017). The Salmon River Steelhead MPG includes the SFSR population (NMFS 2017), which is within the analysis area. The SFSR population includes fish in the SFSR and all of its tributaries, except the Secesh River. This population is found within three major tributaries in the analysis area: the East Fork SFSR, Johnson Creek, and the Upper SFSR. The SFSR steelhead population is considered “maintained,” with a tentative moderate abundance/productivity risk and low distribution and diversity risk (ICTRT 2008). This population is targeted to achieve a proposed status of “viable,” which requires a minimum of low abundance/productivity risk.

Habitat limiting factors for the SFSR steelhead population are linked to human disturbances, such as mining and road construction. Human disturbances and heavy precipitation make the subbasin susceptible to large sediment-producing events that degrade habitat quality for steelhead. Roads located near streams encroach on riparian habitat, limit potential sources of large woody debris, and create passage barriers at road-stream crossings. Priorities for addressing limiting factors in the SFSR steelhead population include mitigation and elimination of sediment inputs from human-caused disturbances and elimination of artificial fish passage barriers.

6.3.2.2 Critical Habitat

The final rule designating Critical Habitat was implemented in January 2006 (70 Federal Register 52630). Critical Habitat for Snake River Basin steelhead is designated throughout much of the analysis area (**Figure 6-7**). Within the areas directly affected by construction and operations, Critical Habitat is designated in the East Fork SFSR drainage to approximately 0.4 km upstream from the confluence with Sugar Creek, including Sugar Creek, and two creeks in the Johnson Creek watershed, Burntlog Creek, and Riordan Creek. Critical habitat for steelhead is not designated upstream from the YPP lake; however, it is assumed that steelhead were found in the headwaters of the East Fork SFSR prior to 1938. Similar to Chinook salmon, the YPP lake cascade barrier precludes steelhead from migrating upstream from the YPP lake, however, NMFS does not consider habitat upstream from the YPP lake to be designated Critical Habitat for steelhead (70 Federal Register 52630).

6.3.2.3 Physical and Biological Features and Recovery Plan

NMFS designated the following essential physical and biological features as primary constituent elements for anadromous salmon and steelhead in freshwater:

- Freshwater spawning (water quality, water quantity, and substrate);
- Freshwater rearing (water quantity and floodplain connectivity, water quality and forage, and natural cover); and

- Freshwater migration (free of artificial obstruction, water quality and quantity, and natural cover).

These physical and biological features were designated because of their potential to develop or improve and eventually provide the needed ecological functions to support species recovery (NMFS 2017).

The 2017 NMFS Recovery Plan included recovery strategies for Salmon River steelhead. Priorities for steelhead populations specific to the East Fork SFSR watershed include: (1) collect and analyze population-specific data to accurately determine population status; (2) maintain wilderness protection and protect pristine tributary habitat; (3) eliminate artificial passage barriers and improve connectivity to historical habitat; (4) reduce and prevent sediment delivery to streams by rehabilitating roads and mining sites; and (5) manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans according to an abundance-based schedule.

6.3.2.4 Temperature Requirements and Baseline

Steelhead have different thermal requirements or limitations for their various life stages. Exceeding thresholds could impact various life-stages and could cause fish to avoid areas or even mortality. The periodicity of each life stage and the accepted stream temperature threshold ranges for various temperature considerations for each species were compiled from regulatory standards and other relevant literature (ESS 2022b), a condensed version of which is provided in **Table 6-15**.

Using the QUAL2K predicted MWMT stream values, and stream segment lengths from the SPLNT Model Refined Modified Proposed Action (ModPRO2) report (Brown and Caldwell 2021a), the length of proposed mine site streams within these temperature thresholds was estimated. The QUAL2K stream segments that contain the segments in which there was modeled IP habitat (see **Section 6.3.2.5**) were evaluated for thermally suitable habitat for life stages that occur in the warmest months. However, it is important to note, the IP model applied more refined spatial scale (i.e., shorter reaches) than were applied in the SPLNT model. Hence, the stream segments evaluated for temperature could have lengths that extended beyond the ends of the segments evaluated for IP. Therefore, the lengths of habitat are not identical, meaning the length of habitat meeting the temperature thresholds may be longer than the length of habitat with IP.

A total of 2.01 km of the East Fork SFSR, starting from 0.89 km below confluence with Sugar Creek up to the YPP cascade barrier, were evaluated for the temperature thresholds. The East Fork SFSR evaluated was based on the modeled IP habitat (see **Section 6.3.2.5** for additional detail). However, it is important to note, the IP model applied more refined spatial scale (i.e., shorter reaches) than were applied in the SPLNT model. Therefore, the lengths of habitat are not identical, meaning the length of habitat meeting the temperature thresholds may be longer than the length of habitat with IP.

Table 6-15 shows that of the entire 2.01 km of potential habitat is within the temperature thresholds for juvenile rearing. It is important to note that the length of potential habitat for steelhead incubation is based on July MWMT; however, there are diurnal variations and hyporheic conditions that protect the eggs and alevins reducing mortality rates. Therefore, while summer temperatures may show zero miles of suitable habitat, this may not be a true representation of the conditions in the river.

Under baseline conditions, steelhead do not occur upstream from the YPP lake; therefore **Table 6-15** shows zero miles of habitat with suitable thermal conditions.

It is important to note that the creeks do experience significant diurnal variations, and that for mobile life stages (i.e., adults and juveniles), if temperatures are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges.

Table 6-15 Steelhead Optimal Temperature Thresholds and Modeled Length of Stream within the Water Temperature Thresholds in July and September

Life Stage / Season[1]	Range of Optimal Temperature Thresholds (°C)	Total Stream Length Above YPP/ Below YPP	Stream Length Within Optimal Temperature Threshold (km)		
			Above YPP	Below YPP	Total
Adult Migration/ March – May	12-19	0 / 2.01	0	--	--
Adult Spawning/ April – June	4-14	0 / 2.01	0	--	--
Incubation/ Emergence/ April – August[2]	6-10	0 / 2.01	0	0	0
Juvenile Rearing / Year-round[2]	10-17	0 / 2.01	0	2.01	2.01 (100%)[3]

Source: EPA 2003, IDAPA 58.01.02 (IDAPA 58.01.02), Poole et al. 2001
[1] It should be noted that the months in the life stage are not applicable for comparison to the SPLNT model results.
[2] Analysis based Summer Maximum (July) 7-Day Average of the Daily Maximum.
[3] Percent of stream length within the usable Intrinsic Potential habitat.
°C = degrees Celsius; % = percent; km = kilometer; YPP = Yellow Pine pit

6.3.2.5 Distribution

Steelhead occur throughout much of the analysis area (**Figure 6-7**), but within the areas affected by construction and operations, their distribution in the East Fork SFSR, up to YPP where a steep high gradient riffle/cascade caused by past mining activities is thought to preclude upstream migration. Steelhead can maneuver through higher gradients than Chinook salmon; however, genetic sampling suggest such migration does not occur above the YPP lake.

While eDNA can detect *O. mykiss* DNA, it cannot distinguish between subspecies (e.g., steelhead, redband trout), nor can it identify hybrids. Hybridization between cutthroat trout and rainbow trout (*Oncorhynchus mykiss spp*.), in waters where they co-occur, is common. Of the 153 individual fish tissue genetic samples collected in 2015 in Meadow Creek and the East Fork SFSR near Meadow Creek (upstream from the YPP), 146 tissue samples were pure westslope cutthroat trout (95.4 percent), and seven tissue samples were westslope cutthroat trout/rainbow trout hybrids (MWH 2017). An additional 33 eDNA and fish tissue samples from various locations upstream from the YPP lake (between 2014–2016) were collected and two fish tested positive for rainbow trout DNA (0.6 percent), one in Meadow Creek Lake and one in the East Fork Meadow Creek. It is likely that the rainbow trout genetics detected from these locations are, in fact, California golden trout (*Oncorhynchus mykiss aguabonita*), a subspecies of rainbow trout that were released in Meadow Creek Lake and are not native to the region.

Golden trout are still stocked by the IDFG in Meadow Creek Lake (IDFG 2019b). Carim et al. (2017) studied fish presence and distribution in Upper East Fork SFSR and Meadow Creek Lake, partially to determine whether eDNA-based detections of rainbow trout could be explained by the presence of the California golden trout subspecies originating from stocked fish in Meadow Creek Lake. This study concluded that the eDNA-based detections of rainbow trout could be explained by the presence of California golden trout originating from the stocked fish in Meadow Creek Lake.

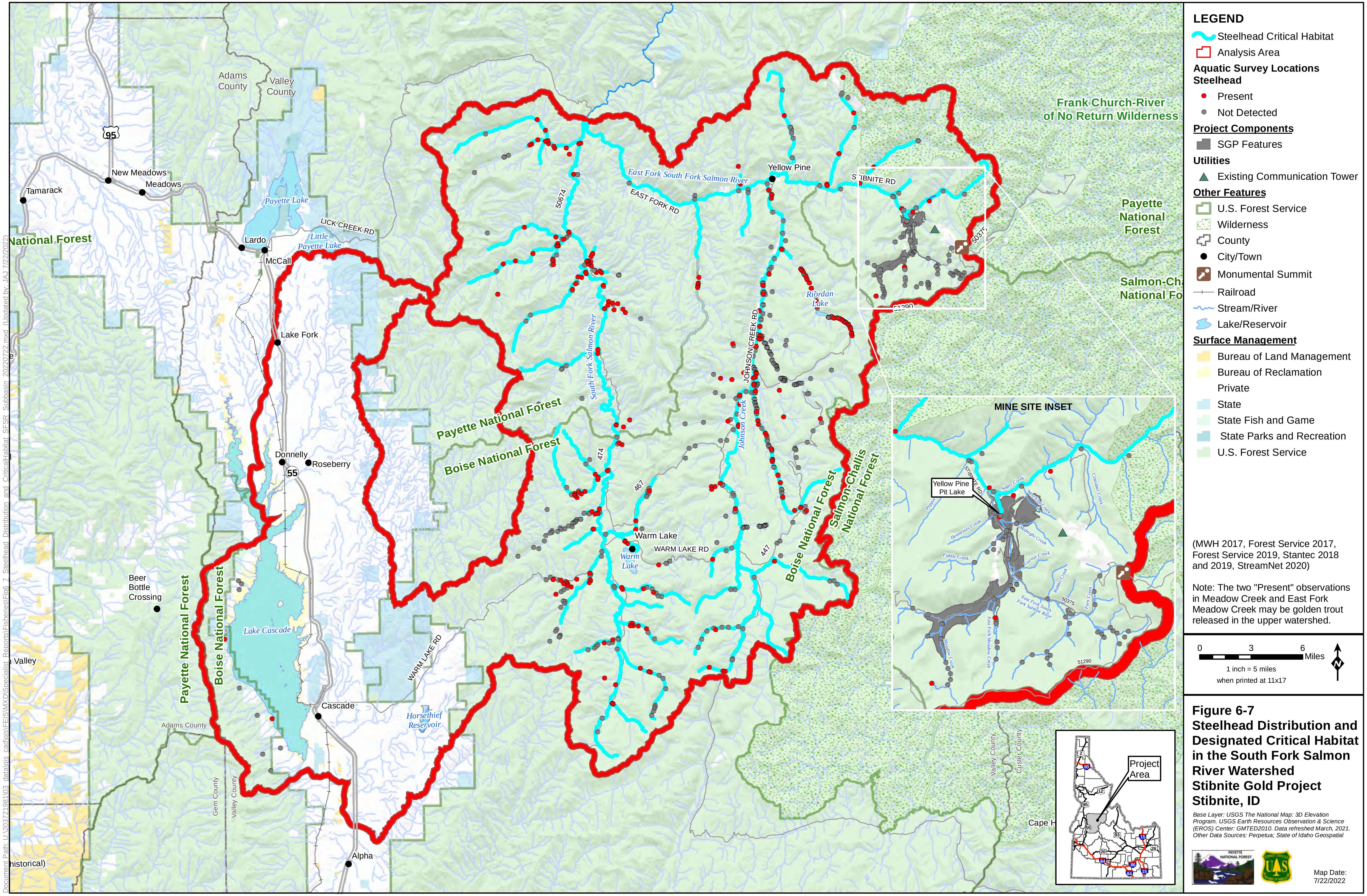


Figure 6-7
Steelhead Distribution and Designated Critical Habitat in the South Fork Salmon River Watershed
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021. Other Data Sources: Perpetua; State of Idaho Geospatial

Map Date: 7/22/2022

Little is known about steelhead use of the YPP lake, but it is likely the distribution is limited. In 2018 and 2019, only 5 and 9 *O. mykiss* were identified in YPP lake, respectively, and were noted as rainbow trout due to the size and time of year of capture (Brown and Caldwell 2019b, 2020a). Unlike Chinook salmon (via trap and haul) and bull trout, steelhead have not been found upstream from the YPP lake since the initiation of historic mining activities (given no documentation prior to mining, it is unknown if they occurred prior to mining activities). However, it is possible some migrating steelhead adults may use YPP lake as a holding area before migrating downstream to more suitable spawning grounds. Similarly, the lake may be used for rearing by some juvenile steelhead that have dispersed upstream from downstream spawning areas (Brown and Caldwell 2019b).

Steelhead occurrence in the analysis area varies by life stage and season. Adult migration occurs between mid-March through May. Spawning occurs from April to mid-June. Incubation/emergence occurs between April and mid-August. Juvenile rearing occurs year-round, with out-migration occurring primarily in June through and September.

Habitat for steelhead is measured using two different tools – Flow productivity to determine the effect of stream flow changes on steelhead productivity and intrinsic potential modeling to determine the potential for streams to support spawning, incubation, and early-rearing habitat.

Flow-Productivity

The effects of streamflow changes on steelhead productivity within the mine site are based upon a SGP flow-productivity model that was developed using the flow-productivity modeling approach for the Big Creek Water Diversion Project (NMFS 2013) Productivity (also referred to as adult or whole life cycle productivity) is estimated as the ratio of the number of returning adults to the total number of fish allowed to spawn naturally during the brood year (Morrow 2018). Therefore, productivity is a unitless measure or quantity of the number of returning adults. The SGP flow-productivity model then regresses productivity against flow metrics using simple linear regression to output flow-productivity (ESS 2022e).

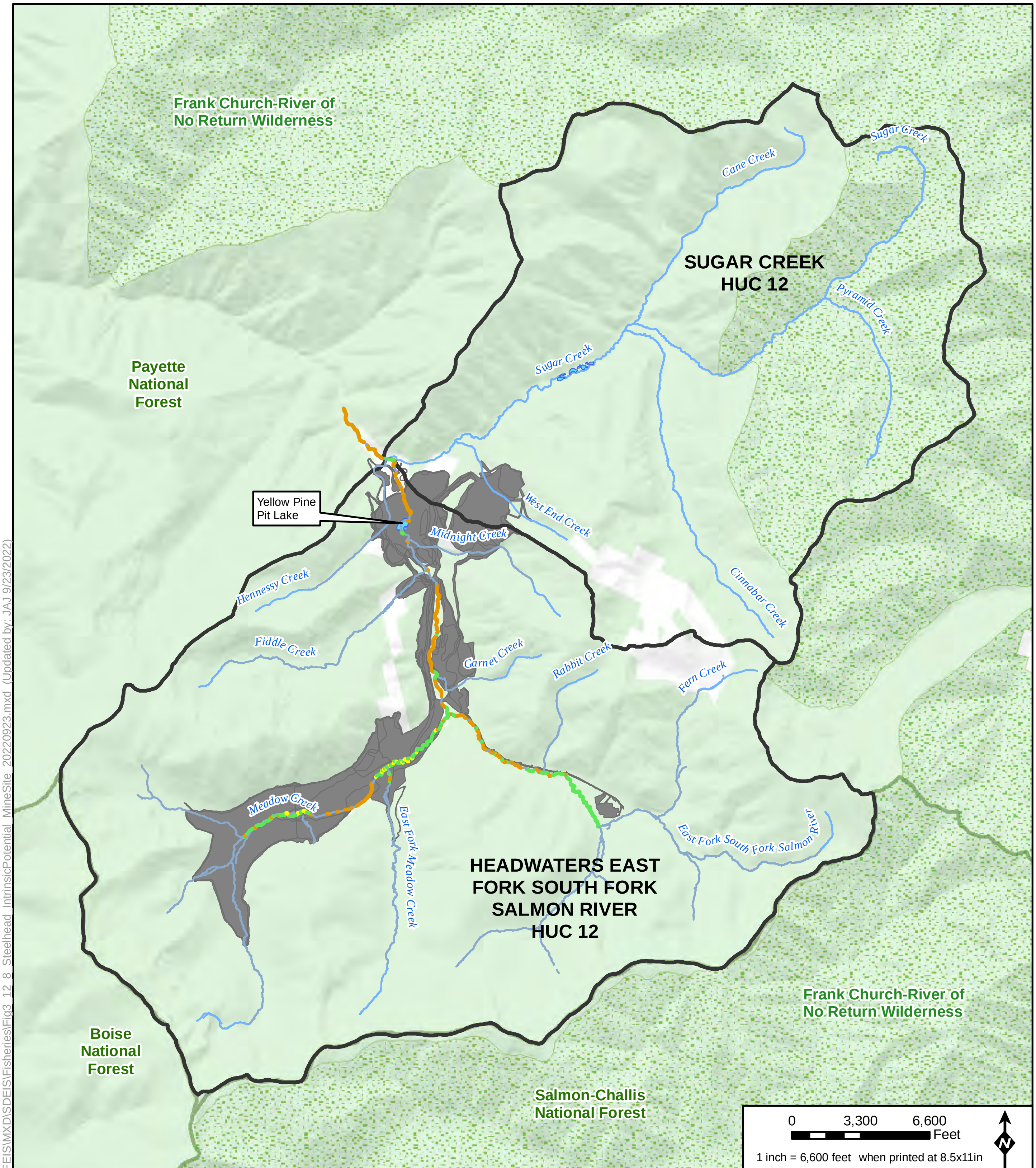
The SGP flow-productivity model uses proxy data from the Lemhi River and assumes that the physical and biological conditions in the Lemhi River are relatable to the mine site streams. However, there are many physical differences between the upper East Fork SFSR and the Lemhi River, including drainage size, flow regime and steelhead populations. Also, the SGP flow-productivity model assumes a fixed number of steelhead spawners each year that occurred in the Lemhi River to occur across all of the mine site streams (ESS 2022e). Therefore, these productivity estimates provide a rough approximation of changes in productivity due to flow within the mine site. Additionally, the differences in streamflow regimes, physical habitat characteristics, population sizes, and other differences between the Lemhi River and the mine site streams creates uncertainty that cannot be addressed with the available data.

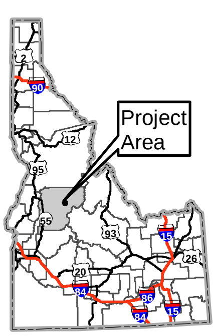
The flow-productivity analysis predicts changes in productivity based solely on streamflow changes and it does not factor in additional habitat changes that would also occur in the analysis area (e.g., direct loss of habitat, water temperature changes, etc.). The model outputs help to show the relative effects of flow modifications on steelhead productivity at the reach level. Steelhead productivity was assessed in four stream reaches (East Fork SFSR above Meadow Creek, East Fork SFSR at Stibnite, East Fork SFSR above Sugar Creek, and lower Meadow Creek). The lower Meadow Creek site (MC-6) was set up to supplement the system of USGS gages. MC-6 specifically examines conditions in the portion of Meadow Creek that is routed through a constructed channel to divert the stream away from historical mine waste.

The flow-productivity model outputs productivity values that are compared to baseline productivity values to calculate the predicted annual percent change in steelhead productivity from baseline productivity. The baseline steelhead productivity value of 1.24 was derived from productivity data collected on the Lemhi River (NMFS 2013). Again, the interpretation of the predicted annual percent change in productivity is based upon the baseline productivity calculated with the Lemhi River data because data is not available within the mine site. Because the productivity value is greater than 1.0, if Lemhi River were an unimpaired system, there would be slightly more returning adults than the spawning brood year.

Intrinsic Potential

The IP model is described in **Section 6.3.1.1**. The IP model was applied to classify the potential for spawning and rearing habitat for steelhead in headwaters of the East Fork SFSR subwatershed (**Figure 6-8**). This area encompasses the mine site area; which includes the East Fork SFSR and tributaries upstream from YPP, Meadow Creek and East Fork Meadow Creek, East Fork SFSR and tributaries between YPP and Sugar Creek, East Fork SFSR downstream from Sugar Creek. Over 51 km were evaluated for IP for steelhead, and under baseline conditions, modeled IP stream length shows approximately 10.67 of potential spawning, incubation, and early-rearing habitat for steelhead in the mine site area (**Table 6-1**). As shown in **Figure 6-8**, high-rated and low-rated steelhead spawning, incubation and early-rearing habitat potentially occurs throughout the East Fork SFSR and Meadow Creek and the additional section of the East Fork SFSR below the confluence with Sugar Creek.





LEGEND

Subwatershed (HUC 12)

Steelhead Intrinsic Potential
- High
- Medium
- Low
- Negligible
- None

Project Components
- Mine Site Components

Other Features
- U.S. Forest Service
- Wilderness
- County
- Stream/River
- Lake/Reservoir

Surface Management
- Private
- U.S. Forest Service

Figure 6-8
Steelhead Intrinsic Potential Habitat Within the Mine Site Subwatershed
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI World Terrain Basemap
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Ecosystem Sciences; Boise National Forest; Payette National Forest

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Table 6-16 Steelhead Intrinsic Potential Habitat for Existing/Baseline Conditions

Steelhead IP[1]	East Fork SFSR and Tributaries Upstream from YPP[2]		Meadow Creek and East Fork Meadow Creek		East Fork SFSR and Tributaries between YPP and Sugar Creek		East Fork SFSR Downstream from Sugar Creek		Total IP Habitat in Mine Site Area (km)[3]
	Length (km)	Percent Total Length	Length (km)	Percent Total Length	Length (km)	Percent Total Length	Length (km)	Percent Total Length	
High	2.16	7.4	2.18	12.9	0.18	4.1	0.03	2.7	4.55
Medium	0	0	0.60	3.5	0	0	0	0	0.60
Low	2.91	10.0	0.87	5.1	0.72	16.6	1.02	91.9	5.52
Total IP Habitat	5.07	17.5	3.65	21.6	0.90	20.7	1.05	94.6	10.67 (21%)[4]
Total Length Evaluated	29.01	-	16.93	-	4.34	-	1.11	-	51.39

[1] Results are presented in the table as the length (kilometers) of stream with usable IP. For steelhead, the IP is rated as high, medium, low, and negligible. “Useable” habitat is defined as all of these classes combined (usable = high + medium + low + negligible).

[2] Does not include the East Fork SFSR tributaries Meadow Creek and East Fork Meadow Creek.

[3] Does not include Sugar Creek.

[4] Total percent of IP habitat within the total length of streams evaluated.

% = percent; East Fork SFSR = East Fork South Fork Salmon River; IP = Intrinsic Potential; km = kilometer; YPP = Yellow Pine pit lake

6.3.3 Bull Trout

6.3.3.1 Status

The USFWS listed the Columbia River DPS of bull trout (*Salvelinus confluentus*) as threatened in June 1998 (63 Federal Register 31647).

Bull trout are currently known to use spawning and rearing habitat in at least 28 streams within the SFSR subbasin, including Burntlog Creek, Trapper Creek, Riordan Lake, East Fork SFSR, Sugar Creek, Tamarack Creek, and Profile Creek. IDFG trend data indicates that the geographic extent of bull trout is increasing (IDFG 2005). Potential threats to the population within the SFSR subbasin include connectivity impairment, habitat degradation, and competition from invasive brook trout (USFWS 2015a); however, fish sampling has not documented brook trout in any of the mine site streams, but this species may occur in several streams in the vicinity of the Burntlog Route (Adams et al. 2002).

6.3.3.2 Critical Habitat

Within the analysis area, the USFWS has designated Critical Habitat for bull trout throughout the South Fork Salmon watershed, including but not limited to in the East Fork SFSR, and in Burntlog, Cane, Cinnabar, Meadow, Tamarack, Trapper, Riordan, and Sugar creeks (75 Federal Register 63898). **Figure 6-9** shows the occurrence locations of bull trout and designated Critical Habitat in the analysis area.

6.3.3.3 Physical and Biological Features and Recovery Plan

Primary constituent elements are physical and biological features that are essential to the conservation of the species. For bull trout these include but are not limited to space for individual and population growth and for normal behavior; food, water, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, or rearing of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species (USFWS 2010).

The most recent 5-year status review for bull trout was published in April 2008 (USFWS 2008); however, a new 5-year review is currently in progress (85 Federal Register 14240; March 11, 2020). The 2008 review concluded that listing the species as “threatened” remained warranted range-wide in the coterminous U.S. Based on this status review, the 2010 recovery report to Congress stated that bull trout were generally “stable” range wide. Since the listing of bull trout, there has been very little change in the general distribution in the coterminous U.S.

The 2015 Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015a) provided recovery unit implementation plans for specific recovery units, including the Upper Snake Recovery Unit, which includes bull trout in the analysis area. Four strategies were identified for the recovery of bull trout and include:

- Protect, restore, and maintain suitable habitat conditions;
- Minimize demographic threats by restoring connectivity of populations, where appropriate, to promote diverse life-history strategies and conserve genetic diversity;
- Prevent and reduce negative effects of non-native fishes and other non-native taxa; and
- Work with partners to conduct research and monitoring to implement and evaluate recovery activities, consistent with an adaptive-management approach using feedback from implemented, site-specific recovery tasks, and considering the effects of climate change.

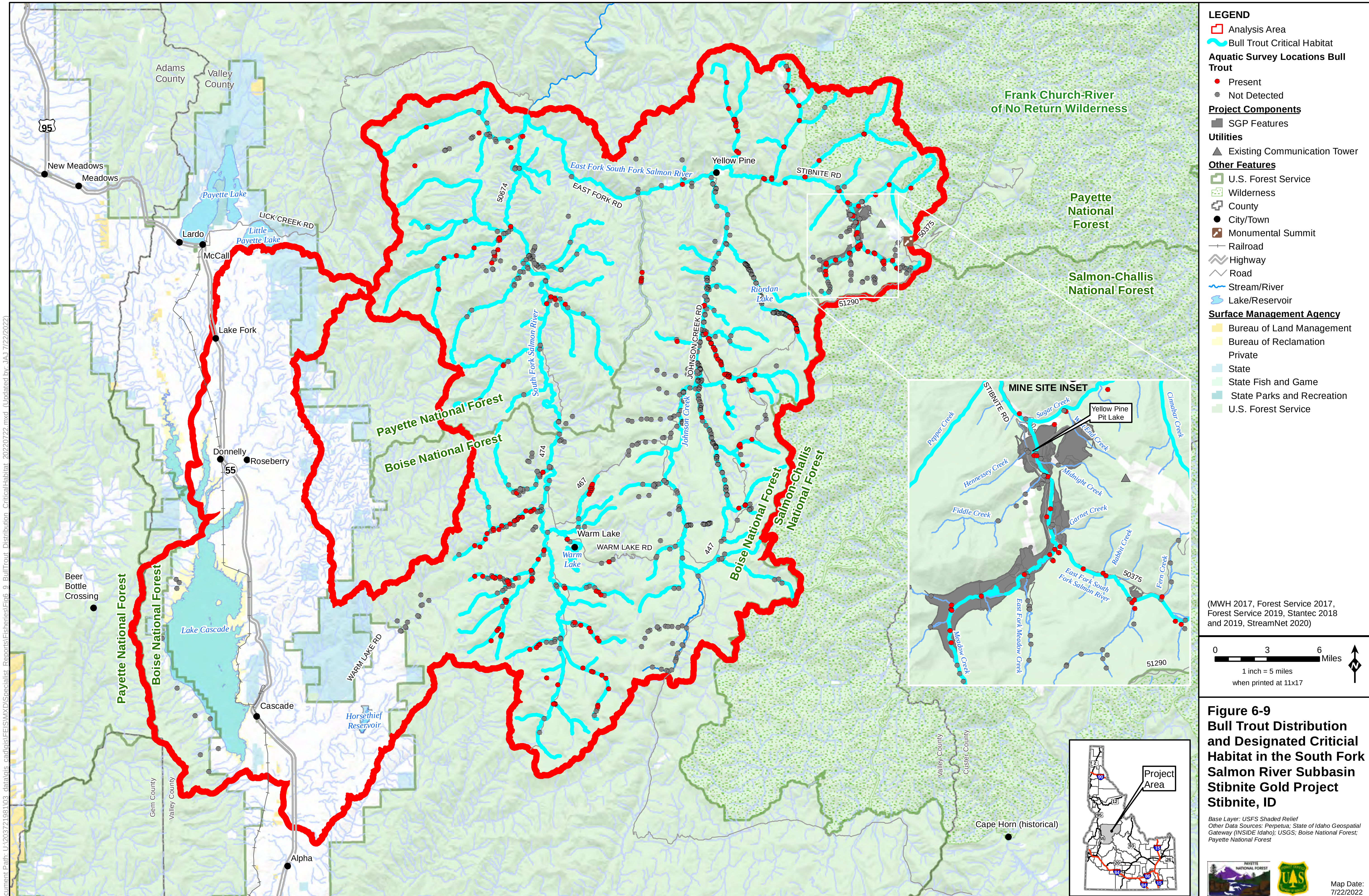


Figure 6-9
Bull Trout Distribution and Designated Criticial Habitat in the South Fork Salmon River Subbasin
Stibnite Gold Project
Stibnite, ID

Base Layer: USFS Shaded Relief
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Large areas of intact habitat exist primarily in the Salmon River drainage, which is the only drainage in the Upper Snake Recovery Unit that still flows directly into the Snake River; most other drainages no longer have direct connectivity due to irrigation diversions or instream barriers (USFWS 2015a).

Bull trout exhibit three life-history strategies in the analysis area: fluvial (stream and river dwelling, spawning in small tributaries); adfluvial (lake dwelling and river spawning); and non-migratory or resident (found in small streams and headwater tributaries). Historically, the Upper Snake Recovery Unit is believed to have largely supported the fluvial life history form; however, many core areas are now isolated or have become fragmented watersheds, resulting in replacement of the fluvial life history with resident or adfluvial forms. The USFWS identified threats to bull trout persistence as "the combined effects of habitat degradation, fragmentation and alterations associated with dewatering, road construction and maintenance, mining, grazing; the blockage of migratory corridors by dams or other diversion structures; poor water quality; incidental angler harvest; entrainment into diversion channels; and introduced non-native species" (64 Federal Register 58910).

6.3.3.4 Temperature Requirements and Baseline

Bull trout have different thermal requirements or limitations for their various life stages. If temperatures are above or below threshold for various life-stages, fish may avoid areas within streams if they are able. Using the QUAL2K predicted stream temperature values and stream segment lengths from the SPLNT Model Refined Modified Proposed Action (ModPRO2) report (Brown and Caldwell 2021a), the length of proposed mine site streams (East Fork SFSR, Meadow Creek, East Fork Meadow Creek, and Fiddle Creek) within these temperature thresholds was estimated (**Table 6-1**). The QUAL2K stream segments that contain the segments in which there was modeled habitat with occupancy probability (see **Section 6.3.3.5**) were evaluated for thermally suitable habitat for all life stages. However, it is important to note, the Occupancy Model (OM) applied a different spatial scale (i.e., shorter reaches) than were applied in the SPLNT model. Hence, the stream segments evaluated for temperature could have lengths that extended beyond the ends of the segments evaluated for OM. Therefore, the lengths of habitat are not identical, meaning the length of habitat meeting the temperature thresholds may be longer or shorter than the length of habitat with OM.

The periodicity of each life stage and the accepted stream temperature threshold ranges for various temperature considerations for each species were compiled from regulatory standards and other relevant literature ESS 2022b, a condensed version of which is presented in **Table 6-1**.

The East Fork SFSR from 0.89 km downstream from the confluence with Sugar Creek to around 5 km upstream from the confluence with Meadow Creek, including Fiddle Creek (total of 12.94 km), and around 13.27 km of Meadow Creek and East Fork Meadow Creek were evaluated for the temperature thresholds.

Overall, there are 26.21 km of available habitat, none of it is within optimal thresholds for incubation/emergence, almost half of it is optimal for juvenile rearing, approximately 6 percent is within the thresholds for adult spawning. Currently, bull trout do not occupy the entire 26.21 km, but they do inhabit sections of stream (spawning, incubating, and rearing) in which water temperatures are often outside the optimal thresholds.

Table 6-17 Bull Trout Optimal Temperature Thresholds and Modeled Length of Stream within the Water Temperature Thresholds in July and September

Life Stage / Season	Range of Optimal Water Temperature Thresholds (°C)	Total Stream Length Above YPP / Below YPP	Stream Length Within Optimal Water Temperature Threshold (km)		
			Above YPP	Below YPP	Total
Adult Spawning/ August – September[1]					
FA	4 – 9	24.20 / 2.01	1.62	0	1.62 (6.2%)[2]
FR	9 – 10	24.20 / 2.01	7.76	0	7.76 (29.7%)[2]
FUR	>10	24.20 / 2.01	14.82	2.01	16.83 (64.5%)[2]
Incubation/Emergence/ April – August[1]					
FA	2 – 5	24.20 / 2.01	0	0	0
FR	5 – 6	24.20 / 2.01	0	0	0
FUR	>6	24.20 / 2.01	24.20	2.01	26.21 (100%)[2]
Juvenile Rearing/ Year-round[3]					
FA	4 – 12	24.20 / 2.01	12.16	0	12.16 (46.6%)[2]
FR	12 – 15	24.20 / 2.01	9.60	2.01	11.61 (44.5%)[2]
FUR	>15	24.20 / 2.01	2.43	0	2.43 (9.3%)[2]

Source: EPA 2003, Forest Service 2003
[1] Analysis based on Fall Maximum 7 Day Average of the Daily Maximum
[2] Percent of stream length is based on the modeled potential habitat
[3] Analysis based Summer Maximum 7 Day Average of the Daily Maximum
°C = degrees Celsius; > = greater than; % = Percent; km = kilometer; FA = Functioning Appropriately; FR = Functioning at Risk; FUR = Functioning at Unacceptable Risk; km = kilometer; YPP = Yellow Pine pit

It is important to note that the length of potential habitat for bull trout incubation is based on September MWMT, however, there are diurnal variations and hyporheic conditions that protect the eggs and alevins reducing mortality rates. Additionally, while the length of stream above and below YPP are not FA and often even FR, there are all life stages of bull trout present, which means successful reproduction is occurring. Therefore, while fall MWMT may show zero miles of suitable spawning and incubation habitat, this may not be a true representation of the conditions in the river. Additionally, if MWMT that for mobile life stages (i.e., adults and juveniles), if temperatures are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges.

6.3.3.5 Distribution

Figure 6-9 displays the distribution of bull trout in the analysis area. Bull trout are not found outside of the SFSR subbasin within the analysis area (Burns et al. 2005). Bull trout occupy most streams affected by both construction and operation of the SGP (MWH 2017).

A subpopulation of bull trout using an adfluvial life history strategy uses the YPP lake for overwintering, with downstream migration to tributaries for spawning (Hogen and Scarnecchia 2006). Hogen and Scarnecchia (2006) found bull trout overwintered in the large rivers downstream from the East Fork SFSR (SFSR and the Salmon River further downstream), and then migrated upstream to the East Fork SFSR in June and July, and further into small tributaries to spawn in August and September. Migrants stage at the mouths of presumptive spawning tributaries from mid-July to mid-August, then migrate into tributaries to spawn from mid-August to mid-September. ESS 2019b provides more detail regarding bull trout use of the YPP lake.

Fluvial populations downstream from the YPP lake quickly out-migrate as far as the mainstem Salmon River (Hogen and Scarnecchia 2006) or move up and into the YPP lake for overwintering. The YPP cascade barrier blocks upstream passage of fluvial populations. Upstream from the YPP cascade barrier, bull trout use either the fluvial or the resident life-history strategy. The extent of available habitat upstream from the YPP lake is limited by gradient barriers, as well, the access to upstream habitat by fluvial populations downstream from the YPP barrier is blocked. Additional information on a population study in the YPP lake is provided in **Section 6.2.2**.

Habitat for bull trout is measured using two different tools – OM to determine occupancy probability and looking at how changes in stream flow affects the amount of available habitat through the use of Physical Habitat Simulation modeling (PHABSIM). Both are described below.

Occupancy Probability

The OM is a tool used to determine the probability of a fish species occupying a particular stream reach (occupancy probability) and to predict changes in the probability given changes to site physical characteristics (Isaak et al. 2015, 2017). The OM was adapted to the scale of the mine site study area and uses data collected at the mine site. The mine site OM quantifies potential habitat based on physical channel characteristics for each stream reach by assigning probabilities (expressed as a percent from 0 to 100) that each of the species would occur in a given stream reach but does not necessarily define their actual presence. There are streams in which there are potential habitat identified from the OM, but where bull trout have not been identified through field surveys.

The length of a stream reach has either a low, medium-low, medium-high, or high occupancy probability (referred to as “available habitat”), which are based on the quartile in which the occupancy probability falls, that is, the first quartile, or the lowest 25 percent, represents a low occupancy probability, and the fourth quartile, or the highest 25 percent, represents a high occupancy probability. Greater detail regarding occupancy modeling is presented in ESS 2022f.

A distance-weighted average was used to represent the average occupancy probability of each stream segment, in other words, the usability of habitat for bull trout. This was calculated by multiplying the proportion of the OM stream reach length within the stream segment (e.g., East Fork SFSR upstream from Meadow Creek) with the occupancy probability of each OM stream reach within the stream segment.

Occupancy modeling methods originate from studies completed by the Rocky Mountain Research Station, a group of scientists funded by the United States Department of Agriculture (Isaak et al. 2015, 2017). The OM was based on three site physical characteristic variables: stream discharge (i.e., flow), summer stream temperature, and reach slope (Isaak et al. 2017), and was conducted at the finer HUC-scale of the mine site area. As part of the Rocky Mountain Research Station studies, data on stream reach variables for large stream networks in the Rocky Mountains/Pacific Northwest were fit to bull trout and westslope cutthroat trout occurrence datasets (presence/absence data) to create parameter estimates used in a logistic regression model. The results of the model can be used to estimate occupancy probabilities for specific areas within any given stream reach where stream flow, summer water temperatures and reach slope are known. For example, an occupancy probability of 10 percent implies that a species will be present in one out of every ten reaches with similar characteristics (temperature, flow and slope) across the region (Rocky Mountains/Pacific Northwest) used to fit the model. Understanding the distinction between the scale of the Isaak et al. 2017 model and the scale of the SGP OM model is important context for placing the results in context.

A site-specific OM was developed to employ the logistical regression derived from the Rocky Mountain Research Station studies to estimate probabilities for both bull trout and westslope cutthroat trout in four stream reaches within the headwaters East Fork SFSR subwatershed (ESS 2022f): East Fork SRSR upstream from the Meadow Creek confluence; Meadow Creek including the East Fork Meadow Creek; East Fork SFSR upstream from the YPP lake and the Meadow Creek confluence, and the East Fork SFSR from the YPP lake and the Sugar Creek confluence. The regression model utilizes parameter values for reach slope, barriers, and changes in stream discharge and water temperature to quantify changes in occupancy probability. This model differs from other analytical approaches in this section which utilize comparisons of parameter values such as stream temperatures to threshold values. Because the OM model regression relates a change in occupancy probability to a change in stream temperature, its results indicate an incremental reduction in occupancy probability associated with an increase in stream temperature instead of a complete reduction upon exceedance of a threshold value. Therefore, because the OM model applies a regression of multiple parameters to the refined stream reaches above, it may provide different results than examination of individual parameters compared to threshold values.

The data for each of the three site physical characteristic variables (i.e., stream discharge, summer stream temperature, and reach slope) were sourced from site-specific models and/or datasets. Stream discharge data were modeled using a basin area-to-streamflow regression equation provided by Rio ASE (2019). Stream temperature data were modeled using QUAL2K, which is a one-dimensional river and stream water quality model, as provided from the SPLNT Existing Conditions Report (Brown and Caldwell 2018). Stream reach slope data were sourced from a site-specific Lidar dataset by extracting the upstream and downstream endpoint elevations from a digital elevation model and dividing the difference by stream reach length.

Stream reaches were eliminated from the data set if they were not suitable to sustain bull trout, either due to having a stream discharge less than 0.2 cubic feet per second, being intermittent in flow, or having a channel slope greater than 15 percent. **Table 6-18** presents a summary of the information applicable for the three variable datasets used in the OM.

Table 6-18 Mine Site Occupancy Model Variable Summary

Parameter	Stream Temperature	Stream Flow	Reach Slope
Unit of Measurement	Mean Temperature (°C)	Mean Discharge (cfs)	Percent Slope
Temporal Resolution	August	July 16 – September 30	Not Applicable
Data Source	SPLNT Model Existing Conditions Report	Basin area-to streamflow regression equation	Delineated in GIS using a 1-meter LiDAR DEM

Source: Brown and Caldwell 2018, RioASE 2021
°C = degrees Celsius; cfs = cubic feet per second; DEM = Digital Elevation Model; GIS = Geographic Information System; LiDAR = Light Detection and Ranging; SPLNT = Stream and Pit Lake Network Temperature

Lengths of habitat and distance-weighted occupancy probabilities for bull trout for each stream reach are presented in **Table 6-1** and **Figure 6-10**. In total, the East Fork SFSR subwatershed contains approximately 33.9 km of habitat available for potential occupancy for bull trout, which is about 69.5 percent of the total length of streams modeled (49 km). Bull trout have not been observed nor their DNA detected in the upper East Fork Meadow Creek nor in Fiddle Creek (MWH 2017), so may not occur in these two systems. Passage into both the upper East Fork Meadow Creek and Fiddle Creek would not be provided as a result of the project. Therefore, while the model results show occupancy probability in these creeks, it does not mean that bull trout do occur, or would occur as a result of the SGP.

A distance-weighted average method was used to represent the average occupancy probability for each stream segment, shown in **Table 6-19**. To produce the distance-weighted average, the occupancy probability of each OM reach was multiplied by the proportion of the reach's stream length to the total length of each stream segment that has some likelihood of being occupied by bull trout.

Based on the model, the Headwaters East Fork SFSR subwatershed (East Fork SFSR upstream from Sugar Creek, Meadow Creek, and EFMC) has an estimated distance weighted average total occupancy probability for bull trout of 7.9 percent for portions of stream reaches with low to high occupancy probabilities. As shown in **Table 6-19** and **Figure 6-10**, the East Fork SFSR has habitat with high occupancy probability, while Meadow Creek does not. The relatively low occupancy probability numbers for bull trout (less than 20 percent) indicate a higher sensitivity to the model input parameters, particularly water temperature and flow.

Table 6-19 Length of Available Habitat and Distance Weighted Average in Percent Occupancy Probability for Bull Trout Under Baseline Conditions

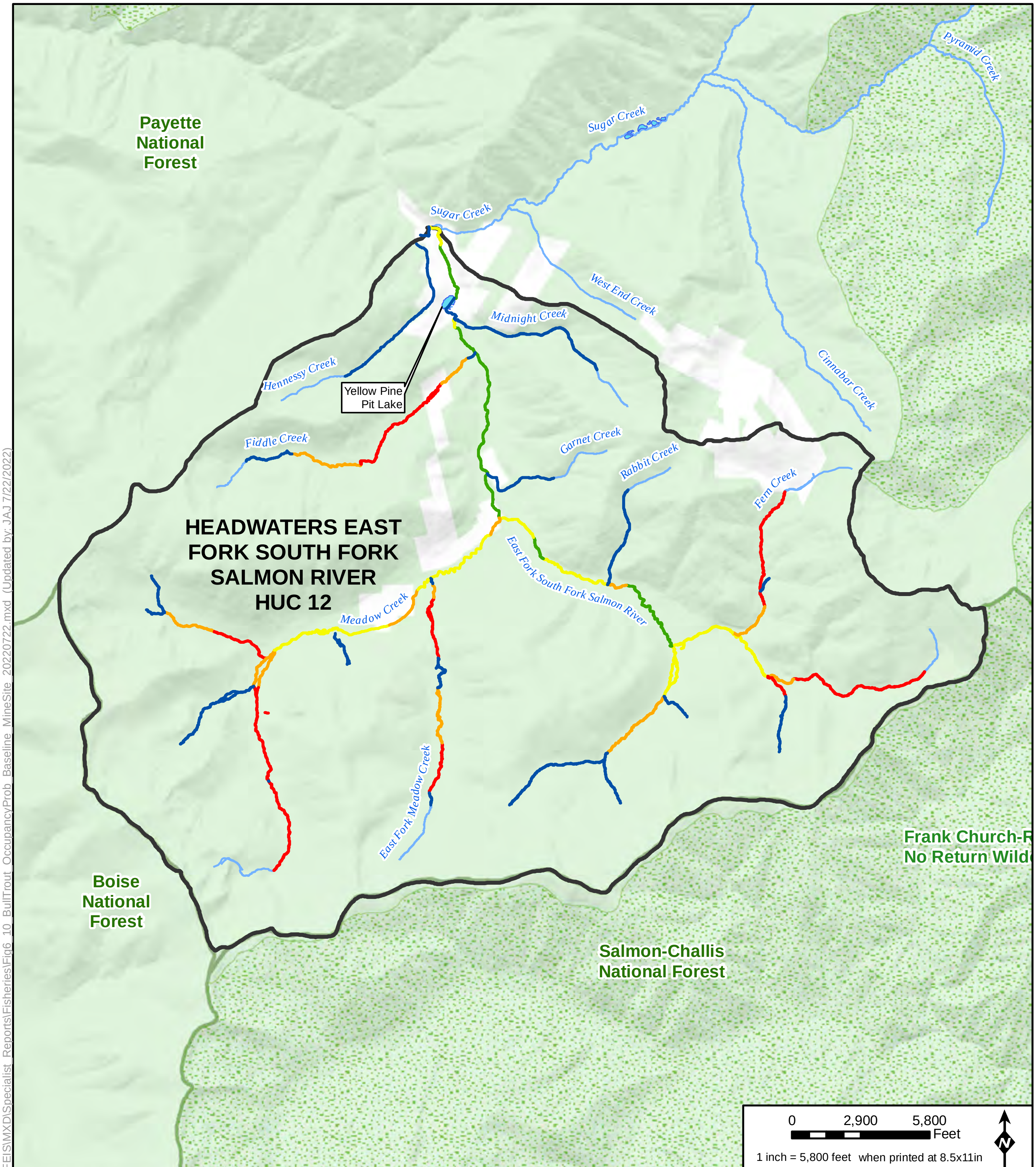
Occupancy Category	East Fork SFSR Upstream from Meadow Creek		Meadow Creak and East Fork Meadow Creek		East Fork SFSR Between Meadow Creek and YPP Lake		East Fork SFSR Between YPP Lake and Sugar Creek	
	km	OP	km	OP	km	OP	km	OP
High	1.59	18.1	0	0	2.91	17.6	0.80	16.2
Medium-High	4.82	11.5	3.45	10.4	0.13	13.2	0.37	13.4
Medium-Low	2.52	6.3	3.43	6.7	1.57	4.4	0	0
Low	4.19	2.3	6.18	2.5	1.93	3.2	0	0
Total	13.12	8.4	13.06	5.7	6.54	10.0	1.17	15.3

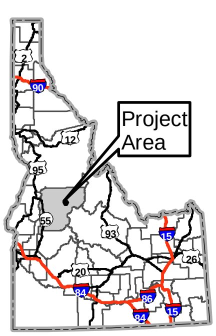
East Fork SFSR = East Fork South Fork Salmon River; km = kilometer: OP = occupancy probability; YPP = Yellow Pine pit

Stream Flow (PHABSIM)

PHABSIM is a modelling technique that predicts the amount of potential fish habitat in a stream or river associated with different volumes of streamflow. First developed by USFWS, the PHABSIM model is widely used as a tool to understand the relationship between streamflow and potential fish habitat. In the late 1980s and early 1990s, the Forest Service conducted a PHABSIM modeling study at several stream locations in the East Fork SFSR watershed as part of the Snake River Basin Adjudication (Maret et al. 2006). The results of this previous study are informative in understanding the potential effects of the SGP on fish habitat. PHABSIM was used for bull trout and cutthroat trout because there was no similar flow-productivity analysis as was applied for Chinook salmon and steelhead using a NMFS-derived tool (ESS 2022g). A summary of the PHABSIM model is provided below. A detailed description of the model and results are provided in ESS 2022g.

The PHABSIM model calculates an index of the amount of microhabitat available for target organisms and life stages at different flow levels, incorporating two major analytical components: stream hydraulics and organism/life stage-specific habitat requirements. These calculations are based on three physical variables: water depth, water velocity, and substrate composition (i.e., streambed particle size). The model uses discrete values of water depth and velocity data collected at a given stream site to simulate the same variables over a broad range of stream flows of interest. Substrate does not change in the model over the range of simulated flows. For each streamflow of interest, the model converts the simulated physical variables into equivalent values of potential fish habitat. This conversion is based on a functional relationship between the three physical variables and fish habitat suitability. Separate conversions were performed in the model for different species (bull trout and cutthroat trout) and life stages of fish. Model output is expressed as Weighted Usable Area (WUA), which represents the square feet of usable habitat per 1,000 feet of stream.





LEGEND

Occupancy Probability Quartile
- Low
- Medium Low
- Medium High
- High
- Unavailable OM Stream Habitat
- Subwatershed (HUC 12)

Other Features
- U.S. Forest Service
- Wilderness
- County
- Lake/Reservoir

Surface Management
- Private
- U.S. Forest Service

Figure 6-10
Bull Trout Occupancy Model Probabilities Under Baseline Conditions in the Mine Site Area
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI World Terrain Basemap
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Ecosystem Sciences; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

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To determine general and relative relationships between streamflow and habitat in the mining reaches, the PHABSIM study compared representative streams that contained similar hydrological and geographical characteristics to the stream characteristics at the proposed mine site. This comparative analysis yielded a general grouping of the PHABSIM study site and proposed mine site streams into three index categories, basically reflecting stream size and discharge: Index 1 (small streams); Index 2 (medium size streams); and Index 3 (large streams). At the proposed mine site, each stream reach (defined below) was assigned an index (**Table 6-20**). For example, Meadow Creek and the East Fork SFSR upstream from Meadow Creek are represented by Stream Index 1, both of which are similar to the Summit Creek site of the PHABSIM study.

Table 6-20 Representative Streams and Corresponding Indices used in the PHABSIM Analysis to Represent Three Types of Flow Conditions at Comparative Mine Site Stream Reaches

Mine Site Stream Reach	Stream Index Number	Representative Stream in PHABSIM Analysis	Representative Mean Discharge (cfs)	Representative Mid-Point Discharge (cfs)	Representative Lower Discharge (cfs)
Meadow Creek, East Fork Meadow Creek, and East Fork SFSR above Meadow Creek	1	Summit Creek	7.8	4.4	1
East Fork SFSR Between Sugar Creek and Meadow Creek	2	Sugar Creek	9.9	5.4	1
East Fork SFSR below Sugar Creek	3	East Fork SFSR Downstream from Sugar Creek	63	44	25

cfs = cubic feet per second; East Fork SFSR = East Fork South Fork Salmon River; PHABSIM = Physical Habitat Simulation;

PHABSIM model output generates a significant volume of information on the relationship between streamflow and WUA (**Table 6-21**). To simplify model output for the purposes of evaluating fish habitat effects of the SGP, two refinements were made to the model results. First, the model output used for the proposed mine site centered on the low-flow period of the year, defined as the months of August through March. Second, the WUA for different life stages of bull trout were evaluated for three key stream flows within the low-flow period: the mean discharge rate, a lower rate close to the minimum discharge rate value for the period, and a mid-point rate between the mean and minimum values (**Table 6-21**).

The quantification of potential SGP impacts on bull trout and cutthroat trout habitat, as defined by WUA, is dependent on several factors. One important factor is the predicted change in baseline flows that would occur in the various mine site stream reaches. Unique changes would occur in each reach throughout the life of the SGP. Another factor is the non-linear relationship between flow and WUA for each fish life stage. The PHABSIM model predicts separate habitat values for all species and all life stages of interest for several stream flow rates, which when viewed graphically, represent a non-linear relationship. Lastly, the PHABSIM model results are based upon WUA data collected from index streams that do not exactly represent the physical and biological conditions of the mine site stream reaches.

Table 6-21 Bull Trout Weighted Usable Area for Three Discharge Rates for Representative Streams

Representative Stream	Discharge		Weighted Usable Area[1]							
	cfs[2]	Percent Change	Adult	Percent Change	Spawning	Percent Change	Fry	Percent Change	Juvenile	Percent Change
Summit Creek (Index 1)	7.8	--	2,505	--	0	N/A	ND	N/A	5,940	--
	4.4	-44	1,451	-42	0	N/A	ND	N/A	3,524	-41
	1.0	-87	261	-90	0	N/A	ND	N/A	635	-89
Sugar Creek (Index 2)	9.9	--	1,176	--	2,127	--	ND	N/A	2,709	--
	5.4	-46	746	-37	1,443	-32	ND	N/A	1,811	-33
	1.0	-90	144	-88	66	-97	ND	N/A	351	-87
East Fork SFSR Downstream from Sugar Creek (Index 3)	63	--	2,184	--	0	N/A	ND	N/A	4,900	--
	44	-30	1,846	-15	0	N/A	ND	N/A	4,340	-11
	25	-60	1,108	-49	0	N/A	ND	N/A	2,690	-45

[1] Weighted Usable Area is defined as the sum of stream surface area within a study site, weighted by multiplying area by habitat suitability variables (most often velocity, depth, and substrate or cover), which range from 0.0 to 1.0 each, and normalized to square units (either feet or meters) per 1000 linear units.
[2] Discharge is measured in cfs.
[3] The underlined value is the mean low-flow-period discharge rate.
cfs = cubic feet per second; East Fork SFSR = East Fork South Fork Salmon River; ND = no data; N/A: not applicable.

6.3.4 Westslope Cutthroat Trout

6.3.4.1 Status

Due to declines in distribution and abundance, westslope cutthroat trout (cutthroat trout) is designated by the Forest Service as a sensitive species. There was a petition to list westslope cutthroat trout as a threatened species under ESA (63 Federal Register 31691); however, the USFWS determined that such a listing was not warranted (65 Federal Register 20120 April 2000).

6.3.4.2 Temperature Requirements and Baseline

Cutthroat trout have different thermal requirements/limitations for their various life stages. The periodicity of each life stage and the accepted stream temperature thresholds/ranges for various temperature considerations for each species were compiled from regulatory standards and other relevant literature (ESS 2022b), a condensed version of which are presented in **Table 6-22**.

Using stream temperature values and stream segment lengths from the SPLNT Model Refined Modified Proposed Action (ModPRO2) report (Brown and Caldwell 2021a), the length of mine site streams within these thresholds was estimated (**Table 6-22**). The East Fork SFSR from 0.89 km downstream from the confluence with Sugar Creek to around 5 km upstream from the confluence with Meadow Creek, including Fiddle Creek (total of 12.94 km), and around 13.27 km of Meadow Creek and East Fork Meadow Creek were evaluated for the temperature thresholds. The sections of the creeks evaluated were based on the modeled OP habitat (see **Section 6.3.3.5** for additional detail). However, it is important to note, the OM applied a different spatial scale (i.e., shorter reaches) than were applied in the SPLNT model. Therefore, the lengths of habitat are not identical, meaning the length of habitat meeting the temperature thresholds may be longer or shorter than the length of habitat with an occupancy probability.

Table 6-22 Westslope Cutthroat Trout Optimal Temperature Thresholds, and Modeled Length of Stream within the Water Temperature Thresholds in July and September

Life Stage / Season	Range of Optimal Temperature Thresholds (°C)	Total Stream Length Above YPP / Below YPP	Stream Length Within Water Temperature Threshold (km)		
			Above YPP	Below YPP	Total
Adult Migration/ March – June	15 – 19	24.10 / 2.01	--	--	--
Adult Spawning/ April – mid-July	4 – 14	24.10 / 2.01	--	--	--
Incubation/Emergence/ April – August[1]	6 – 10	24.10 / 2.01	0.85	0	0.85
Juvenile Rearing/ Year-round[1]	10 – 20	24.10 / 2.01	23.34	2.01	25.35 (87.8%)[2]

Source: EPA 2003.
[1] Analysis based Summer (July) MWMT
[2] Percent of stream length within modeled potential habitat.
°C = degrees Celsius; % = Percent; km = kilometer; YPP = Yellow Pine pit

Overall, there is minimal habitat suitable for incubation/emergence, but a significant portion of the usable habitat is within the temperature thresholds for juvenile rearing (**Table 6-22**). It is important to note that the length of potential habitat for westslope cutthroat trout incubation is based on September MWMT; however, there are diurnal variations and hyporheic conditions that protect the eggs and alevins reducing mortality rates. Additionally, while the length of stream above and below the YPP do not always meet the thermal requirements, there are all life stages of cutthroat trout present, which means successful reproduction is occurring. Therefore, while fall MWMT may show less than one mile of suitable incubation habitat, this may not be a true representation of the conditions in the river. Additionally, if MWMT for mobile life stages (i.e., adults and juveniles) are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges.

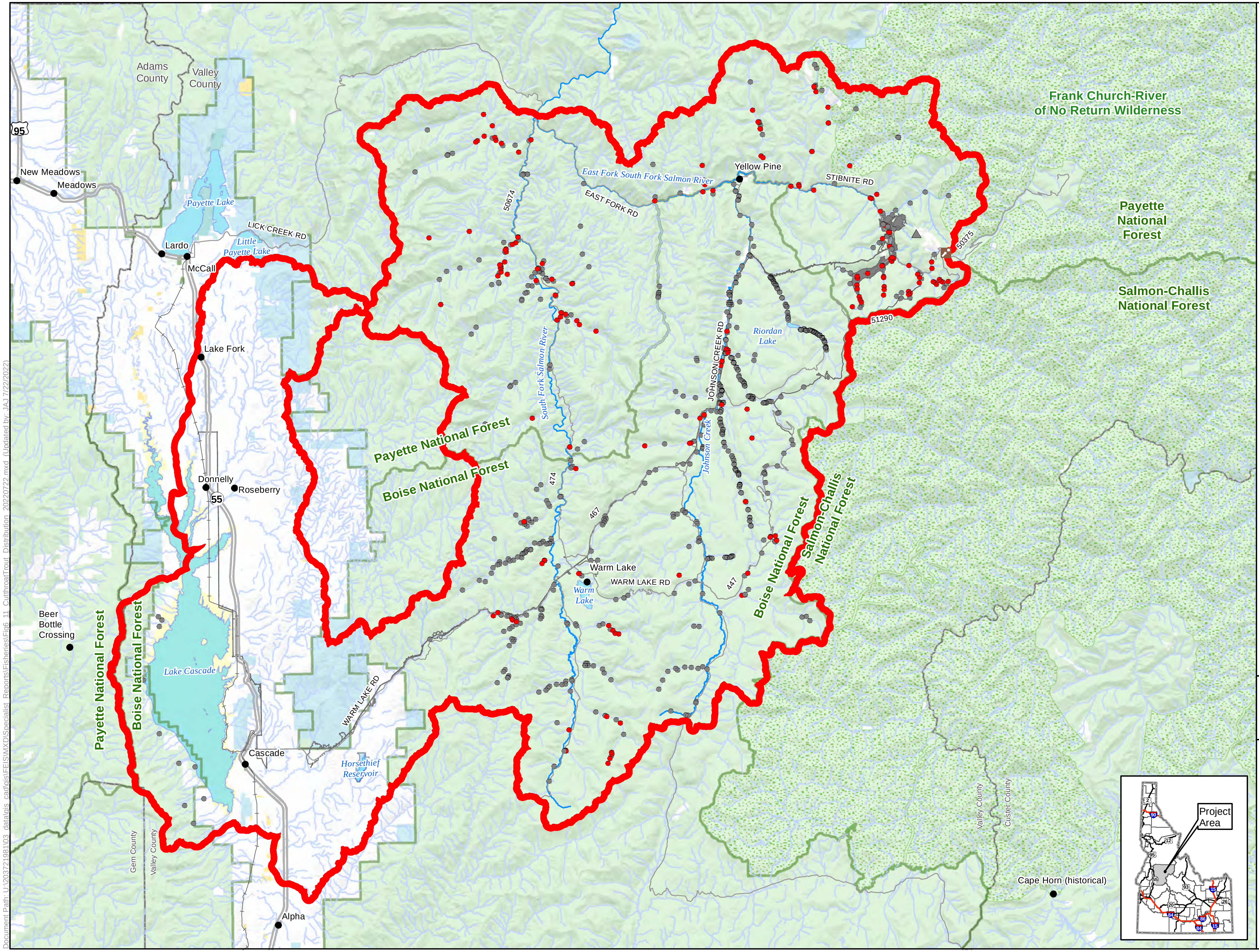
6.3.4.3 Distribution

Cutthroat trout are not found outside of the SFSR subbasin within the analysis area. They are found both upstream and downstream from the YPP lake. The distribution of westslope cutthroat trout in the analysis area is shown in **Figure 6-11**.

Cutthroat trout spatial and temporal occurrence in the analysis area varies by life stage, (e.g., juveniles using nursery and rearing habitat or spawning adults). Adult migration occurs between mid-March and July with the peak from mid-April to mid-June. Spawning occurs from late April to July when water temperatures are near 10°C. Peak spawning is between early May and early July. Incubation/emergence occurs between mid-April and September. Juvenile rearing occurs year-round. Emigration occurs between April and December. Life stage periodicity tables are presented in ESS 2022b.

Cutthroat trout begin to mature at age three, but usually spawn first at age four or five. Cutthroat trout may be resident (non-migratory carry out all life processes in tributaries), fluvial (migratory: reside in rivers and streams and migrate to tributaries to spawn), or adfluvial (lake-dwelling and migrate to tributaries to spawn).

Recent fish sampling was performed in the YPP lake to provide information on relative abundance and movement of cutthroat trout (Brown and Caldwell 2019b, 2020a). A total of 32 cutthroat trout were captured over three sampling events in May, July, and September 2018, leading to only one population estimate of 50 individuals. The movement study results showed the majority of the 32 tagged cutthroat trout remained in the YPP lake; only four moved downstream and were not detected returning upstream. The 2019 study resulted in population estimates ranging from 33 to 101 individuals. The size structure of westslope cutthroat trout was skewed towards larger fish. Fish less than 150- to 200-millimeter fork length were not found.



LEGEND

Analysis Area

Aquatic Survey Locations

Cutthroat Trout

- Present
- Not Detected

Project Components

- SGP Features

Utilities

- Existing Communication Tower

Other Features

- U.S. Forest Service
- Wilderness
- County
- City/Town
- Monumental Summit
- Railroad
- Highway
- Road
- Stream/River
- Lake/Reservoir

Surface Management Agency

- Bureau of Land Management
- Bureau of Reclamation
- Private
- State
- State Fish and Game
- State Parks and Recreation
- U.S. Forest Service

(MWH 2017, Forest Service 2017, Forest Service 2019, Stantec 2018 and 2019, StreamNet 2020)

0 2.5 5 Miles

1 inch = 4.88 miles when printed at 11x17

Figure 6-11
Westslope Cutthroat Trout Distribution in the South Fork Salmon River Subbasin
Stibnite Gold Project
Stibnite, ID

Base Layer: USGS Shaded Relief
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Occupancy Probability

Occupancy modeling was performed for westslope cutthroat trout using the same approach as bull trout (**Section 6.3.3.5**). Based on field surveys, westslope cutthroat trout occur in throughout the headwaters of the East Fork SFSR, including in Meadow Creek, East Fork Meadow Creek, and Fiddle Creek. Occupancy modeling provides probabilities for potential habitat in each of these systems.

In total, the Headwaters East Fork SFSR subwatershed contains nearly 34 km of stream channel that is potential usable habitat for western cutthroat trout (**Table 6-23** and **Figure 6-12**) based on OM results, which is approximately 67 percent of the total length of streams in the subwatershed (50.6 km). The Headwaters East Fork SFSR subwatershed has a distance weighted average occupancy probability of 64.3 percent for portions of stream reaches with low to high occupancy probabilities and each reach within the subwatershed are presented in **Table 6-23** and **Figure 6-12**. The relatively high occupancy probability numbers for cutthroat trout (mostly greater than 60 percent) indicate a higher tolerance to the model input parameters, particularly water temperature and flow.

Descriptive statistics for lengths of available habitat and occupancy probabilities by stream reach are presented in detail in ESS 2022f.

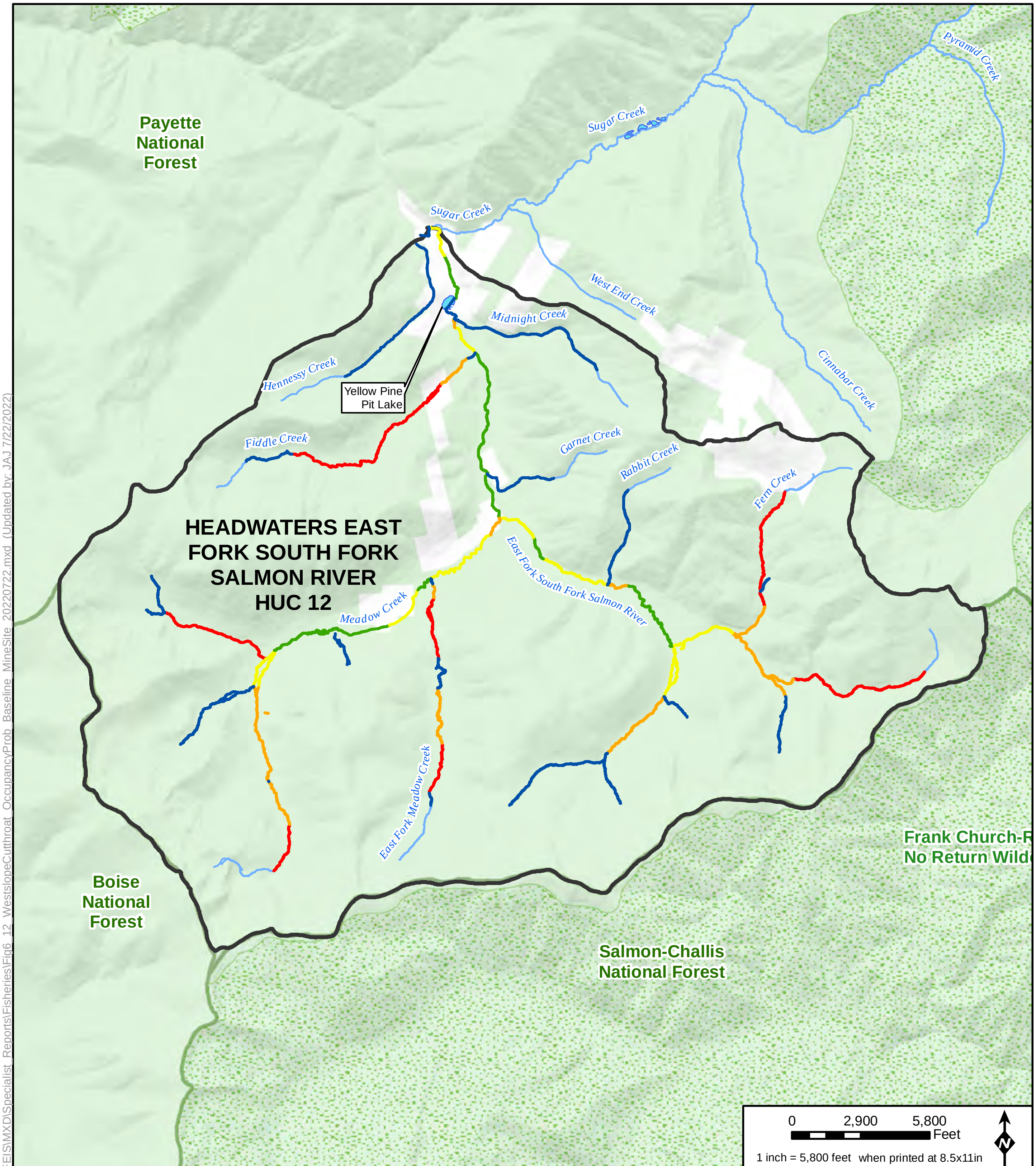
Table 6-23 Length of Available Habitat and Distance Weighted Average in Percent Occupancy Probability for Westslope Cutthroat Trout Under Baseline Conditions

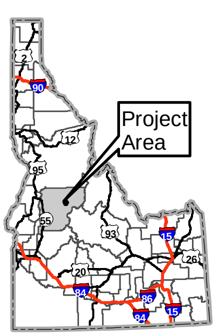
Occupancy Category	East Fork SFSR Upstream from Meadow Creek		Meadow Creak and East Fork Meadow Creek		East Fork SFSR Between Meadow Creek and YPP Lake		East Fork SFSR Between YPP Lake and Sugar Creek	
	km	%OP	km	%OP	km	%OP	km	%OP
High	1.59	69.5	2.21	68.8	2.54	69.7	0.64	68.8
Medium-High	3.95	67.1	3.04	67.2	0.46	67.6	0.53	67.0
Medium-Low	3.78	64.3	3.68	64.1	0.64	63.0	0	0
Low	3.79	59.1	4.13	58.6	2.98	59.7	0	0
Total	13.12	64.3	13.06	63.9	6.54	64.2	1.17	68.0

% = percent; East Fork SFSR = East Fork South Fork Salmon River; km = kilometer; OP = Occupancy Probability; YPP = Yellow Pine Pit

Stream Flows (PHABSIM)

The same PHABSIM approach previously described for bull trout was used for westslope cutthroat trout (see **Section 6.3.3.5**) For each of the three discharge rates and Stream Index, **Table 6-24** provides the WUA value for four westslope cutthroat trout life stages, along with a percentage reduction in WUA relative to the mean discharge rate WUA value.





LEGEND

Occupancy Probability Quartile

- Low
- Medium Low
- Medium High
- High
- Unavailable OM Stream Habitat
- Subwatershed (HUC 12)

Other Features

- U.S. Forest Service
- Wilderness
- County
- Lake/Reservoir

Surface Management

- Private
- U.S. Forest Service

Figure 6-12
Westslope Cutthroat Trout Occupancy Model Probabilities Under Baseline Conditions in the Mine Site Area
Stibnite Gold Project
Stibnite, ID

Base Layer: ESRI World Terrain Basemap
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); USGS; Ecosystem Sciences; Boise National Forest; Payette National Forest

Map Date: 7/22/2022

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Table 6-24 Westslope Cutthroat Trout Weighted Usable Area for Three Discharge Rates for Representative Streams

Representative Stream	Discharge		Weighted Usable Area[1]							
	cfs[2]	Percent Change	Adult	Percent Change	Spawning	Percent Change	Fry	Percent Change	Juvenile	Percent Change
Summit Creek (Index 1)	7.8[3]	--	2,007	--	14,320	--	9,084	--	0	N/A
	4.4	-44	891	-56	13,111	-8	5,989	-34	0	N/A
	1	-87	8	-99	7,117	-50	1,589	-83	0	N/A
Sugar Creek (Index 2)	9.9[3]	--	1,687	--	7,338	--	5,849	--	2,958	--
	5.4	-46	794	-53	6,896	-6	4,256	-27	2,139	-28
	1	-90	20	-99	3,997	-46	1,270	-78	428	-86
East Fork SFSR Downstream from Sugar Creek (Index 3)	63[3]	--	9,788	--	13,345	--	16,220	--	0	N/A
	44	-30	6,640	-32	14,644	10	15,254	-6	0	N/A
	25	-60	3,196	-67	15,272	14	12,393	-24	0	N/A

[1] Weighted Usable Area is defined as the sum of stream surface area within a study site, weighted by multiplying area by habitat suitability variables (most often velocity, depth, and substrate or cover), which range from 0.0 to 1.0 each, and normalized to square units (either feet or meters) per 1000 linear units.

[2] Discharge is measured in cfs.

[3] The underlined value is the mean low-flow-period discharge rate.

cfs = cubic feet per second; East Fork SFSR = East Fork South Fork Salmon River; ND: No data were available from the PHABSIM study; N/A: not applicable.

7.0 Environmental Consequences

7.1 Impact Definitions

The impacts definitions for intensity, duration (FSH 1909.15, 152b), and context are provided in **Table 7-1**.

Table 7-1 Impact Definitions

Attribute	Term	Description
Intensity	Negligible	Impacts would result in a change in current conditions that would be too small to be physically measured using normal methods or would not be perceptible. There is no noticeable effect on the natural or baseline setting. There are no required changes in management or utilization of the resource.
Intensity	Minor	Impacts would result in a change in current conditions that would be just measurable with normal methods or barely perceptible. The change may affect individuals of a population or a small portion of a resource, but it would not result in a modification in the overall population, or the value or productivity of the resource. There are no required changes in management or utilization of the resource.
Intensity	Moderate	Impacts would result in an easily measurable change in current conditions that is readily noticeable. The change affects a large percentage of a population, or portion of a resource which may lead to modification or loss in viability, value, or productivity in the overall population or resource. There are some required changes in management or utilization of the resource.
Intensity	Major	Impacts are considered significant. Impacts would result in a large, measurable change in current conditions that is easily recognized. The change affects a majority of a resource or individuals of a population, which leads to significant modification in the overall population, or the value or productivity of the resource. This impact may not be in compliance with applicable regulatory standards or impact thresholds, requiring large changes in management or utilization of the resource.
Duration	Temporary	Impacts that are anticipated to last no longer than 1 year.
Duration	Short-Term	Impacts that are anticipated to begin and end within the first 3 years during the construction phase.
Duration	Long-Term	Impacts lasting beyond 3 years to the end of mine operations and through reclamation, approximately 20 years.
Duration	Permanent	Impacts that would remain after reclamation is completed.
Context	Localized	Impacts would occur within the analysis area or the general vicinity of the Operations Area Boundary.
Context	Regional	Impacts would extend beyond the Operations Area Boundary and local area boundaries.

Intensity is the severity or levels of magnitude of an impact.
Duration is the length of time an effect would occur.
Context is the effect(s) of an action that must be analyzed within a framework, or within physical or conceptual limits.

7.2 Direct and Indirect Effects

Direct and indirect effects described in this section are considered to be negative unless explicitly described as beneficial.

7.2.1 Assumptions and Information Availability

To analyze impacts on fish resources and fish habitat the following assumptions were made:

- The proposed East Fork SFSR diversion tunnel under the 2021 MMP would provide passage for all four special status fish species. This assumption is based on professional judgment and review of other similar or longer diversion tunnels that have been documented to be fish passable (Gowans et al. 2003; Rogers and Cane 1979; Wollebaek et al. 2011). This analysis also includes a brief description of the effects if the diversion tunnel does not provide passage as planned (USFWS 2019).
- The constructed and enhanced stream reaches would perform as described in the Stream Design Report (Rio ASE 2021).
- The stream temperature analysis is based on the duration of SGP phases as: construction – 3 years; mining – 15 years; closure and reclamation – 5 years; and post-closure to Mine Year 112.
- The stream flow analysis within the combined stream and pit water temperature models (SPLNT models, Brown and Caldwell 2018, 2021a, 2021b) accurately reflect future conditions, which is based on historic conditions.

Much of the fish habitat modeling and analysis presented in this section is based on the hydrologic and site-wide water chemistry modeling performed by Perpetua or its consultants. Predictions generated by groundwater and hydrologic models (Brown and Caldwell 2021b) are associated with a degree of uncertainty and can be limited in their predictive ability (see model uncertainty sections of Forest Service 2023c, 2023d).

Several assumptions regarding physical, biological, and chemical conditions were made to address incomplete information at the time of this analysis.

- Reach-specific fish spatial distribution (i.e., presence/absence) data were not available for all streams potentially affected by the action alternatives, especially the streams outside the mine site. Population estimates were not available; as described in the Aquatic Resources 2016 Baseline Study Report Addendum (GeoEngineers 2017), the results of the multiple years of diver-based snorkel surveys are limited and variable.
- Some habitat conditions could not be quantitatively evaluated due to a lack of available data or a suitable site-specific model (e.g., impacts of stream flow reductions on overwintering fish, and a site-specific stream flow/productivity model). Other examples include lack of modeling of existing habitat for many fish at multiple life stages. There is a lack of a site-specific, two-dimensional hydraulic-based habitat suitability model. The nearest sites where data have been collected and modeling performed are on several streams in the Upper East Fork SFSR (Sugar Creek, Tamarack Creek, Profile Creek, Quartz Creek, and the East Fork SFSR).

7.2.2 No Action Alternative

Under the No Action Alternative, the Forest Service would not approve the SGP, and therefore no activities proposed on Forest Service lands would be approved.

Under the No Action Alternative, there would be no surface (open-pit) mining or ore processing to extract gold, silver, and antimony, and no underground exploration or sampling or related operations and facilities on NFS lands. Perpetua could continue to conduct surface exploration that has been previously approved. Perpetua would continue to comply with reclamation and monitoring commitments included in the applicable Golden Meadows Exploration Project Plan of Operations (Midas Gold 2016). These commitments include reclamation of the drill pads and temporary roads and monitoring to ensure that BMPs are in place and effective so that soil erosion and other potential resource impacts are avoided or minimized. This also would include monitoring commitments required by the Forest Service relating to the Golden Meadows Exploration Environmental Assessment (Forest Service 2015).

In the absence of the SGP, current uses by Perpetua on patented mine/mill site claims, and on PNF and BNF would continue. Uses of NFS lands include mineral exploration, dispersed and developed recreation, such as pleasure driving, hunting, off-highway-vehicle use, camping, hiking, snowmobiling, bird watching, target shooting, firewood cutting, and other forms of recreation. Private businesses, such as outfitter and guide services, also operate on the Forest through special use permits. Access to federal land in the area would continue as governed by law, regulation, policy, and existing and future landownership constraints, the latter of which may include denial of access over private land.

Under the No Action Alternative there would be no SGP-caused impacts on physical stream channels, WCIs, individual fish (including federally listed and forest service species sensitive species), or fish habitat.

7.2.3 2021 Modified Mine Plan

The descriptions of effects are organized as follows: direct impact-causing activities (i.e., physical stream channel changes) and the Direct Effects to Individuals section, are discussed first because those activities would have the greatest potential to impact fish and fish habitat at the mine site. Habitat changes are described next (Watershed Condition Indicators/Habitat Elements) and separated into two subsections (mine site and off-site). This is followed by more detailed descriptions of impacts to each of the four main species (Chinook salmon, steelhead, bull trout, and westslope cutthroat trout).

7.2.3.1 Direct Impacts to Individuals

The following analysis of effects associated with fish resources and fish habitat is considered within the overall context that resident and anadromous fish species could be affected, including three species listed as threatened under the ESA, and one Forest Service sensitive species, the westslope cutthroat trout. While these listed and sensitive species are the focus of the analyses, the effects described are expected to additionally impact other fish species in the analysis area in comparable ways.

The SGP affects watersheds within the analysis area differently depending on the activities proposed for each area. The majority of the mining activity occurs within the headwaters of the East Fork SFSR subwatershed (HUC 170602080201). In this subwatershed, surface water conditions would be affected by ground disturbance, development of mine facilities, and water abstraction for mine dewatering, contact water management, and consumptive use. As a result, stream flows in the watershed would be reduced by up to 30 percent during operations. While EDFs and regulatory requirements maintain water chemistry conditions, removal of riparian shading increases predicted stream temperatures by up to 6.6°C until a time that restoration efforts would effectively shade stream flows and reduce temperatures toward baseline conditions. When the tools utilized to evaluate fish habitat (e.g., intrinsic potential, occupancy, and flow productivity modeling) are applied to the forecasted flow and temperature conditions in the headwaters of the East Fork SFSR watershed, they indicate a change from existing conditions.

Under the SGP, there would be limited mining activity in the Sugar Creek watershed (HUC 170602080202) with most of the effects associated with diverting the West End Creek around the West End pit. 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 flow reductions in Sugar Creek attributable to the SGP would be typically less than 1 percent with a maximum monthly difference of 3 percent. Predicted stream temperature changes would be between 0.1 and 0.3°C, with maximum summer temperatures ranging from 15.5°C to 15.7°C compared to a baseline temperature condition of 15.4°C. Application of fish habitat evaluation tools (i.e., intrinsic potential [IP] model, occupancy probability model, flow-productivity calculation, PHABSIM) to these conditions in Sugar Creek would not indicate an observable change from existing conditions. For the other watersheds in the analysis area, SGP-related effects are associated with site access and transportation which are not expected to affect streamflow and temperature conditions to the degree that fish habitat evaluation tools would indicate an observable change from existing conditions.

Because of the minimal SGP effects anticipated to Sugar Creek, the focus of the environmental consequences analyses is on the headwaters of the East Fork SFSR.

Dewatering, Fish Salvage, Relocation

Stream Crossings

Dewatering, fish salvage, and relocation may be necessary for culvert replacement, new culvert installation, and potentially for bridge maintenance, and could cause injury or mortality to fish in the immediate vicinity or during relocation activities if required. The standard procedures to be developed for dewatering at the mine site also would be used for activities in all other SGP areas (Brown and Caldwell, McMillen Jacobs, and BioAnalysts, 2021b); therefore, the number of injuries or mortalities is expected to be minimized. Approximately 71 water crossings would be required for access roads, and a number of these would cross fish-bearing waterbodies. Fish salvage would be required for dewatering and all in-water work at stream crossings in all fish-bearing water bodies and fish impacts would be limited to minor (less than 10 percent) fish loss associated with fish salvage. Fish salvage work would require prior state and federal agency consultations and follow USFWS Recommended Fish Exclusion, Capture, Handling, and Electroshocking Protocols and Standards (USFWS 2012). Dewatering and in-water work at stream crossings would be spatially limited relative to the larger-scale work occurring in the active mine area. Therefore, effects of the SGP on fish at stream crossings would be negligible, temporary, and localized.

Stream Channels

Fish salvage and relocation would be conducted prior to stream channel dewatering due to mining, construction, restoration, road crossing maintenance, or other activities. The Fisheries and Aquatic Resources Mitigation Plan (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b) outlines the sequence for fish salvage work including site preparation, work area isolation, fish capture, fish handling, and fish relocation. Dewatering would impact streams including East Fork SFSR upstream from YPP lake, East Fork SFSR downstream from YPP lake, Fiddle Creek, Meadow Creek and tributaries, and East Fork Meadow Creek. In total, 17.11 km of stream channel are estimated to be subject to dewatering and fish salvage, with some reaches dewatered, and fish salvaged, more than once (**Table 7-2**). Fish relocation areas have been established for both permanent and temporary removal associated with different salvage locations (**Table 7-3**). Permanent fish relocation would be used where stream channels would be diverted and dewatered over long periods of time. Temporary relocation areas would be used where short-term operation activities would require relocation upstream from the isolated work area, and the fish would then be allowed to migrate back into the work area once the instream work is completed and access is re-established.

Fish salvage would prevent population-level impacts to fish within the active mine area but result in some incidental mortality (generally less than 10 percent), and have a moderate, localized, long-term impact on all fish species within the analysis area. Additional information on the salvage and relocation protocols and implementation is provided in the Fisheries and Aquatic Resources Mitigation Plan (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b).

Table 7-2 Purpose, Location, Stream Length and Lake Area Affected

Purpose	Location	Stream Length Affected (m)	Lake Area Affected (m^2)	Fish Salvage Operations
Mine Site Excavation and East Fork SFSR Diversion Tunnel	East Fork SFSR upstream from YPP lake	475	N/A	Work area isolation, fish salvage, relocation
	YPP Lake	N/A	18,267	
	East Fork SFSR downstream from YPP Lake	639	N/A	
Grown Media Stockpile	Fiddle Creek	515	N/A	
TSF Development	Meadow Creek and Tributaries	7,249	N/A	
Hangar Flats Development	Meadow Creek	2,175	N/A	
Stream Restoration	East Fork Meadow Creek	2,532	N/A	
East Fork SFSR Diversion Tunnel Maintenance	East Fork SFSR	Variable	N/A	Work area isolation, fish salvage, and temporary displacement
Stream Enhancement	Meadow Creek	718	N/A	
Stream Enhancement	East Fork SFSR	2,706	N/A	
Culvert Replacement	East Fork SFSR Box Culvert	100	N/A	

Source: Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b
Key: East Fork SFSR = East Fork South Fork Salmon River; N/A = Not Applicable; m = meter; m^2 = square meter; TSF = tailings storage facility; YPP = Yellow Pine pit

Table 7-3 Fish Salvage Locations and Permanent and Temporary Fish Relocation Areas

Fish Salvage Location	Fish Relocation Type	Relocation Stream	Relocation Area
East Fork SFSR from YPP lake outlet to North Portal of Diversion Tunnel	Permanent	East Fork SFSR	Downstream from North Portal of Diversion Tunnel to confluence with Sugar Creek
		East Fork SFSR	Downstream from confluence with Sugar Creek
		Sugar Creek	Upstream from confluence with East Fork SFSR
YPP Lake	Permanent	East Fork SFSR	Downstream from North Portal of Diversion Tunnel to confluence with Sugar Creek
		East Fork SFSR	Downstream from confluence with Sugar Creek
		Sugar Creek	Upstream from confluence with East Fork SFSR

Fish Salvage Location	Fish Relocation Type	Relocation Stream	Relocation Area
East Fork SFSR from South Portal of Tunnel to YPP lake inlet	Permanent	East Fork SFSR	Downstream from North Portal of Diversion Tunnel to confluence with Sugar Creek
		East Fork SFSR	Downstream from confluence with Sugar Creek
		Sugar Creek	Upstream from confluence with East Fork SFSR
Fiddle Creek	Permanent	Fiddle Creek	Upstream from Fiddle Creek media stockpile
Meadow Creek	Permanent	Meadow Creek	Downstream from TSF development
		East Fork SFSR	Upstream from confluence with Meadow Creek
		East Fork SFSR	Downstream from confluence with Meadow Creek
East Fork SFSR Box Culvert Replacement	Temporary	East Fork SFSR	East Fork SFSR downstream from isolation work area
			East Fork SFSR upstream from isolation work area
Meadow Creek (restoration)	Temporary	Meadow Creek	Upstream from isolation work area
Meadow Creek (enhancement)	Temporary	Meadow Creek	Upstream from isolation work area

Source: Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b
Key: East Fork SFSR = East Fork South Fork Salmon River; TSF = tailings storage facility; YPP = Yellow Pine pit

Yellow Pine Pit Lake

Salvage and relocation of fish from the YPP lake (19,267 square meters) would require a single larger and longer effort compared to multiple smaller fish salvage efforts in dewatered stream reaches. However, impacts to fish species present, such as capture stress and incidental mortality rates, are expected to be comparable due to similarity in the capture methods used (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b). A fish barrier would be installed and designed to allow fish to leave the YPP lake but not allow fish to migrate upstream. The purpose of the barrier would be to ensure that the fewest number of individual ESA-listed fish species are present in the YPP lake when the draining process begins. The upstream fish barrier would be in place in advance of the completion of the East Fork SFSR diversion tunnel and relocation of flow from the East Fork SFSR into the diversion tunnel to minimize fish abundance in the lake prior to dewatering (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b). In other respects, dewatering and fish salvage in the YPP lake would be similar to other areas of the SGP with prior agency consultation, less than 10 percent mortality, and following USFWS Recommended Fish Exclusion, Capture, Handling, and Electroshocking Protocols and Standards (USFWS 2012). Dewatering and associated fish salvage in the YPP lake would have a moderate, localized, long-term impact on all fish species within the analysis area.

Noise and Vibration

Access Roads, Utilities, and Offsite Facilities

Blasting would occur during construction of portions of the Burntlog Route and the new transmission line. Blasting can cause serious injury or mortality to fish; however, these activities would follow applicable regulations and standards (described in more detail below). Therefore, negligible, temporary, and localized effects to fish or fish habitat are expected from blasting along portions of the Burntlog Route.

Operations

Explosives would 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. Most of the blasting required at the mine site would be in and near the Yellow Pine, Hangar Flats, and West End pits, with some that may be required for construction of stream diversions at the TSF, YPP, and TSF Buttress. Such blasting would generally occur on hillsides and at higher elevations, with considerable distance between streams and the origin of the blasts.

Blasting and drilling activities near fish-bearing streams have the potential to affect fish by producing hydrostatic pressure waves, and create underwater noise and vibration, thereby temporarily altering in-stream conditions. Effects on fish from changes in hydrostatic pressure are not related to the distance of the fish from the point of impact, but to the level and duration of the sound exposure (Hastings and Popper 2005).

In order to avoid injury, instantaneous sound levels should be less than 206 peak decibels (dB) and extended time should be less than 187 dB (183 dB for fish less than 2 grams) sound exposure level, referenced at 1 micropascal for sound traveling through water, measured at a distance of 10 meters (Fisheries Hydroacoustic Working Group 2008).

In addition to sound effects, excessive ground vibrations have the potential to affect fish, particularly the sensitive egg life stage (Timothy 2013, Kolden and Aimone-Martin 2013). Smirnov (1954, as cited in Alaska Department of Fish and Game 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 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).

Safe setback distances for blasting in or near water for the protection of fish have been established (Dunlap 2009; Kolden and Aimone-Martin 2013; Timothy 2013; Wright and Hopky 1998). Perpetua (2021a) has committed to comply with blasting standards set forth in Wright and Hopky (1998), and Timothy (2013). These standards have been shown to minimize the risk of injury or mortality to all life stages of fish.

As part of the SGP Environmental Monitoring and Management Plan, an Explosives and Blasting Management Plan would be developed that would ensure compliance with the blasting requirements of the Mine Safety and Health Administration, 30 Code of Federal Regulations 56, Subpart E – Explosives and 30 Code of Federal Regulations 57, Subpart E – Explosives. The blasting plan would include the setback distances and other BMPs.

A spreadsheet tool was developed to compute the required setback distances from fish-bearing streams and lakes (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b). The results indicate that a 425-foot blasting setback from the closest point in the blast field to stream and lake habitats should be protective in most cases, assuming a 40-foot bench height. These findings were used to examine likely areas where blasting would be near streams or lakes. For a 20-foot bench height, the examination indicated that a 239-foot blasting setback could be met everywhere within the mine plan. Considering a 40-foot bench, blasts may encroach on the 425-foot blasting setback in limited areas adjacent to the YPP lake near the East Fork SFSR diversion tunnel and adjacent to the Hangar Flats pit where Meadow Creek is closest to the pit. In those areas where blasting is nearer to streams and lakes and impacts may occur, it is possible that the bench heights could be adjusted to 20 feet, reducing the required setback.

In addition to protective setbacks and bench height, Perpetua may employ other methods when warranted, such as using controlled blasting techniques following industry BMPs, modifying blasting variables including charge size, and vibration and overpressure monitoring.

Because all blasting would be conducted in compliance with applicable regulations and standards (Brown and Caldwell, McMillen Jacobs, and BioAnalysts 2021b), the noise and vibration effects of the SGP to fish are expected to be negligible, long-term, and localized.

Spill Risk

There is the potential for spills to occur along access roads as fuel and other materials are trucked to and from the SGP during construction of the access roads and mine facilities. 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 culvert are fish-bearing, spills into any waterway could travel downstream to fish-bearing waters.

Overall, design features required by the Forest Service (**Table 2-2**), design features proposed by Perpetua (**Table 2-3**), and permit stipulations and regulatory requirements from state and federal agencies would reduce the risk of spills and ensure that effective response is provided should a spill occur.

Mine transport begins on Warm Lake Road (CR 10-579) where the risk of spills would be lower, as it is paved and maintained by Valley County. 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 Burnt Log Road (Forest Road 447). The location of the spill risk would change as the SGP progresses under the 2021 MMP. Johnson Creek and the portion of the East Fork SFSR between the village of Yellow Pine and the Operations Area Boundary would be at risk of any significant spills of hazardous materials during the first one to two years of the SGP when the Johnson Creek Route would be used as the access route during the Burntlog Route construction. For the remainder of the mine life, the waterbodies along the Burntlog Route would be at risk from any significant spills.

The combination of the proposed monitoring, planning, and control practices described in the preceding narrative for transport and handling of fuels and hazardous materials and committed design measures would minimize the risk of accidental releases during the transportation, storage, management, and use of hazardous materials. Nevertheless, the proximity of the access roads to surface water resources increases the potential for a release to enter water which could result in major consequences. It is expected that the risk of a spill large enough to negatively affect fish or aquatic habitat would be low, but the risk occurs throughout the period of the operations. The effects of the SGP on fish and aquatic habitat from contaminants from a spill are expected to be minor, long-term, and localized.

Altered Physical Stream Structure

The SGP would result in stream channel changes, including dewatering, restoration, and enhancements within the active mine area (**Figure 7-1)**. Physical alterations to stream structure from the SGP that would result in impacts to fish generally fall into three phased categories:

- Construction: Dewatering of some stream channels and other aquatic habits and facility construction prior to the active mining period. Fish salvage and other measures would minimize impacts
- Active Mining Period: Maximum dewatering and reduction of stream habitat would occur during this period. Operation of the East Fork SFSR fishway would occur during this period to allow fish

to bypass active mining areas and minimize impacts. Reclamation and restoration of some stream habitats would occur during this period

- Reclamation and Restoration: Excavated areas would be filled and reclaimed. Stream channel would be restored and fish barriers eliminated resulting in a net increase in accessible stream habitat relative to baseline conditions.

Construction and operation under the 2021 MMP would eliminate the existing YPP lake, and important bull trout rearing/feeding habitat, and stream reaches currently occupied by Chinook salmon, steelhead, bull trout, and westslope cutthroat trout. The YPP lake would be replaced with a lake feature called Stibnite Lake which would be designed to serve similar functions to the existing YPP lake including lentic fish rearing/feeding habitat and temperature buffering (Rio ASE 2021). Relative to baseline conditions, construction during the active life of the mine would result in a maximum of 4 percent loss of stream channel habitat above the Sugar Creek confluence occurring by Mine Year 12 based on total estimated stream length (Rio ASE 2021). Reclamation and restoration starting in the active mining period and continuing post-closure would result in a 4 percent increase in total channel habitat length relative to baseline conditions. Specific stream channel restoration plans are discussed in the Stibnite Gold Stream Design Report (Rio ASE 2021). **Table 7-4** presents the annual timeline of major changes to physical stream habitats including elimination and restoration.

Table 7-4 Annual Timeline of Major Changes to Physical Stream Habitats

Period and Mine Years	Activity
Pre-Production/Construction (-3 to -1)	
-3 to -1	Existing Garnet Creek diversion extended around plant site; restored downstream from plant site
	Begin construction of East Fork SFSR diversion tunnel around Yellow Pine pit (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
-1	Fiddle Creek piped beneath growth media stockpile
	Midnight Creek diverted into East Fork SFSR upstream from the diversion tunnel, and Hennessy Creek diverted into Fiddle Creek
-1 continued	East Fork SFSR diversion tunnel and associated fishway completed; East Fork SFSR diverted into tunnel and Yellow Pine pit lake dewatering begins
	Upper Midnight Creek placed in pipe under the West End haul road
	West End Creek diverted around West End pit
	Enhancement in East Fork SFSR (excluding Yellow Pine pit) and the lower portion of Meadow Creek
	Sediment control and rock drain constructed on East Fork Meadow Creek

Period and Mine Years	Activity
Mine Operations (1 to 15)	
1	Upper East Fork Meadow Creek meadow, groundwater table, and associated wetlands restored
3	Divert Meadow Creek into a restored channel around Hangar Flats pit footprint and downstream approximately 1000 feet
	Restore the lower section of East Fork Meadow Creek (downstream from the rock drain) to its new confluence with Meadow Creek
5	Yellow Pine pit backfill begins
6-7	Hangar Flats pit backfilled
8	Midnight pit backfilled
10	Yellow Pine pit backfill completed
	Yellow Pine pit backfill surface preparation for stream liner and placement of floodplain material and growth media
	Construct West End Lake overflow channel
11	Yellow Pine pit stream restoration including East Fork SFSR, Hennessy Creek, and Midnight Creek
	Flow restored to East Fork SFSR and Hennessy Creek over the Yellow Pine backfill
	East Fork SFSR 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
13	Flow restored to lower Midnight Creek including restored stream over Yellow Pine pit backfill
	Remaining road crossings removed and remaining portions of Midnight Creek restored (upstream from Yellow Pine pit)
	Removal of diversion around West End pit
	West End 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
	East Fork SFSR 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
19-23	Meadow Creek surface prep 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

Period and Mine Years	Activity
23	Plant site decommissioning completed
	Garnet Creek and associated wetland restored through decommissioned plant site
	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
	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
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
41	Water treatment plant decommissioned, and water treatment plant site reclaimed

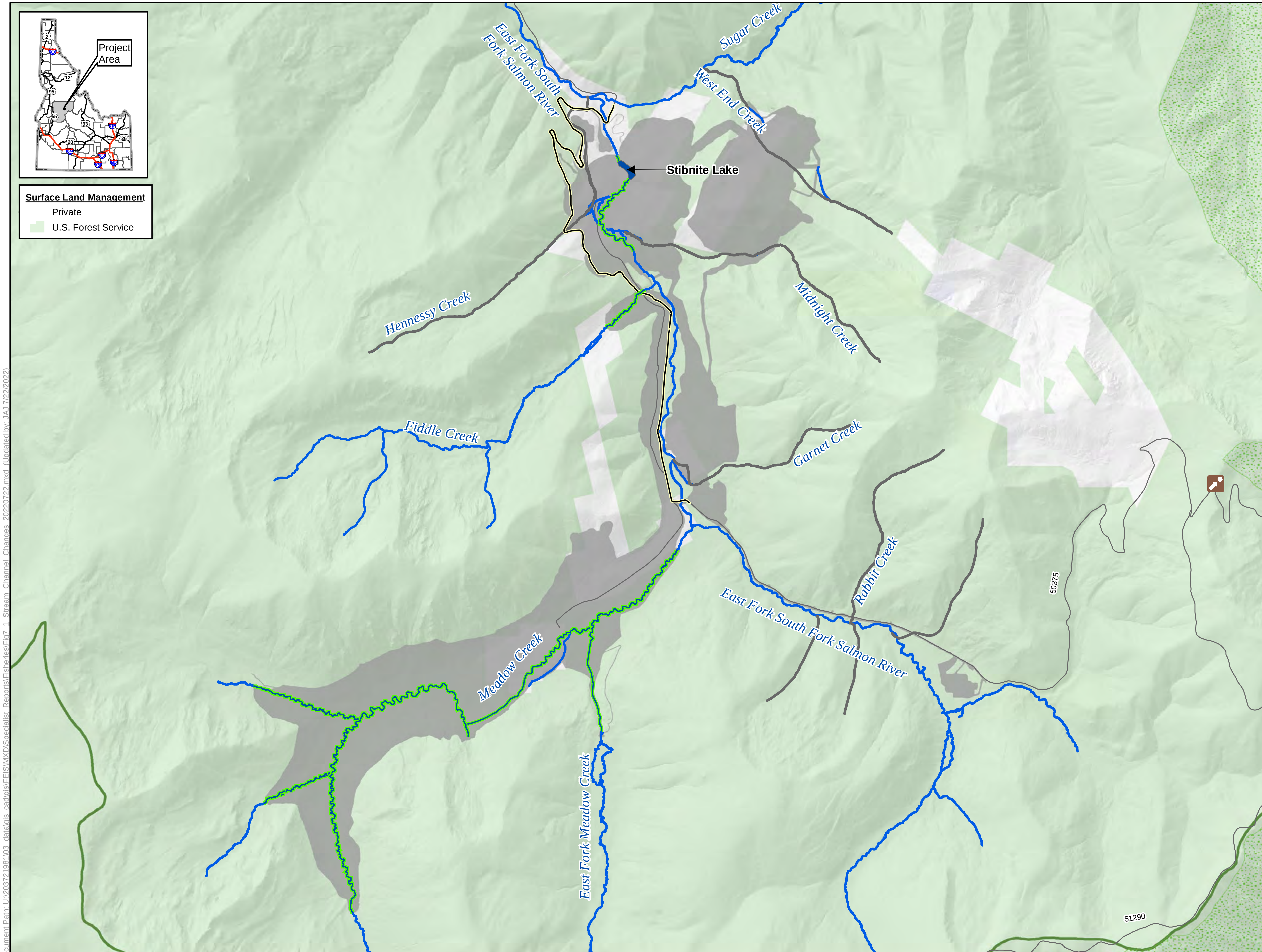
East Fork SFSR = East Fork South Fork Salmon River; TSF = tailings storage facility

The construction and operation of the East Fork SFSR fishway would allow any fish passing through the fishway to access upstream areas thereby limiting the overall fish population impact of habitat reduction in the area of the active mine for a period of approximately 12 years. The fishway would serve to reduce the overall impacts of dewatering, diversion, and stream channel elimination in the active mine. Protective measures, such as routing stream flow around construction areas or during stream restoration activities would be implemented to protect water quality.

Changes in age structure, habitat use, productivity, and species composition would occur within the analysis area during the period of active mining due to extensive physical stream structure changes (**Figure 7-1**). However, the spatial extent and magnitude of these changes would be reduced by fisheries protection measures such as the East Fork SFSR fishway. By Mine Year 11, the fishway would be replaced with an open channel through which volitional passage could occur. Incremental improvements in fish passage and habitat quality would occur through the restoration process leading to an improved permanent condition relative to baseline.

Restoration of stream and lake habitats and riparian vegetation within the active mine area after reclamation would result in a net increase in stream length and accessible fish habitat post-closure relative to baseline conditions and volitional fish access to habitats upstream from YPP lake (Rio ASE 2021). The YPP lake would be replaced with the proposed Stibnite Lake which would provide lentic rearing habitat within the mine area for bull trout and other species without impeding upstream passage. During the 12-year period in which the YPP lake is unavailable and before the Stibnite Lake is created, bull trout would not have access in the mine area to lake habitat, an important habitat for the adfluvial bull trout. This would result in a major, long-term, localize impact to bull trout.

Stream enhancements in the East Fork SFSR and lower Meadow Creek would include improvements to physical channel processes and habitat largely within the existing stream channel. This would be accomplished by selectively installing large woody debris and rock structures, creating pools, enabling improved sediment sorting, and generally increasing hydraulic and habitat diversity. Enhancement efforts also may include floodplain reconnection and establishment of riparian vegetation, achieved by excavation of legacy fill material down to bankfull level (Rio ASE 2021).



LEGEND

Project Components*

- SGP Features
- Post-Closure Perennial Restored
- Stream **
- Non-fish-bearing Stream
- Stibnite Lake
- Public Access Road ***

Other Features

- U.S. Forest Service
- Wilderness
- Monumental Summit
- Road

* Project Components are associated with all Alternatives
** Perennial streams are not depicted for the entire map area.
Only perennial streams within the Operations Area Boundary are depicted.
*** Public Access Road associated with 2021 MMP

0 0.25 0.5 Miles

1 inch = 0.5 miles when printed at 11x17

N

Figure 7-1
Stream Channel Changes During Construction, Active Mining, and Reclamation/Restoration Phases
Stibnite Gold Project
Stibnite, ID

Base Layer: Hillshade derived from LiDAR supplied by Midas Gold
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Document Path: U:\2037219\81\03_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig7_1_Stream_Channel_Changes_20220722.mxd (Updated by: JAJ 7/22/2022)

The Fisheries and Aquatic Resource Mitigation Plan and the Fishway Operations and Management Plan (Brown and Caldwell 2021a) describe in detail how impacts to fish populations within the SGP would be mitigated through fish salvage/rescue in dewatered channels, minimizing runoff impacts, use of fish screens to prevent entrainment, and operation of the East Fork SFSR fishway or trap and truck alternatives. These plans also describe the release of trapped fish at locations with suitable conditions for occupancy.

The effects of the SGP construction activities would have a major, short-term, localized impact on Chinook salmon, steelhead, bull trout, and westslope cutthroat trout. The effects of the SGP and disturbance to the streams due to mining activities would have a major, long-term, and localized, impact on Chinook salmon, steelhead, bull trout, and westslope cutthroat trout. The restoration activities, particularly providing volitional passage in the East Fork SFSR, would result in a major, permanent, regional and beneficial effect on Chinook salmon, steelhead, bull trout, and westslope cutthroat trout within the vicinity of the mine.

7.2.3.2 Impacts to Watershed Condition Indicators/Fish Habitat Elements

WCIs, described in **Section 6.1.3**, analyzed in detail at the mine site of impacts described in the following sections.

Water Temperature

Predicted future temperature increases resulting from the 2021 MMP were evaluated using a SPLNT model (Brown and Caldwell 2021a) which calculated a MWMT. **Section 6.3.1.4** provides additional detail on the methods applied, and the SGP Water Quality Specialist Report for additional information on the modeling results (see Table 7-21 in the SGP Water Quality Specialist Report, Forest Service 2023c).

The fish species of greatest management concern considered in this analysis that would be impacted by the SGP are all salmonids that are adapted to a cold-water thermal regime, requiring cooler water to complete their life cycle. When water temperatures exceed the tolerance limits for the species life stages, they may be impaired or their survivability decreases.

A summary of predicted water temperatures under the 2021 MMP are presented in **Table 7-5**. The periods evaluated include the baseline conditions, those within the mine operations (Mine Years 6, 12 and 18), one within the closure and reclamation period (Mine Year 22), and several in the post-closure period (Mine Years 27, 32, 52 and 112). The post-closure period represents how the mine site would function after the facilities and permitted discharges have been removed, dewatering and mining have been discontinued, and the channels and vegetation have been fully reclaimed.

It should be noted the SPLNT model used for the temperature predictions in **Table 7-5** do not account for changes to stream temperatures caused by changing climate conditions. This means that modeled future water temperatures (e.g., Mine Year 112) assumed that without the 2021 MMP, stream temperatures would be similar to the historic water temperature data (Brown and Caldwell 2018). In reality, water temperatures would likely be higher if climate change had been incorporated into the model. As described in **Section 6.1.3.1**, climate change would 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). This range of expected temperature increase attributable to climate change is based on a forecast period approximately 75 years shorter than the model predictions through Mine Year 112. Due to the potential effects of climate change and other uncertainties in stream water temperatures over the long-term such as effects of stream restoration and riparian shading, later year model predictions have more uncertainty than earlier year model predictions. This uncertainty is discussed further in the sensitivity analysis section of Brown and Caldwell 2018 and the uncertainty analysis section of Forest Service 2023c.

In the East Fork SFSR upstream from Meadow Creek, water temperatures tend to be cooler than the downstream reaches because this consists of the headwaters. Water temperatures in this section of the East Fork SFSR under the 2021 MMP would be similar to those under baseline conditions, and therefore could be used as cool water refugia if other portions of the subwatershed have unsuitable thermal conditions.

Meadow Creek upstream from East Fork Meadow Creek has decreasing water temperatures during mine operations and closure/reclamation activities (Mine Year 6 through Mine Year 18 as shown in **Table 7-5**) because water being piped is not exposed to solar radiation. Once the pipeline is removed, however, water temperatures increase until around Mine Year 27, at which time the replanted riparian vegetation becomes more established and stream shade is increased and water temperatures begin to decrease. This decrease continues through at least Mine Year 112. The temperature changes within the portion of Meadow Creek adjacent to the TSF area were also examined. This portion of Meadow Creek exhibits the specific effects of existing mining disturbance on the baseline condition and then the specific effects of TSF operation followed by stream restoration across the TSF and TSF Buttress. Predicted temperatures during the early years of restored flow across the TSF and TSF Buttress are higher than average temperatures over the entirety of Meadow Creek because early revegetation efforts have not reached their riparian shading potential. However, the reduction from existing conditions is smaller because the TSF area has a higher temperature under existing conditions than Meadow Creek as a whole.

East Fork Meadow Creek experiences an increase in summer and fall maximum water temperatures during mine operations and closure/reclamation activities (Mine Year 6 through Mine Year 18) and post-closure until Mine Year 52, at which point the temperatures decline compared to the baseline conditions (**Table 7-5**). Restoration activities on the East Fork Meadow Creek is slated to begin in mine year 1, with the construction of the rock drain starting in Mine Year 3. East Fork Meadow Creek flowing through the rock drain would reduce its exposure to solar radiation, thus resulting in a decrease in change in water temperatures between the meadow and the lower section of East Fork Meadow Creek during the summer and fall months. By Mine Year 112, the reduction in water temperature between the meadow and the lower East Fork Meadow Creek is around 0.5°C for both the summer and fall maximums.

Water temperatures in the warmer summer and fall months in Meadow Creek downstream from East Fork Meadow Creek substantially decreases relative to the baseline conditions during mine operations and closure/reclamation activities (Mine Year 6 through Mine Year 18), though there is an increase at Mine Year 27, which then continues to decline until Mine Year 112 (**Table 7-5**). These decreases during mine operations are a result of decreased solar radiation upstream sources (upper Meadow Creek and East Fork Meadow Creek). The removal of the low-flow piping along the TSF in Mine Year 23 would result in water temperatures increasing, though not as high as baseline conditions, and subsequently decreasing as the revegetation efforts take effect. This section retains some connection to groundwater which helps maintain a lower temperature as well.

The East Fork SFSR between Meadow Creek and YPP experiences decreases in summer maximum water temperatures relative to baseline conditions. There is a slight increase in temperatures, still lower than baseline, after Mine Year 22 once the low-flow piping along the TSF is removed, and temperatures continue to decrease once the revegetation efforts take effect (**Table 7-5**). Fall maximum water temperature decrease throughout the operations, closure, and post-closure periods (**Table 7-5**).

Table 7-5 Maximum Weekly Water Temperatures during July (Summer) and September (Fall) for Modeled Mine Years for the 2021 Modified Mine Plan

Stream Drainage	Season	Baseline (°C)	Mine Year 6 (°C)	12 (°C)	18 (°C)	22 (°C)	27 (°C)	32 (°C)	52 (°C)	112 (°C)	Change from Baseline to 27 (°C)	Change from Baseline to 52 (°C)	Change from Baseline to 112 (°C)
East Fork SFSR Upstream from Meadow Creek	Summer	13.4	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	-0.1	-0.1	-0.1
	Fall	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	-0.1	-0.1	-0.1
Meadow Creek Upstream from East Fork Meadow Creek	Summer[1]	14.0	12.4	12.3	12.4	12.4	20.8	18.6	17.1	15.1	6.8	3.1	1.1
	Fall[1]	12.0	10.5	10.5	10.5	10.5	16.0	13.8	12.7	11.3	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	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	1.7	-1.1	-2.7
Meadow Creek Downstream from East Fork Meadow Creek	Summer	19.4	17.6	16.5	16.3	16.1	18.5	17.9	16.6	15.2	-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	-2.0	-3.5	-4.3
East Fork Meadow Creek	Summer	14.6	15.8	15.4	15.3	15.2	14.9	14.8	14.4	14.2	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	0.2	0.0	-0.3
East Fork SFSR between Meadow Creek and YPP	Summer	17.3	16.3	15.6	15.8	15.9	16.3	15.9	15.2	14.7	-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	-1.4	-2.0	-2.2
East Fork SFSR between YPP and Sugar Creek	Summer	14.1	16.1	15.8	15.7	15.6	15.6	15.4	14.8	14.5	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	0.6	0.1	-0.1
East Fork SFSR Downstream from Sugar Creek	Summer	14.9	16.0	15.0	15.1	15.1	15.0	14.9	14.7	14.5	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	-0.3	-0.6	-0.6

Increased temperatures attributable to climate change are not incorporated in the reported predicted values.
Uncertainty in predicted temperature values increases over time due to assumptions made about the effects of stream restoration and riparian shading.
[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
°C = degrees Celsius; East Fork SFSR = East Fork South Fork Salmon River; YPP = Yellow Pine pit lake

East Fork SFSR between YPP and Sugar Creek, and similarly the East Fork SFSR roughly 1 km downstream from Sugar Creek, experiences an increase in summer and fall maximum water temperatures at Mine Year 6 because of 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 (**Table 7-5**). By Mine Year 112, summer maximum water temperatures in the East Fork SFSR between YPP and Sugar Creek are about 0.4°C higher than baseline conditions, but fall maximum temperatures, and summer maximum and fall maximum temperatures below Sugar Creek end up between 0.1 and 0.6°C below baseline conditions (**Table 7-5**).

The effects of the SGP on fish caused by changes to water temperature are expected to be minor to moderate, permanent, localized for Meadow Creek upstream from the East Fork Meadow Creek, East Fork Meadow Creek, and East Fork SFSR downstream from YPP. . Changes to water temperature in the EFSFSR upstream from Meadow Creek is expected to be negligible, permanent and localized. The effects of the SGP on fish are expected to be major, permanent localized, and beneficial for Meadow Creek downstream from the East Fork Meadow Creek, and for the East Fork SFSR between Meadow Creek and YPP.

Sediment and Turbidity

Fish population abundance, distribution, and survival have been linked to levels of turbidity and silt deposition. Excess sediment can degrade spawning gravels, reduce embryo survival and emergence, impair growth and survival of juvenile salmonids, fill pool habitat, and reduce the productivity of aquatic macroinvertebrates and other prey items for fish (Bjornn et al. 1977; Suttle et al. 2004). Prolonged exposure to high levels of suspended sediment would create a loss of visual capability in fish in aquatic habitats within the analysis area, leading to reduced feeding and growth rates; a thickening of the gills, potentially causing the loss of respiratory function; clogging and abrasion of gills; and increases in stress levels, reducing the tolerance of fish to disease and toxicants (Waters 1995, Newcombe and Jensen 1996; Wilber and Clark 2001). It can also cause the movement and redistribution of fish populations.

<u>Outside the Mine Site Area</u>

Construction and use of roads can accelerate erosion and sediment delivery to streams and have been identified as the primary contributor of sediments to stream channels in managed watersheds (Trombulak and Frissell 2000). During the Burntlog Route construction, including bridge and culvert installations, the potential exists for increased runoff, erosion, and sedimentation resulting from localized vegetation removal and soil excavation which could result in increased sediment load in streams. Construction of and upgrades to access roads creates a potential for increased runoff, erosion, and sedimentation as a result of localized vegetation removal and excavation of soil, rock, and sediment, which could result in increased sediment load in streams. Expected permit stipulations from IDWR and IDEQ would ensure streambank vegetation would be protected except where its removal is necessary. New cut or fill slopes not protected with some form of stabilization measures would be seeded and planted with native vegetation to prevent erosion. Use of temporary erosion and sediment control BMPs also would be employed.

During the construction phase, the SGP would be accessed by routes that would cross 43 of the 71 streams listed in Table 7-19 of the SGP Water Quality Specialist Report (Forest Service 2023c). 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). There is also an approximately five-mile segment of Warm Lake Road within 100 feet of Warm Lake Creek. The number of vehicle trips per day also is used in this analysis as a metric for potential increases in erosion and sedimentation. A total of 65 vehicle trips per day would occur during the construction phase (Table 7-2 in the SGP Access and Transportation Specialist Report, Forest Service 2023e). During the mining and ore processing operations phase (approximately 15 years), a total of 50 vehicle trips per day are anticipated on average per day (year-round) during operations utilizing the Burntlog Route. During the closure and reclamation phase, traffic along the Burntlog Route would be reduced to a total of 27 vehicle trips per day (year-round).

For stream crossings, Perpetua would replace existing, or install new, culverts or bridges at crossings along the Johnson Creek (CR 10-579), McCall-Stibnite (CR 50-412), and Burnt Log (Forest Road 447) roads. Existing bridges and culverts along Warm Lake Road would remain. If not properly designed, constructed, and maintained, culverts and bridges could constrict natural stream flow leading to an increase in water velocity at the downstream end of the structure. This could lead to stream bank and/or streambed erosion, and/or excessive erosion at the structure. Erosion of the streambed and/or banks could result in downstream sedimentation, a change in the morphology of the stream, and/or a change to the aquatic habitat. If a structure does not allow for adequate flow, water could pool excessively on the upstream side. As such, stream crossings associated with access roads would be designed to minimize potential impacts on surface water hydrology, water quality, and fish passage. The Forest Service would require stream crossings to 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. New culverts would also be designed and installed consistent with Forest Service guidelines for fish passage.

During the Burntlog Route construction including bridge and culvert installations, the potential exists for increased runoff, erosion, and sedimentation as a result of localized vegetation removal and excavation of soil, rock, and sediment, which could result in increased sediment load in streams. Expected permit stipulations from the IDWR and IDEQ would ensure that streambank vegetation would be protected except where its removal is absolutely necessary; that new cut or fill slopes not protected with some form of riprap would be seeded and planted with native vegetation to prevent erosion; use of temporary erosion and sediment control BMPs associated with a stormwater pollution prevention plan; and that all activities would be conducted in accordance with Idaho environmental anti-degradation policies, including IDEQ water quality regulations and applicable federal regulations. Permit stipulations and BMPs would serve to minimize sediment impacts.

For the Burntlog Route, the potential for sedimentation would be minimized using standard erosion control measures, such as silt fencing, ditch checks, and other measures, which would be installed and maintained to minimize the potential for erosion and sedimentation. Numerous small (15- to 60-inch) drainage culverts would be installed along the Burntlog Route to reduce rutting and shunt water out of ditches and off the road prism, which would serve to reduce erosion from the road into streams. Perpetua would maintain a hardened road surface with gravel surfacing to promote an efficient and useable all-weather road while minimizing erosion (Perpetua 2021b).

Additionally, Perpetua would be required to comply with specific design requirements as part of the IDWR Stream Channel Alteration Permit, such as line of approach, minimum bridge clearance and minimum culvert size per length, and anchoring on steep slopes. Bridges and culverts would be maintained to allow proper drainage and limit sediment delivery to area streams.

Based on permit-related design requirements, use of BMPs, and required maintenance activities, the potential for access road-related erosion and sedimentation would be minimal (limited to periods of substantial overland flow, such as from very large rainfall events).

Utilities associated with the SGP (existing transmission line upgrades and structure work, right-of-way (ROW) clearing, new transmission line, and transmission line access roads) would cross 37 different streams, as identified in Table 7-20 in the SGP Water Quality Specialist Report (Forest Service 2023c). Of the 37 streams that would be crossed, 26 would be related to the upgrade of existing Idaho Power Company transmission lines, where the existing transmission line ROW crosses various streams. 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. Expected permit stipulations from IDWR and IDEQ would be similar to the examples provided above for access roads and would ensure the use of erosion and sediment control BMPs associated with a stormwater pollution prevention plan. ROW vegetation clearing would retain vegetation root structure within soils thus reducing erosion concerns.

Surface water quality also could be impacted during construction by fugitive dust from vehicles and heavy equipment that settles into adjacent water bodies. Reduction of these potential impacts would be achieved through fugitive dust control at the SGP. In dry months, Perpetua would spray water on mine haul roads as necessary to mitigate dust emissions in compliance with state and Forest Service requirements.

The extent of sedimentation effects from fugitive dust would be concentrated at the SGP; however, due to the nature of sediment transport by streams, the geographic extent of the impact could extend farther downstream in the East Fork SFSR depending on site- and event-specific factors. The duration for traffic-related dust and erosion/sedimentation would last throughout the mine construction, operations, and post-closure periods; however, the potential for these effects would be incrementally reduced during closure and reclamation due to reduced activity at the SGP and stabilization of disturbed areas. Therefore, the effects of fugitive dust on fish would be minor, long-term and localized.

The effects of the SGP construction of temporary roads and transmission lines on sedimentation on fish and aquatic habitat are expected to be moderate, short-term, and localized.

<u>Within the Mine Site Area</u>

Construction and active mining would disturb, excavate, and move soil and overburden thereby raising the potential for sediment runoff and suspended sediment increases in surface waters. Total suspended solids (TSS) in surface water are generally correlated with turbidity (Nephelometric Turbidity unit (NTU)), which is a more visually apparent estimator of sediment contamination. Under baseline conditions, turbidity is generally low (less than 5 NTU) with occasional spikes of up to 70 NTU during snowmelt or rainfall events (Forest Service 2023c). The greatest potential for Project-related increases in stream sedimentation would come during storm events causing overland flow across exposed soil, excavated areas, and roads. BMPs would 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 would affect sediment transport and deposition. Under baseline conditions, sediment entering the East Fork SFSR primarily comes from Sugar Creek, Meadow Creek, and East Fork Meadow Creek. Applicable sediment control design techniques BMPs would be used to minimize sediment runoff and erosion along roads and excavated areas. On the mine site and along the Burntlog route, expected permit conditions from IDWR and IDEQ would protect streambank vegetation, require culvert maintenance, and require low impact snow removal techniques.

Surface water quality also could be impacted during operations, closure, and reclamation by fugitive dust from vehicles and heavy equipment that settles into adjacent water bodies, as described above, outside the mine site area.

Potential Project-related sediment impacts on fish would include temporary turbidity increases during runoff events and localized deposition of fine sediment in stream channels. Turbidity increases during runoff events have the potential to temporarily change fish behavior but are unlikely to be severe enough, relative to baseline fluctuations, to cause fish mortality or health impacts. Increases in fine sediment deposition within stream channels have the potential to decrease spawning gravel suitability and decrease benthic invertebrate production within gravel riffles. These impacts would impact spawning/incubation and rearing/feeding life stages, respectively, of Chinook salmon, steelhead, bull trout, and westslope cutthroat trout. With the application of sediment reduction BMP's and surface runoff minimizing design techniques, the impacts of sediment in surface water to fish are predicted to be measurable but not severe, limited to the mine area, and occur during the active mining period. However, the restoration efforts in the East Fork Meadow Creek would result in a substantial decrease in sediment input into Meadow Creek and the East Fork SFSR. The cumulative impacts on the EFSFSR of moderate sediment impacts from active mining and construction combined with the beneficial impacts of East Fork Meadow Creek restoration cannot be predicted quantitatively and would occur at different locations and times. Therefore, a combination of both beneficial and moderate detrimental sediment impacts is assumed.

The effects of the SGP on sediment and turbidity during operations on Chinook salmon, steelhead, bull trout, and westslope cutthroat trout will be moderate, long-term and localized impacts to their behavior and health, but post-closure due to restoration actions will be moderate, permanent, localized, and beneficial.

Physical Barriers

Physical barriers can affect fish population dynamics by reducing or blocking access to fish habitat. These barriers can be natural (gradient, woody debris, etc.) or human-made (culverts, altered creek channels due to human activities). These barriers, both outside and within the mine site area, are discussed below.

<u>Outside the Mine Site Area</u>

During the construction of the Burntlog Route or of temporary roads, culverts would be constructed or replaced, which may affect fish access in different sections of streams. Surveys were conducted to identify fish bearing streams along the Burntlog Route (Stantec 2018 and 2019). Any new or reconstructed crossing is required to be fish passable, which would increase or re-establish fish access where it had been reduced or blocked unless there is a risk of passing non-native fish species. The potential re-establishment of access upstream from these culverts could affect the composition of the localized fish assemblages. Changes in types of fish present and the abundance of fish could increase the risk of injury and mortality for some species. For instance, additional habitat could benefit some species, while the presence of additional fish in previously inaccessible reaches would introduce competition for resources. These changes may affect the distribution and relative abundance of fish populations in affected streams.

Furthermore, establishing or increasing access could allow non-native species to access upstream habitat that is currently blocked, such as brook trout. Brook trout are known to compete with bull trout for resources and habitat (USFWS 2008). Brook trout also are known to hybridize with bull trout, which has the potential to negatively impact the genetic integrity, and/or result in negative changes to the local population of bull trout (USFWS 2008). According to the Forest Plan standard, no barrier will be removed if increasing access between non-native species to sensitive native species would occur. Additionally, brook trout presence is minimal in the Burntlog Route (MWH 2017, Stantec 2018 and 2019), therefore the likelihood of impacts due to brook trout presence is low.

The effects of the SGP on fish access during construction of temporary roads and the culverts are expected to be minor, short-term, and localized, but with improved passage at the crossings and expanded access to habitat when construction is completed, will be minor, long-term, localized, and beneficial.

Within the Mine Site Area

Fish passage barriers can negatively impact fish population dynamics by reducing, or completely blocking, available habitat during certain life stages. Existing fish passage barriers within the mine site were identified as either complete - no species can move upstream or downstream at any time of year; or partial - the barrier may not exist at high flows but at certain flows (i.e., low flows) some fish may not be able to pass. Passage barriers are further categorized by natural - not caused by human action, such as a rock dam, log jam, and steep slopes; or artificial - caused by human action, such as culverts, stream alteration, and surface water diversions (BioAnalysts 2019).

Existing and predicted fish passage barriers, as well as the removal of barriers resulting from SGP activities under the 2021 MMP are shown in **Figure 7-2**. **Table 7-6** presents a summary of the fish barriers conditions, as well as the length of stream channel changes post-closure, which includes both the new access as well as blocked access to stream channels into existing stream reaches in construction diversion and stream enhancements.

Species-specific impacts to fish habitat resulting from passage barriers were assessed for Chinook salmon and steelhead through the evaluation of the extent of both Critical Habitat and IP (**Sections 7.2.3.4** and **7.2.3.5**). Impacts to fish habitat from passage barriers for bull trout and westslope cutthroat trout were assessed by quantifying the extent of Critical Habitat (bull trout) and occupancy probability (for both) (**Sections 7.2.3.6** and **7.2.3.7**). Additional information is provided in ESS 2022a.

The greatest benefit to Chinook salmon and steelhead passage comes in Mine Year -1 with the completion of the fishway, which would allow these species to volitionally access habitat that they have not naturally accessed for decades. The fishway may be a partial barrier by discouraging migration of some fish, but the extent of this is unknown. By Mine Year 11, the East Fork SFSR, where the Yellow Pine Pit is located, would have been restored, providing natural conditions for volitional passage. Additionally, the box culvert, 2.88 km upstream from the YPP cascade barrier would be modified to provide full passage under all flow conditions. This substantially increases the amount of habitat volitionally available to Chinook salmon and steelhead that are not currently accessible (**Table 7-6**).

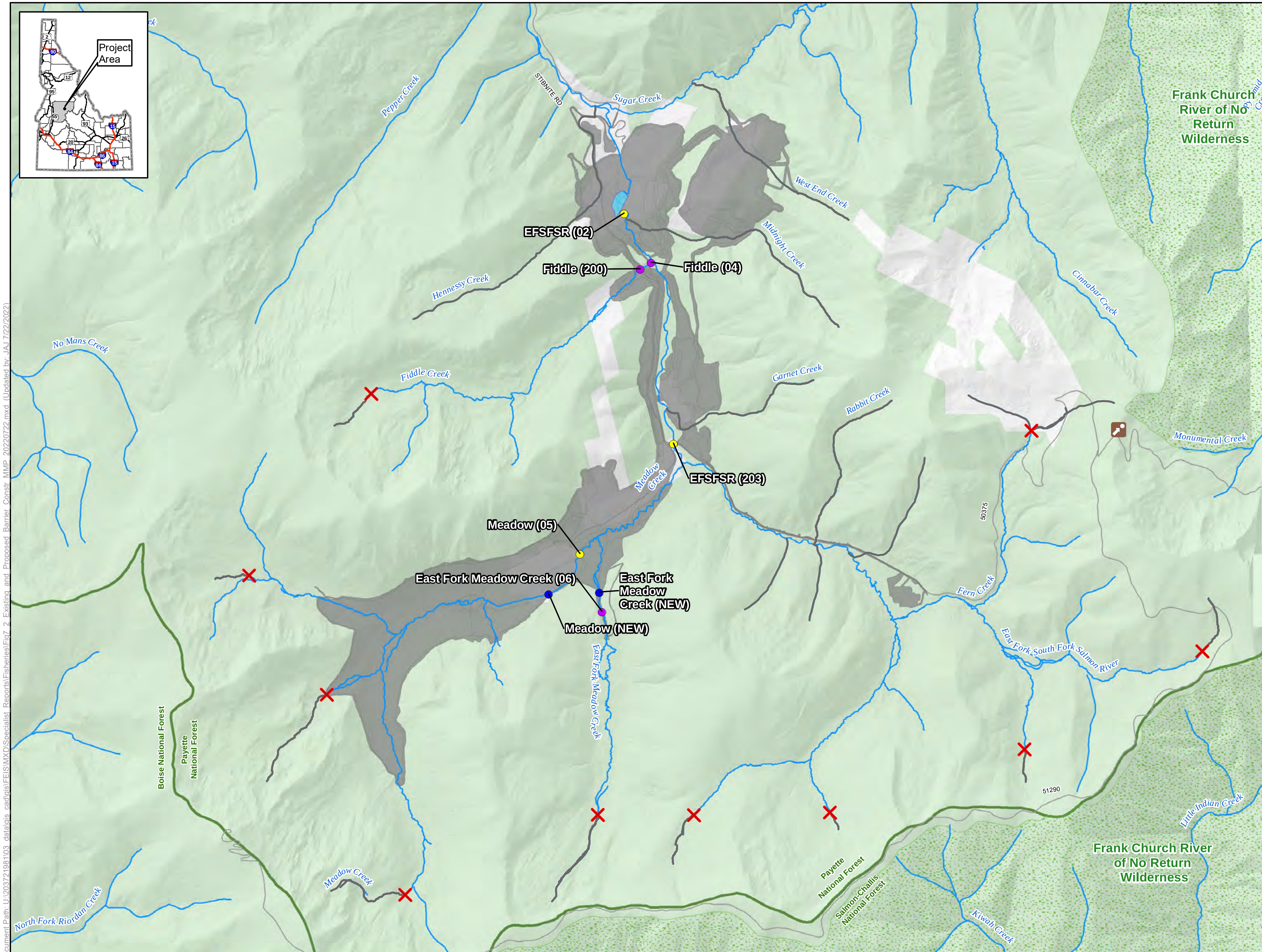
Based on the current known extent of bull trout occupancy, bull trout may be extirpated because of the low number of individuals and the lack of passage that could add individuals from the reaches upstream from the TSF when the reaches within the footprint would be dewatered and flow would be diverted into the diversions that route water around the facilities. With the gradient barrier that would be created along the TSF, there would be no mechanism by which bull trout would be able to volitionally (i.e., naturally) recolonize the reaches upstream from or on top of the TSF. Based on the current known extent westslope cutthroat trout occupancy, fish in the upper headwaters of Meadow Creek would remain isolated.

The effects of the SGP on fish access for Chinook salmon and steelhead, to upstream habitat are expected to be major, permanent, and localized benefits, but for bull trout and westslope cutthroat trout the effects are expected to be major, permanent, and localized impacts.

Table 7-6 Length of Habitat Gained or Lost under Post-Closure Conditions Relative to Baseline Conditions for Existing and Expected Future Fish Passage Barriers Constructed or Removed in Mine Site Area Streams

Stream/ Location	Mine Year Added/Removed	Length of Chinook Salmon Habitat (km)		Length of Steelhead Habitat (km)		Length of Bull Trout and Cutthroat Trout Habitat (km)	
		Change Attributed to Barrier [1,2]	Change in Total Available[1,2,3]	Change Attributed to Barrier[2]	Change in Total Available[2]	Change Attributed to Barrier[1,4]	Change in Total Available[1,4]
Existing Barriers							
East Fork SFSR above YPP (02) Artificial – Gradient	Removed: -1 (Diversion Tunnel); 11 (Channel reconstruction)	+19.65[1] +8.87[2]	+1.44[1] +0.27[2]	+8.72[2]	+1.77[2]	+19.54[1] +32.82	+1.31[1] +1.96[4]
East Fork SFSR (203) Artificial – Box Culvert	Removed -1	+16.87[1] +6.29[2]	+1.44[1] +0.27[2]	+6.90[2]	+1.77[2]	+16.66[1] 26.43	+1.31[1] +1.96[4]
Fiddle Creek (04) Artificial – Gradient	Removed -4	NP	NP	NP	NP	NP[1] -0.72[4]	NP[1] +1.96[4]
Fiddle Creek (200) Artificial – Culvert	Removed -4	NP	NP	NP	NP	NP[1] 0.71[4]	NP[1]
Meadow Creek (05) Artificial – Gradient	Removed 3	NP	NP	NP	NP	NP	NP
East Fork Meadow Creek (06) Natural – Gradient	Removed -1	NP	NP	NP	NP	NP	NP
Created Barriers							
Meadow Creek Diversion Artificial – Gradient	New -2	NP	NP	NP	NP	NP	NP
Meadow Creek TSF Artificial – Gradient	New 18	0.58 -1.02[2]	+1.44[1] +0.27[2]	-0.14	+1.77	-0.61[1] +0.28[4]	+1.31[1] +1.96[4]
East Fork Meadow Creek Artificial – Rock Drain/Gradient	New -1	NP	NP	NP	NP	NP[1]	NP[1]
East Fork Meadow Creek Artificial – Gradient	New Mine Year 22	NP	NP	NP	NP	NP[1] -0.63[4]	NP[1] +1.96[4]

[1] Results based on potential usable Critical Habitat (excludes Meadow Creek critical habitat which is not usable critical habitat for Chinook salmon under baseline conditions)
[2] Results based on usable Intrinsic Potential habitat, but not always accessible
[3] Not all of the total habitat is accessible habitat under baseline conditions
[4] Results based on usable occupancy potential, but not always accessible
East Fork SFSR = East Fork South Fork Salmon River; km = kilometer; NP = not present, YPP = Yellow Pine pit



LEGEND

- Upstream Extent of Fish Presence
- Existing Barrier No Change
- Existing Barrier With Change
- New Barrier

Project Components*

- SGP Features

Other Features

- U.S. Forest Service
- Wilderness
- Monumental Summit
- County
- Road
- Non-fish-bearing Stream
- Stream/River
- Lake/Reservoir

*Project Components are associated with 2021 MMP

Note:

East Fork Meadow Creek is also known as Blowout Creek

The McCall – Stibnite Road (CR 50-412) consists of Lick Creek Road, East Fork South Fork Salmon River Road (East Fork Road) and Stibnite Road.

0 0.3 0.6 Miles

1 inch = 0.6 miles when printed at 11x17

N

Figure 7-2
Existing and Proposed Barrier Construction or Removals for the Modified Mine Plan
Stibnite Gold Project
Stibnite, ID

Base Layer: Hillshade derived from LiDAR supplied by Midas Gold
Other Data Sources: Perpetua; State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest

Map Date: 7/22/2022

Document Path: U:\2037219811003_data\gis_cad\gis\FEIS\MXD\Specialist_Reports\Fisheries\Fig7_2_Existing_and_Proposed_Barrier_Constr_MMP_20220722.mxd (Updated by: JAJ 7/22/2022)

Chemical Contaminants

Outside the Mine Site Area

There is the potential for spills to occur along access roads as fuel and other materials are trucked to and from the SGP. If a spill were to occur at a stream crossing or near a stream, surface water could be impacted. Discussion of very low probability scenarios for a large release (tanker truck or concentrate truck rollover), and more probable scenarios involving small releases, is provided in Forest Service 2023c. Overall, environmental design features required by the Forest Service (**Table 2-2**), design features proposed by Perpetua (**Table 2-3**), and permit stipulations and regulatory requirements from state and federal agencies (including use of U.S. Department of Transportation [USDOT]-certified containers and USDOT-registered transporters) would reduce the risk of spills and ensure that effective response is provided should a spill occur.

The most probable release scenario associated with truck transport on the access routes to the SGP would be relatively small amounts of fuel spilled from vehicles themselves and attributed to mechanical failure or human error. Under this scenario, immediate cleanup actions would include deployment of containment and spill recovery materials, and removal of impacted soil. Fuel spilled to soils/roadbed could be readily contained and recovered, while fuel which enters waterways via roadside drainages may be difficult or impossible to fully recover and there would be potential for migration beyond the immediate spill area. Spill response materials on the vehicles and pre-positioned along the access routes and in SGP response vehicle would include materials to contain and recover floating oil. Response actions would include notification to the appropriate regulatory agencies.

Small volume release scenarios would be temporary due to prompt response and cleanup actions; however, higher volume/lower probability spill scenarios could result in longer-term remedial actions and impacts. The risk of spills would last throughout the life of the SGP (long term). Effects would generally be local and in close proximity to the release source in most scenarios; however, if surface or groundwater were to be impacted with fuels or other hazardous materials, the potential for migration beyond the local area could occur.

A low probability release of liquid petroleum or hazardous material from a bulk truckload could potentially occur assuming the puncture of the bulk tanker in the accident. Under this scenario, spilled material would be released to the immediate roadbed area, and potentially impact physical resources and ecological receptors (e.g., vegetation or wildlife) and nearby surface water depending on the topography and location. 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 (as needed) would help to limit impacts.

A release of large quantities of solid hazardous materials such as cyanide or antimony concentrate would also be unlikely. Breaches of the shipping containers for these materials in the case of an accident could release the solid materials to the ground where it would 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 would be less likely than for liquid materials but could be possible in wet weather conditions. Again, spill response and recovery measures would help to limit impacts.

The pilot vehicles that would accompany all transports of fuel or hazardous materials between the SGLF and the Operations Area Boundary would carry spill response tools and materials, communications equipment, and 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 would essentially be immediate.

Spill containment and countermeasures equipment and materials would be pre-positioned at the SGP mine site, Burntlog Maintenance Facility, and SGLF. In the event of a major spill requiring assistance from any of these locations, the radio communications between the pilot vehicles and these facilities would enable a timely response which would take an estimated 45 minutes to mobilize and arrive at the spill site.

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 Burntlog Route crosses 37 streams and includes 9 miles of road that are within 0.5 mile of surface water resources. 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 East Fork SFSR and Johnson Creek waterways. Though the Burntlog Route includes a greater number of stream crossings, the Johnson Creek Route includes significantly greater proximity to water resources. The potential consequences from trucking spills would thus be greater along the Johnson Creek Route that would be utilized during construction of the Burntlog Route.

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 diesel 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. Most of the streams with segments in proximity to access roads support Chinook salmon, steelhead trout, bull trout, and cutthroat trout. The intensity of the impact of a hazardous materials spill on fish and fish habitat could be high; as a large diesel spill could kill 100 percent of the Chinook salmon 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 be killed (EPA 2019). The severity of the impact would depend on the timing, size, and location of the spill. Small spills in deep open waters are expected to rapidly dilute; however, fish kills have been reported for small spills in confined, shallow water (EPA 2019).

As an example, schools of adult Chinook salmon (20 to 100 individuals) have been seen in the East Fork SFSR and Johnson Creek. Thus, a large spill could potentially kill a substantial number of adult salmon depending on various factors (NMFS 1995). A spill in the fall could kill all the 1-year old juveniles and zero age eggs/alevins, thus eliminating 2 years of Chinook salmon progeny. 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 eggs, alevins, and juveniles for several years (Korn and Rice 1981; Moles et al. 1981).

It is expected the risk associated with a spill large enough to negatively affect fish or aquatic habitat would generally be low but possible. This varies depending on the substance that is spilled but considers typical substances that would be transported. An exception may be when materials are transported during inclement weather conditions, this could increase the risk to moderate. Spills during the winter would be easier to contain because spilled material would 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.

While the likelihood of a spill is negligible to moderate, the magnitude of impacts could be major to individuals exposed to harmful concentrations of hazardous materials making impacts of spills moderate, temporary and localized depending on the type of material releases, the location of the spill, and the presence of fish and aquatic species in the affected area.

Within the Mine Site Area

The West End pit lake, unlike other active mine and facility areas, would not be reclaimed or restored and would not meet water quality criteria for fish occupancy. Based on the pit lake geochemical model (Forest

Service 2023c), predicted West End pit lake water chemistry exhibits circumneutral pH conditions with TDS concentrations below 130 mg/L. Antimony, arsenic, and mercury concentrations that exceed the strictest potentially applied water quality standards would occur in the West End pit throughout the operating and closure period. Predicted concentrations of copper and lead are predicted to exceed the strictest potentially applied water quality standards during pit dewatering operations, when produced water is routed for consumptive use and water treatment but decrease below those levels during as the lake fills. Concentrations of arsenic, mercury, and antimony are predicted to slightly exceed the strictest potentially applied water quality standards permanently post-closure. The West End pit lake would be fishless given the absence of fish in West End Creek. Therefore, impacts to fish from contaminants in the West End pit lake would be limited to contaminants entering Sugar Creek via outlet seepage after the closure and reclamation of the mine. Outlet spillage creating a direct connection between West End pit lake and West End Creek is not anticipated. The discharge of West End Creek into Sugar Creek will be approximately 0.05 cfs, small relative to the flow of the creek and any contaminants from the West End pit lake would be further diluted at the confluence with the East Fork SFSR. Effects of the SGP to fish, including Chinook salmon, steelhead, bull trout, and west slope cutthroat trout, as well as other native fish species in Sugar Creek, from the West End pit lake contaminants would be minor, permanent, and localized.

Wastewater treatment plant effluent would be discharged to the East Fork SFSR at a location near the worker housing facility. Treatment residuals would be dewatered and transported to a permitted, off-site landfill for disposal. The sanitary wastewater treatment and discharge would occur at a single location during the active life of the mine and therefore impacts to fish would be minor, long-term, and localized.

Fuel storage and handling would be conducted in accordance with a Spill Prevention, Control, and Countermeasure Plan that would utilize surface storage tanks with primary and secondary containment. There would not be any uncontained or underground infrastructure associated with fuel storage. Therefore, releases from fuel storage would not be expected to contact the environment or affect fish and aquatic species, so effects would be none to negligible, long-term, and localized.

Long-term impacts from contaminants would include those during the active mine life and reclamation periods during which contact water would be treated to minimize multiple contaminants. Chemical contaminant loads were modeled under baseline, active mining, and post-reclamation conditions at multiple sites within the SGP area (**Table 7-7**) (Forest Service 2023c). Impact magnitudes for contaminants are measured relative to IDEQ criteria for protection of aquatic life.

<u>*Copper and Aluminum*</u>

Exceedances of criteria for copper and aluminum occur under baseline conditions at some sites near the TSF but not downstream below Sugar Creek under baseline conditions. No exceedances are expected to during active mining and post-closure (**Table 7-7**). The impacts of copper and aluminum are expected to be minimal relative to baseline conditions. Therefore, the health effects of the SGP on fish are expected to be negligible or beneficial, long-term, and localized.

<u>*Arsenic and Antimony*</u>

Surface water concentrations of arsenic and antimony downstream from the mine site area would be reduced during the active mining period relative to baseline conditions due to water treatment (Forest Service 2023c). Permanent impacts to contaminant concentrations in downstream surface waters would extend post-closure. Model results (Forest Service 2023c) indicate antimony concentrations in the East Fork SFSR downstream from Sugar Creek would be reduced permanently post-closure but arsenic concentrations would return to at or near baseline levels over time. The effects the SGP on fish related to arsenic and antimony would be minor, long-term, localized, and beneficial.

Table 7-7 Exceedance of Analysis Criteria, Operations and Post Closure for Assessment Nodes

Constituent of Concern		Aluminum[1]	Copper[2]	Antimony[3]	Arsenic[4]	Mercury[5]
Analysis Criteria		**0.36 mg/L**	**0.0024 mg/L**	**0.0056 mg/L**	**0.010 mg/L**	**2 ng/L (total mercury)**
Nodes	**Stream**	**Exceedance During Operations (Highest Concentration)[6]**				
YP-T-27	Meadow Creek	None	None	Seasonal peaks lower than baseline seasonal peaks (0.007 mg/L versus 0.018 mg/L).	Seasonal peaks lower than baseline seasonal peaks (0.023 mg/L versus 0.083 mg/L).	Seasonal peaks above baseline seasonal peaks (5 ng/L versus 2 ng/L).
YP-T-22	Meadow Creek	None	None	Seasonal peaks lower than baseline seasonal peaks (0.014 mg/L versus 0.025 mg/L).	Seasonal peaks lower than baseline seasonal peaks (0.018 mg/L versus 0.075 mg/L).	Seasonal peaks above baseline seasonal peaks (5 ng/L versus 2 ng/L).
YP-SR-10	East Fork SFSR	None	None	Seasonal peaks lower than baseline seasonal peaks (0.018 mg/L versus 0.030 mg/L).	Seasonal peaks lower than baseline seasonal peaks (0.023 mg/L versus 0.051 mg/L).	Seasonal peaks higher than baseline seasonal peaks (4 ng/L versus 3 ng/L).
YP-SR-8	East Fork SFSR	None	None	Concentrations below baseline conditions (0.004 to 0.021 mg/L versus 0.006 to 0.031 mg/L) throughout mining.	Concentrations below baseline conditions (0.012 to 0.032 mg/L versus 0.018 to 0.052 mg/L) throughout mining.	Seasonal peaks higher than baseline seasonal peaks (4 ng/L versus 3 ng/L).
YP-SR-6	East Fork SFSR	None	None	Concentrations below baseline conditions (0.005 to 0.027 mg/L versus 0.006 to 0.030 mg/L) throughout mining.	Concentrations at or below baseline conditions (0.013 to 0.041 mg/L versus 0.017 to 0.041 mg/L) throughout mining.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L).
YP-SR-4	East Fork SFSR	None	None	Concentrations primarily below baseline conditions (0.005 to 0.063 mg/L versus 0.008 to 0.056 mg/L) throughout mining. Concentrations above baseline occur in Mine Year -2 at the transition from baseline to construction.	Concentrations below baseline conditions (0.013 to 0.097 mg/L versus 0.019 to 0.120 mg/L) throughout mining.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L).

Constituent of Concern		Aluminum[1]	Copper[2]	Antimony[3]	Arsenic[4]	Mercury[5]
Analysis Criteria		**0.36 mg/L**	**0.0024 mg/L**	**0.0056 mg/L**	**0.010 mg/L**	**2 ng/L (total mercury)**
YP-SR-2	East Fork SFSR	None	None	Concentrations primarily below baseline conditions (0.004 to 0.041 mg/L versus 0.005 to 0.037 mg/L) throughout mining. Concentrations above baseline occur in Mine Year -2 at the transition from baseline to construction.	Concentrations below baseline conditions (0.010 to 0.066 mg/L versus 0.014 to 0.076 mg/L) throughout mining.	Concentrations at or slightly above baseline conditions (4 to 10 ng/L versus 3 to 10 ng/L) throughout mining.
YP-T-6	West End Creek	None	None	None	None	Concentrations above baseline conditions 37 to 63 ng/L versus 4 to 6 ng/L) throughout mining.
YP-T-1	Sugar Creek	None	None	None	Concentrations at or slightly below baseline conditions (0.007 to 0.015 mg/L versus 0.007 to 0.016 mg/L) throughout mining.	Concentrations at or slightly above baseline conditions (6 to 9 ng/L versus 6 to 8 ng/L) throughout mining.
Node	**Stream**	**Exceedances Post-Closure (highest Concentration)[6]**				
YP-T-27	Meadow Creek	None	None	Seasonal peaks lower than baseline seasonal peaks (0.008 mg/L versus 0.018 mg/L) until Mine Year 20.	Seasonal peaks lower than baseline seasonal peaks (0.017 mg/L versus 0.083 mg/L) until Mine Year 20.	Seasonal peaks at baseline seasonal peaks (2 ng/L versus 2 ng/L) throughout post-closure period.
YP-T-22	Meadow Creek	None	None	Seasonal peaks lower than baseline seasonal peaks (0.006 mg/L versus 0.025 mg/L) until Mine Year 20.	Seasonal peaks lower than baseline seasonal peaks (0.013 mg/L versus 0.075 mg/L) until Mine Year 20.	Seasonal peaks at baseline seasonal peaks (2 ng/L versus 2 ng/L) throughout post-closure period.
YP-SR-10	East Fork SFSR	None	None	None	Seasonal peaks lower than baseline seasonal peaks (0.013 mg/L versus 0.075 mg/L) until Mine Year 20.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L) throughout post-closure period.

Constituent of Concern		**Aluminum[1]**	**Copper[2]**	**Antimony[3]**	**Arsenic[4]**	**Mercury[5]**
Analysis Criteria		**0.36 mg/L**	**0.0024 mg/L**	**0.0056 mg/L**	**0.010 mg/L**	**2 ng/L (total mercury)**
YP-SR-8	East Fork SFSR	None	None	Seasonal peaks lower than baseline seasonal peaks (0.011 mg/L versus 0.031 mg/L) throughout post-closure-period.	Concentrations below baseline conditions (0.012 to 0.025 mg/L versus 0.018 to 0.052 mg/L) throughout post-closure period.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L) throughout post-closure period.
YP-SR-6	East Fork SFSR	None	None	Concentrations below baseline conditions (0.005 to 0.020 mg/L versus 0.006 to 0.030 mg/L) throughout post-closure period.	Concentrations below baseline conditions (0.012 to 0.029 mg/L versus 0.017 to 0.041 mg/L) throughout post-closure period.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L) throughout post-closure period.
YP-SR-4	East Fork SFSR	None	None	Concentrations below baseline conditions (0.005 to 0.023 mg/L versus 0.008 to 0.056 mg/L) throughout post-closure period.	Concentrations below baseline conditions (0.013 to 0.063 mg/L versus 0.019 to 0.120 mg/L) throughout post-closure period.	Seasonal peaks at baseline seasonal peaks (3 ng/L versus 3 ng/L) throughout post-closure period.
YP-SR-2	East Fork SFSR	None	None	Concentrations below baseline conditions (0.003 to 0.016 mg/L versus 0.005 to 0.037 mg/L) throughout post-closure period.	Concentrations below baseline conditions (0.010 to 0.047 mg/L versus 0.014 to 0.076 mg/L) throughout post-closure period.	Concentrations at or slightly below baseline conditions (3 to 9 ng/L versus 3 to 10 ng/L) throughout post-closure period.
YP-T-6	West End Creek	None	None	Concentrations slightly above baseline conditions (0.008 to 0.014 mg/L versus 0.008 to 0.012 mg/L) throughout post-closure period.	Concentrations slightly above baseline conditions (0.064 to 0.094 mg/L versus 0.064 to 0.088 mg/L) throughout post-closure period.	Concentrations above baseline conditions (4 to 10 ng/L versus 4 to 6 ng/L) throughout post-closure period.

Constituent of Concern		Aluminum[1]	Copper[2]	Antimony[3]	Arsenic[4]	Mercury[5]
Analysis Criteria		**0.36 mg/L**	**0.0024 mg/L**	**0.0056 mg/L**	**0.010 mg/L**	**2 ng/L (total mercury)**
YP-T-1	Sugar Creek	None	None	None	Concentrations at or slightly above baseline conditions (0.007 to 0.017 mg/L versus 0.007 to 0.016 mg/L) throughout post-closure period.	Concentrations at baseline conditions (6 to 8 ng/L versus 6 to 8 ng/L) throughout post-closure period.

Source: SRK 2018, Brown and Caldwell 2020b

[1] Aluminum: Lowest predicted for the SGP area based on Recommended Aquatic Life Criteria (EPA 2018); The same water quality data as in the Biotic Ligand Model were used (Brown and Caldwell 2020b)

[2] Copper analysis criteria was derived using the Biotic Ligand Model per guidance contained in IDEQ (2017). A conservative chronic copper analysis criteria 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 2020b), preliminary calculations using the Biotic Ligand Model and site-specific data have produced similar values to the standard derived using these regional classifications.

[3] Antimony does not have a specified NMFS or USFWS standard and is based on EPA's human health chronic criterion for consumption of water and organisms is 0.0056 mg/L.

[4] Arsenic: NMFS (2014) and USFWS (2015) both determined jeopardy for the chronic criterion proposed by EPA for Idaho Water Quality Standards (0.150 mg/L). NMFS (2014) directed EPA to promulgate or approve new aquatic life criterion. In the interim, NMFS directed EPA to ensure the 0.010 mg/L human health criterion applied in all National Pollutant Discharge Elimination System permits. USFWS (2015) directed EPA to ensure that the 10 µg/L recreational use standard is applied in all Water Quality Based Effluent Limitations (WQBELs) and Reasonable Potential to Exceed Calculations using the human health criteria and the current methodology for developing WQBELs to protect human health.

[5] Mercury: NMFS (2014) and USFWS (2015) both determined jeopardy for the chronic criterion proposed by EPA for Idaho Water Quality Standards (0.000012 mg/L total 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. Where fish tissue is not readily available, then NMFS specified application of a 0.000002 mg/L criteria (as total mercury) in the interim. USFWS (2015) directed EPA to use the 2001 EPA/2005 Idaho human health fish tissue criterion of 0.3 milligram per kilogram wet weight for WQBELs and reasonable potential to exceed criterion calculations using the current methodology for developing WQBELs to protect human health.

[6] Predicted future concentrations are reported on a monthly basis. Concentrations in some locations vary naturally on a seasonal basis and, therefore, exceed baseline in certain months (usually Spring) and are lower than baseline in other months. Exceedances reported in this table are only those interpreted to be a result of mining activity, and not due to natural seasonal variability.

East Fork SFSR = East Fork SFSR; mg/L = milligrams per liter; ng/L = nanograms per liter

<u>*Mercury*</u>

Mercury concentrations in the East Fork SFSR downstream from Sugar Creek would be predicted to increase during active mining due to expanded excavation. Concentrations would then be predicted to decrease post-closure but remain slightly elevated relative to baseline conditions (Forest Service 2023c). Baseline, predicted active mine, and predicted post-closure mercury concentrations in the East Fork SFSR downstream from Sugar Creek would not exceed the aquatic life criterion. However, uncertainty remains whether incremental change in mercury concentrations beyond baseline would increase bioaccumulation of methylmercury in fish tissue at concentrations exceeding the tissue-based criterion. Methylation and bioaccumulation of mercury generally increases downstream in most watersheds. Through bioaccumulation and biomagnification, methylmercury reaches the highest concentrations in the tissues of longer lived, larger, or more piscivorous fish species. Therefore, the magnitude of potential permanent impacts to downstream fish from incremental changes in long-term or permanent mercury transport downstream from the mine area is unknown. Long-term, regional influences on downstream methylmercury concentrations in fish are not quantified. However, mercury methylation rates in the Salmon River watershed, typically between 0.37 and 1 percent (Fleck et al. 2016), are not expected to be modified by the Project effects.

Stream Flow

Changes in stream flow directly affects fish habitat. Changes to stream flow were evaluated using simulated monthly discharges for the August to March low-flow period for Mine Years -2 through post-closure. The SGP Water Quantity Specialist Report (Forest Service 2023d) provides additional descriptions of how much streamflow changes as a function of mine operations, including locations without gaging data (i.e., downstream from Sugar Creek). **Table 7-8** shows predicted (simulated) monthly stream flows during the August to March low flow period at five USGS gaging stations and one location in lower Meadow Creek in mine site streams (**Figure 6-10**) and predicted change from average baseline low flow period stream flows. **Figure 7-3** shows the percent change in simulated stream flows graphically.

The greatest predicted changes to stream flow under the 2021 MMP would be in the East Fork SFSR and in Meadow Creek in the vicinity of the TSF. While most of the streams would return to at or near baseline flows post-closure (post-closure flows represent an average of the predicted flows from Mine Years 21 through 112), Meadow Creek flows downstream from the TSF would be reduced by a maximum of 36.4 percent during mine operations. Flow increases in Mine Year 5 at some nodes are due to dewatering and subsequent filling of the Hangar Flats pit and dewatering of the YPP.

The effects of the SGP on changes in stream flow would be major, long-term (occurring during operations) and localized at the Meadow Creek, East Fork SFSR at Stibnite, and East Fork SFSR upstream from Sugar Creek sites, but minor, long-term (occurring during operations) and localized at the East Fork SFSR upstream from Meadow Creek. Permanent effects from changes in streamflow, that occur during the post-closure are negligible across all of the mine sites. The effects of reduced stream flow on habitat and productivity are described in the sections below.

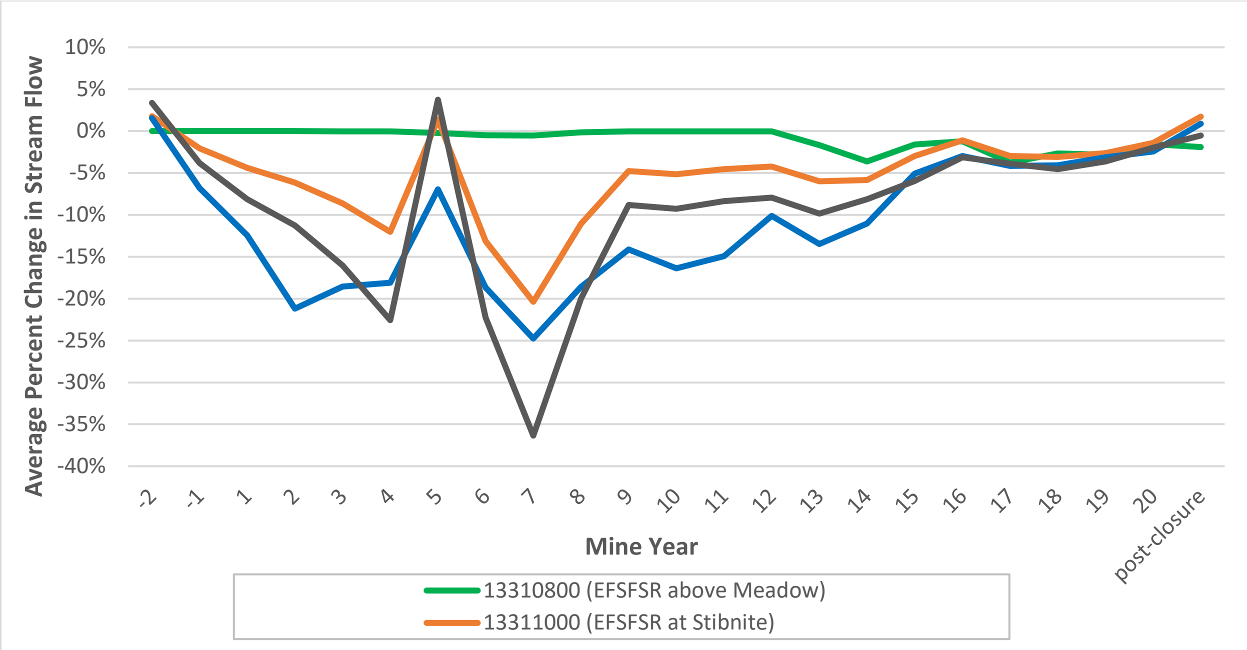


Figure 7-3 Average Percent Change in Stream Flow During the Low Flow Period (August to March)

Table 7-8 Percent Change in Streamflow from Baseline Streamflow for the Low-Flow Period over the Active Mine Years and Post-Closure Period

USGS Gage	13311250	1331100	13310800	MC-6
Mine Year	**East Fork SFSR Upstream from Sugar (%)**	**East Fork SFSR at Stibnite (%)**	**East Fork SFSR Upstream from Meadow Creek (%)**	**Meadow Creek (%)**
-2	1.5	1.8	0.0	3.4
-1	-6.8	-2.1	0.0	-3.8
1	-12.4	-4.4	0.0	-8.1
2	-21.2	-6.2	0.0	-11.2
3	-18.6	-8.6	0.0	-16.0
4	-18.1	-12.0	0.0	-22.6
5	-6.9	1.4	-0.2	3.7
6	-18.7	-13.1	-0.5	-22.3
7	-24.8	-20.4	-0.5	-36.4
8	-18.6	-11.1	-0.2	-20.0
9	-14.1	-4.8	0.0	-8.8
10	-16.4	-5.1	0.0	-9.3
11	-14.9	-4.5	0.0	-8.4
12	-10.1	-4.2	0.0	-7.9
13	-13.5	-6.0	-1.7	-9.8
14	-11.0	-5.9	-3.6	-8.2
15	-5.1	-3.0	-1.6	-5.9

USGS Gage	13311250	1331100	13310800	MC-6
Mine Year	**East Fork SFSR Upstream from Sugar (%)**	**East Fork SFSR at Stibnite (%)**	**East Fork SFSR Upstream from Meadow Creek (%)**	**Meadow Creek (%)**
16	-3.0	-1.1	-1.2	-3.1
17	-4.2	-3.0	-3.8	-3.9
18	-4.1	-3.1	-2.7	-4.5
19	-3.1	-2.6	-2.8	-3.6
20	-2.4	-1.4	-1.6	-2.0
Post-Closure	0.9	1.7	-1.9	-0.6

The Low-Flow Period for Post-closure is defined as average of Mine Years 21 through 112. Numbers represent percent change in stream flow; negative numbers indicate a reduction in stream flow while positive numbers indicate an increase in stream flow. Sugar Creek is summarized by itself because data were available for Sugar Creek. There is a relationship between percent change in flow and the amount of available habitat per species and life stage. MC-6 is located in the lower reaches of Meadow Creek

% = percent; East Fork SFSR = East Fork South Fork Salmon River

7.2.3.3 Summary of Effects to Watershed Condition Indicators

The WCIs evaluate stream function by measuring elements that reflect water quality, habitat access, channel conditions and dynamics, flow and hydrology, and watershed conditions. As discussed in **Section 6.1.3**, not all WCI indicators summarized for baseline conditions are of equal value in determining the potential impacts of the SGP within the analysis area. The impact analyses addressed the WCIs which are summarized in **Table 7-9**.

Table 7-9 Summary of Changes to Key Watershed Condition Indicators at the Mine Site

WCI	Stream Segment	Baseline	Change From Baseline		
			Construction (Mine Year -1 to 1)	**Operation/ Closure (Mine Year 1 to 20)**	**Post-Closure (Mine Year 20+)**
Water Temperature	East Fork SFSR Between Sugar Creek and YPP	FR	FR (*)	FR (*)	FR (+)
	East Fork SFSR Between YPP and Meadow Creek	FR	FR (*)	FR (*)	FR (+)
	Meadow Creek and East Fork Meadow Creek	FR	FR (+)	FR (+)	FR (+)
	East Fork SFSR Upstream from Meadow Creek	FR	FR (*)	FR (*)	FR (*)
Sediment and Turbidity	East Fork SFSR Between Sugar Creek and YPP	FUR	FUR (*)	FR (*)	FR (+)
	East Fork SFSR Between YPP and Meadow Creek	FUR	FUR (*)	FR (*)	FR (+)
	Meadow Creek and East Fork Meadow Creek	FUR	FUR (*)	FR (+)	FR (+)
	East Fork SFSR Upstream from Meadow Creek	FUR	FUR (*)	FUR (*)	FUR (*)

WCI	Stream Segment	Baseline	Change From Baseline		
			Construction (Mine Year -1 to 1)	Operation/ Closure (Mine Year 1 to 20)	Post-Closure (Mine Year 20+)
Physical Barriers	East Fork SFSR Between Sugar Creek and YPP	FUR	FA (+)	FA (+)	FA (+)
	East Fork SFSR Between YPP and Meadow Creek	FUR	FA (+)	FA (+)	FA (+)
	Meadow Creek and East Fork Meadow Creek	FUR	FUR (-)	FUR (-)	FUR (-)
	East Fork SFSR Upstream from Meadow Creek	FUR	FA (+)	FA (+)	FA (+)
Change in Peak/Base Flows	East Fork SFSR Between Sugar Creek and YPP	FA	FA (*)	FR (-) to Mine Year 6; FA (*) after Mine Year 6	FA (*)
	East Fork SFSR Between YPP and Meadow Creek	FA	FA (*)	FR (-) to Mine Year 6; FA (*) after Mine Year 6	FA (*)
	Meadow Creek and East Fork Meadow Creek	FA	FA (-)	FR (-) to Mine Year 6; FA (*) after	FA (*)
	East Fork SFSR Upstream from Meadow Creek	FA	FA (*)	FA (*)	FA (*)
Chemical Contaminants	East Fork SFSR Between Sugar Creek and YPP	FUR	FUR (*)	FR (+)	FR (+)
	East Fork SFSR Between YPP and Meadow Creek	FUR	FUR (*)	FR (+)	FR (+)
	Meadow Creek and East Fork Meadow Creek	FUR	FUR (*)	FR (+)	FR (+)
	East Fork SFSR Upstream from Meadow Creek	FA	FA (*)	FA (*)	FA (*)

Changes from baseline: (+) = increase from baseline functional index; (-) = decrease from baseline functional index; (*) = negligible or no change from baseline functional index

East Fork SFSR = East Fork South Fork Salmon River; FA = Functioning Appropriately; FR = Functioning at Risk; FUR = Functioning at Unacceptable Risk; WCI = Watershed Condition Indicator; YPP = Yellow Pine pit

7.2.3.4 Impacts to Chinook Salmon

Chinook salmon would be affected by the 2021 MMP through changes in water temperature and flow, which affects other factors such as productivity, IP, and Critical Habitat. The effects to Chinook salmon are described below.

Water Temperature

As described in **Section 6.3.1.4**, water temperature is an important factor affecting the survival of each Chinook salmon life stage. The accepted stream temperature thresholds/ranges for life stages were compiled from regulatory standards and other relevant literature (ESS 2022b). ESS (2022b) presents quantification of baseline habitat availability (in relation to stream temperature) for Chinook salmon and analyzes the likely effects of changes to stream temperatures on available habitat as a result of implementation of the SGP. The following is a summary of the analysis and potential impacts from water temperature changes in streams at the mine site.

The highest modeled temperatures (i.e., maximum weekly summer temperatures) from SPLNT modeling (Brown and Caldwell 2019a) for a stream reach were compared to accepted stream temperature thresholds/ranges to determine the baseline length of available habitat. Predicted stream temperatures from SPLNT modeling were used to forecast the potential changes to the amount of available habitat for each life stage for multiple mine years. Note that the SPLNT model did not consider the effects of climate change; modeled temperature results would likely be higher if climate change had been a factor in the model.

Table 7-10 presents the length of usable IP habitat that fall within the temperature threshold categories for Chinook salmon adult migration and early life stages, and length of Critical Habitat for juvenile rearing. Length of habitat for Chinook salmon adult migration and juvenile rearing are based the amount of habitat with suitable thermal conditions using the summer maximum temperatures, which applied a maximum weekly ‘constant’ temperature for July (ESS 2022b). Spawning and incubation/emergence apply the fall maximum temperature, which applied a maximum weekly ‘constant’ temperature for September (ESS 2022b) while spawning and incubation/emergence apply the fall maximum temperature.

Detailed data for Chinook salmon under the 2021 MMP are presented in the update of ESS 2022b.

As shown in **Table 7-10**, the adult migration and spawning life stages experience a reduction in habitat that meets the thermal requirements for Chinook salmon. These reductions are either due to water temperatures that are too high or too low for the specific life stage, or due to limited access to suitable habitat (e.g., Meadow Creek). Juvenile rearing experience an increase in thermally-suitable habitat. Relative to baseline conditions:

- There would be a decrease in habitat conditions for migrating adults upstream from the YPP lake cascade barrier that meet the temperature criteria because water temperatures are lower than the thermal requirements. These habitats are not volitionally available to Chinook salmon under baseline conditions. The impacts shown are based on water temperatures that are mostly lower than the thermal criteria. While the temperatures are typically slightly lower than the thermal criteria, migration would likely not be impaired.

- There would be a net decrease in thermally suitable spawning habitat both upstream and downstream from YPP lake cascade barrier during operations and post-closure due to a slightly warmer MWMT.

- There would be a net increase in thermally suitable habitat conditions for incubation and emergence during operations through post-closure both upstream and downstream from the YPP lake cascade barrier.
- There would be a net increase in thermally suitable juvenile rearing habitat during operations through post-closure.

It is important to note that the stream lengths identified in **Table 7-10** assume Chinook salmon already occur upstream from the YPP lake; however, unless they are released by IDFG, Chinook salmon do not naturally occur.

Creeks in the mine site area do experience significant seasonal and diurnal variations, and for mobile life stages (i.e., adults and juveniles), if MWMT are above the optimal thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges. Through stream restoration and enhancement actions, stream cover and instream structures may provide thermal refugia.

Based on modeled results, the effects of the SGP on Chinook salmon caused by changes to temperature-based suitable habitat are expected to be minor, permanent, and localized; however, given Chinook salmon would be able to volitionally access habitat upstream from YPP, the effects of the SGP on Chinook salmon are expected to be minor, permanent, and localized but beneficial.

Table 7-10 Length of Stream Habitat that Meets the Optimal Thermal Requirements for Chinook Salmon Under the 2021 Modified Mine Plan

Life Stage	Baseline (km)	Mine Year								Change from Baseline to 112 (km)
		6 (km)	12 (km)	18 (km)	22 (km)	27 (km)	32 (km)	52 (km)	112 (km)	
Below Yellow Pine Pit Cascade Barrier										
Adult Migration[1]	0	0	0	0	0	0	0	0	0	0
Adult Migration[2]	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Spawning[3]	0	0	0	0	0	0	0	0	0	0
Spawning[4]	2.01	1.48	1.66	0.73	0.73	1.66	1.66	1.66	1.66	-0.35
Incubation/Emergence	0	0	0	0	0	0	0	0.73	0.73	+0.73
Juvenile Rearing[5]	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Total Available Habitat	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Above Yellow Pine Pit Cascade Barrier										
Adult Migration[1]	2.43	0	0.25	0.69	0.25	2.93	2.68	1.07	0	-2.43
Adult Migration[2]	7.48	3.35	4.25	5.78	5.50	5.78	6.57	6.57	6.57	-0.91
Spawning[3]	1.51	0.28	0	0	0	0	0	0	0	-1.51
Spawning[4]	10.92	6.85	8.02	9.91	9.91	10.07	10.07	10.07	10.07	-0.85
Incubation/ Emergence	3.44	3.50	7.46	7.39	8.02	7.39	7.39	7.39	7.39	+3.95
Juvenile Rearing[5]	17.51	10.94	13.43	13.35	13.35	18.97	18.97	18.97	18.97	+1.46-
Total Available Habitat	10.92[6] 17.51[5]	6.85[6] 10.94[5]	8.02[6] 13.43[5]	9.91[6] 13.35[5]	9.91[6] 13.35[5]	10.07[6] 18.97[5]	10.07[6] 18.97[5]	10.07[6] 18.97[5]	10.07[6] 18.97[5]	-0.85[6] +1.46[5]

[1] Results based in USEPA criteria for optimal swimming performance – 15-19°C
[2] Results based on USEPA criteria for minimizing disease risk – 12-13°C and elevated disease risk 14-17°C
[3] Results based on IDAPA criteria of 13°C maximum temperature for spawning
[4] Results based on USEPA criteria of 4-14°C temperature for spawning
[5] Results based on modeled Critical Habitat
[6] Results based on usable Intrinsic Potential habitat
km = kilometer

Flow-Productivity

A flow-productivity model was used to examine the effects of predicted flow changes associated with the 2021 MMP on Chinook salmon productivity (see **Section 6.3.1.1** for additional detail on the model). Annual flow productivity was determined as the long-term percent change from the existing or baseline conditions for each mine year. To analyze the altered stream flow across the mine area, flow-productivity outputs were used from three of the USGS stream flow gages (East Fork SFSR above Sugar, East Fork SFSR at Stibnite, East Fork SFSR above Meadow) and lower Meadow Creek (MC-6).

Table 7-11 and **Figure 7-4** show the average Chinook salmon flow-productivities for each stream flow site over pertinent periods throughout mine operations and post-closure. The greatest, reduction in flow-productivity averaged over the long-term period (Mine Years -2 to 20) are in the East Fork SFSR upstream from Sugar Creek (-10.5 percent) and in Meadow Creek (-8.9 percent). Most of the Chinook salmon productivity on the East Fork SFSR upstream from Sugar Creek is greatly impacted by mine operations that alter stream flow over the life of the mine. Similarly, most of the productivity in Meadow Creek is greatly impacted by changes in stream flow caused by mine operations in Meadow Creek. The East Fork SFSR above Meadow Creek is less impacted by changes in stream flow over the long-term. Similarly, most of the Chinook salmon productivity throughout the mine area is minimally affected by altered stream flow post-closure.

Table 7-11 Percent Change in Chinook Salmon Productivity Relative to Baseline Productivity by Mine Year and Location

Period	Mine Year	East Fork SFSR above Meadow Creek (USGS Gage 13310800)	East Fork SFSR at Stibnite (USGS Gage 13311000)	East Fork SFSR above Sugar Creek (USGS Gage 13311250)	Meadow Creek (MC-6)
Baseline Productivity		1.06	1.06	1.06	1.06
Mine Years -2 to 20 Percent Change from Baseline	-2	0%	2.0%	1.8%	3.9%
	-1	0%	-3.3%	-6.4%	-5.9%
	1	0%	-6.0%	-15.9%	-10.8%
	2	0%	-6.0%	-16.9%	-10.5%
	3	0%	-10.8%	-18.4%	-18.6%
	4	-0.1%	-7.2%	-13.7%	-12.2%
	5	-0.4%	-2.4%	-9.3%	-1.7%
	6	-0.6%	-15.7%	-19.5%	-23.4%
	7	-0.4%	-17.7%	-21.4%	-28.6%
	8	-0.1%	-7.4%	-15.1%	-12.7%
	9	0%	-4.5%	-13.1%	-8.0%
	10	0%	-4.9%	-15.1%	-8.6%
	11	0%	-4.9%	-14.5%	-8.6%
	12	-0.6%	-5.4%	-10.0%	-9.4%
	13	-2.5%	-6.2%	-12.7%	-9.4%
	14	-3.8%	-6.5%	-11.4%	-9.0%
	15	-0.2%	-1.8%	-3.5%	-4.7%
	16	-2.2%	-3.5%	-3.5%	-4.2%

Period	Mine Year	East Fork SFSR above Meadow Creek (USGS Gage 13310800)	East Fork SFSR at Stibnite (USGS Gage 13311000)	East Fork SFSR above Sugar Creek (USGS Gage 13311250)	Meadow Creek (MC-6)
	17	-3.9%	-4.4%	-4.4%	-5.3%
	18	-1.9%	-3.5%	-3.5%	-4.5%
	19	-3.2%	-3.1%	-3.1%	-3.4%
	20	-1.0%	-1.6%	-1.6%	-0.6%
Mine Years -2 to 20 Productivity (Percent Change from Baseline)	Minimum	1.02 (-3.9%)	0.87 (-17.7%)	0.83 (-21.4%)	0.78 (-28.6%)
	Mean	1.05 (-1.0%)	1.00 (-5.7%)	0.95 (-10.5%)	0.97 (-8.9%)
	Maximum	1.06 (0.0%)	1.08 (2.0%)	1.08 (1.8%)	1.10 (3.9%)
Mine Years 21 to 112 Productivity (Percent Change from Baseline)	Mean	1.04 (-1.8%)	1.08 (1.8%)	1.07 (1.1%)	1.05 (-0.6%)

Note: The Mine Years –2 to 20 were selected because stream flows equilibrate at year 20. Therefore, the average annual percent change in productivity for Mine Years 21 through 112 represents a post-closure condition.

Key: % = percent; East Fork SFSR = East Fork South Fork Salmon River; MC = Meadow Creek

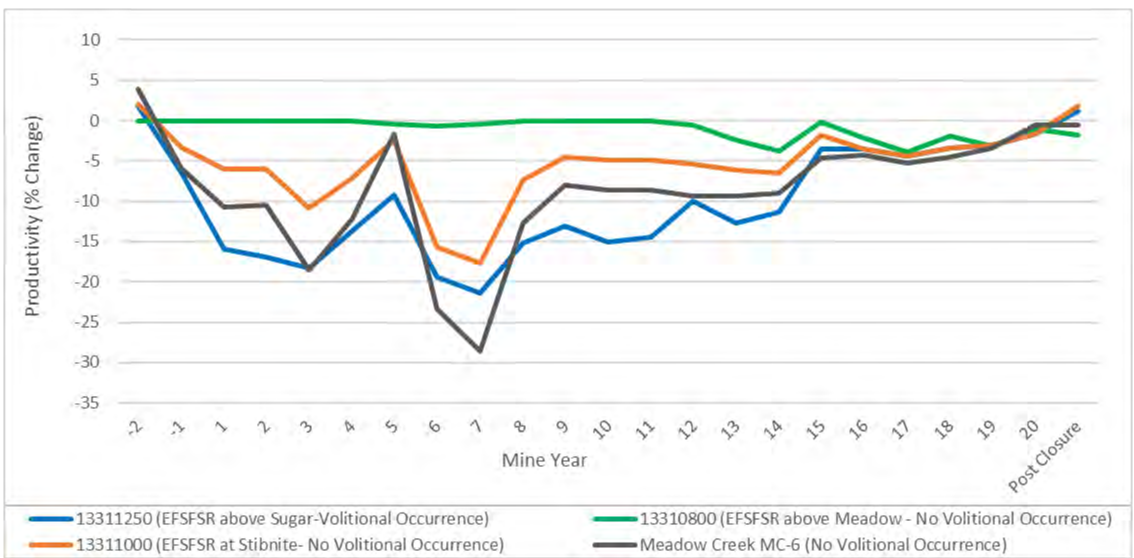


Figure 7-4 Percent Change in Chinook Salmon Productivity from Baseline Conditions by Mine Year and Location (USGS Gaging Stations and MC-6)

Changes in Chinook productivity also occur from Mine Years 3 to 8, where productivity fluctuates in the East Fork SFSR above Meadow Creek, East Fork SFSR above Sugar Creek, and Meadow Creek locations (**Table 7-11**; **Figure 7-4**). This decrease in productivity occur during periods of mine operations that results in dewatering. The increase in productivity in Mine Year 5 is due to reductions of water abstraction during operations from dewatering and subsequent filling of the Hangar Flats pit and dewatering of the YPP.

Chinook salmon do not volitionally occur upstream from the YPP lake cascade barrier under baseline conditions. However, at mine year -1, the diversion tunnel is constructed allowing for volitional passage. For the Meadow Creek, East Fork SFSR at Stibnite, and East Fork SFSR above Sugar Creek sites, the effects of the SGP on Chinook salmon productivity are expected to be moderate, long-term (occurring during operations), and localized. For the East Fork SFSR above Meadow Creek site, the effects of the SGP on Chinook salmon productivity are expected to be minor, long-term (occurring during operations) , and localized. Permanent effects from changes in productivity, that occur during the post-closure are negligible across the mine site.

Intrinsic Potential

An IP model was developed to evaluate segments of stream within the SGP area to determine the watershed's capacity to provide quality habitat for Chinook salmon (see **Section 6.3.1.1** and ESS 2022d for additional information).

For Chinook salmon, habitat assessed for IP was categorized into 1 of 4 rankings including high, medium, low, and negligible. Throughout the construction period and life of the mine, the stream length of each ranking of IP model habitat were determined. **Table 7-12** summarizes the years in which there is a large change in IP and includes total length of IP in the baseline conditions and at the end of the mine life. Additionally, **Figure 7-5** shows all Chinook salmon IP habitat within the analysis area broken down by year and includes key SGP events that effect the amount and quality of IP habitat.

Table 7-12 Stream Length with Intrinsic Potential Habitat for Chinook Salmon Throughout the Mine Life

IP Rating	Intrinsic Potential Habitat (km)							
	Baseline	Mine Year						Net Loss/Gain
		3	5	6	11	15	23 to 112	
East Fork SFSR and Tributaries Upstream from Yellow Pine Pit Cascade Barrier								
High	0	0	0	0	0	0	0	0
Medium	0.66	0.63	0.63	0.63	0.63	0.63	0.63	-0.03
Low	4.29	4.26	4.26	4.26	4.83	4.83	4.83	+0.54
Negligible	1.05	0.78	0.78	0.78	0.78	0.78	0.78	-0.27
Total IP Habitat	6.00	5.68	5.68	5.68	6.25	6.25	6.25	+0.25
Total Length of Habitat Evaluated	29.01	28.35	28.35	28.35	28.92	28.92	28.92	-0.09

IP Rating	Intrinsic Potential Habitat (km)							
	Baseline	Mine Year						Net Loss/Gain
		3	5	6	11	15	23 to 112	
Meadow Creek and East Fork Meadow Creek								
High	0.66	0	0	0	0	0	0	-0.66
Medium	0.9	0.31	1.66	0.31	0.31	1.66	2.45	+1.55
Low	1.21	0.24	0.24	0.24	0.24	0.24	0.24	-0.97
Negligible	0.1	0	0	0	0	0	0	-0.1
Total IP Habitat	2.86	0.55	1.89	0.55	0.55	1.89	2.68	-0.18
Total Length of Habitat Evaluated	16.93	15.53	15.53	15.53	15.53	15.53	15.69	-1.24
East Fork SFSR and Tributaries between Yellow Pine Pit and Sugar Creek								
High	0	0	0	0	0	0	0	0
Medium	0.18	0	0	0	0	0	0	-0.18
Low	0.84	0.35	0.35	0.35	1.26	1.26	1.26	+0.42
Negligible	0.15	0.12	0.12	0.12	0.12	0.12	0.12	-0.03
Total IP Habitat	1.17	0.47	0.47	0.47	1.38	1.38	1.38	+0.21
Total Length of Habitat Evaluated	4.34	4.47	4.47	4.47	3.45	3.45	3.45	-0.89
East Fork SFSR Downstream from Sugar Creek								
High	0	0	0	0	0	0	0	0
Medium	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0
Low	1.02	1.02	1.02	1.02	1.02	1.02	1.02	0
Negligible	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0
Total IP Habitat	1.11	1.11	1.11	1.11	1.11	1.11	1.11	0
Total Length of Habitat Evaluated	1.11	1.11	1.11	1.11	1.11	1.11	1.11	0
Headwaters East Fork SFSR Subwatershed								
Total IP Habitat Below YPP	2.28	1.58	1.58	1.58	2.49	2.49	2.49	+0.21
Total IP Habitat Above YPP	8.86	6.23	7.57	6.23	6.8	8.14	8.93	+0.07
Total IP Habitat	11.15	7.81	9.15	7.81	9.29	10.63	11.42	+0.28

East Fork SFSR = East Fork South Fork Salmon River; IP = Intrinsic Potential; km = kilometer

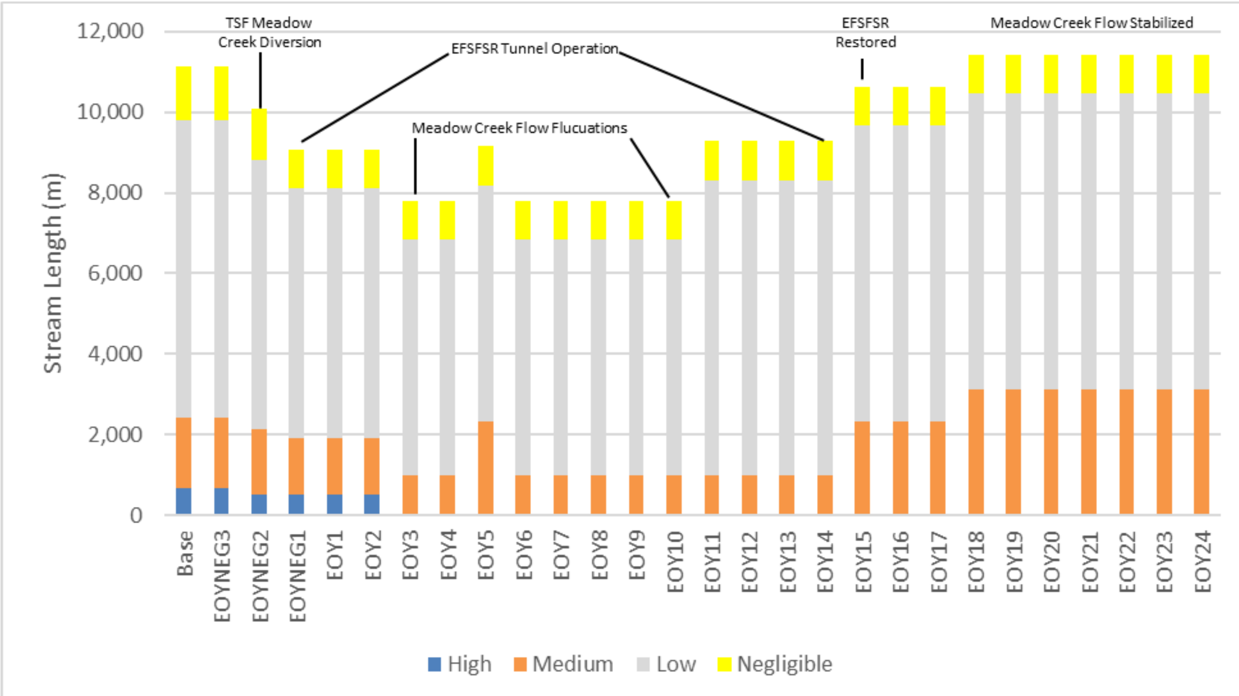


Figure 7-5 Chinook Salmon Intrinsic Potential Habitat in the Mine Site Area Over 28 Years (Mine Years -4 to 24)

Throughout the life of the mine, most of the changes to IP habitat for Chinook salmon cause major or moderate negative impacts. By Mine Year 3, Meadow Creek would lose all high and negligible and over half medium and low-quality IP habitat because the mining activities along the TSF would block fish access. Additionally, physical modification of ground surface in the vicinity of the East Fork SFSR causes a loss of medium, low, and negligible quality IP habitat just upstream from Midnight Creek. During Mine Year 5 operational changes at YPP cause flow increases in Meadow Creek drastically raising the medium quality IP habitat however in Year 6 flows return to similar to before reducing medium IP back down again in Mine Year 6. By Mine Year 11, the East Fork SFSR regains some low-quality IP habitat above Midnight Creek due to the start of reclamation and the end of physical modifications of ground surface in the vicinity of East Fork SFSR. By Mine Year 15 and Mine Year 18, Meadow Creek gains back a significant amount of medium quality IP habitat due to dewatering pumping stopping. Finally, by the end of the mine life, the IP habitat stays the same as year 18 due to presumed wetted widths in the restored stream channels (designed wetted width slightly less than 3.6 m compared to greater than or equal to 3.6 m wetted width required for Chinook salmon).

The IP model does not take current species presence or physical barriers into account, and all evaluated stream segments that fit the IP criteria are considered usable IP habitat. Therefore, IP habitat may be present in stream segments where Chinook salmon do not naturally occur upstream from YPP; Chinook salmon have been periodically translocated upstream from YPP by the IDFG and the Nez Perce Tribe. While there are 11.15 km of total IP habitat under baseline conditions, only 2.28 km or 20.4 percent of that IP habitat is in stream segments where Chinook salmon naturally occur. In addition, the only high IP habitat found in baseline conditions was in Meadow Creek, some of which is blocked by a physical barrier. By Mine Year 112, 0.21 km or 17.9 percent of the IP habitat downstream from YPP would be gained. Upstream from YPP, 0.07 km or an additional 0.79 percent of IP habitat would be gained and all high IP habitat would be lost. Notably, most of the medium IP that remains in Meadow Creek at Mine Year 23 is also blocked by a physical barrier to Chinook salmon so is not accessible (**Figure 7-6**).

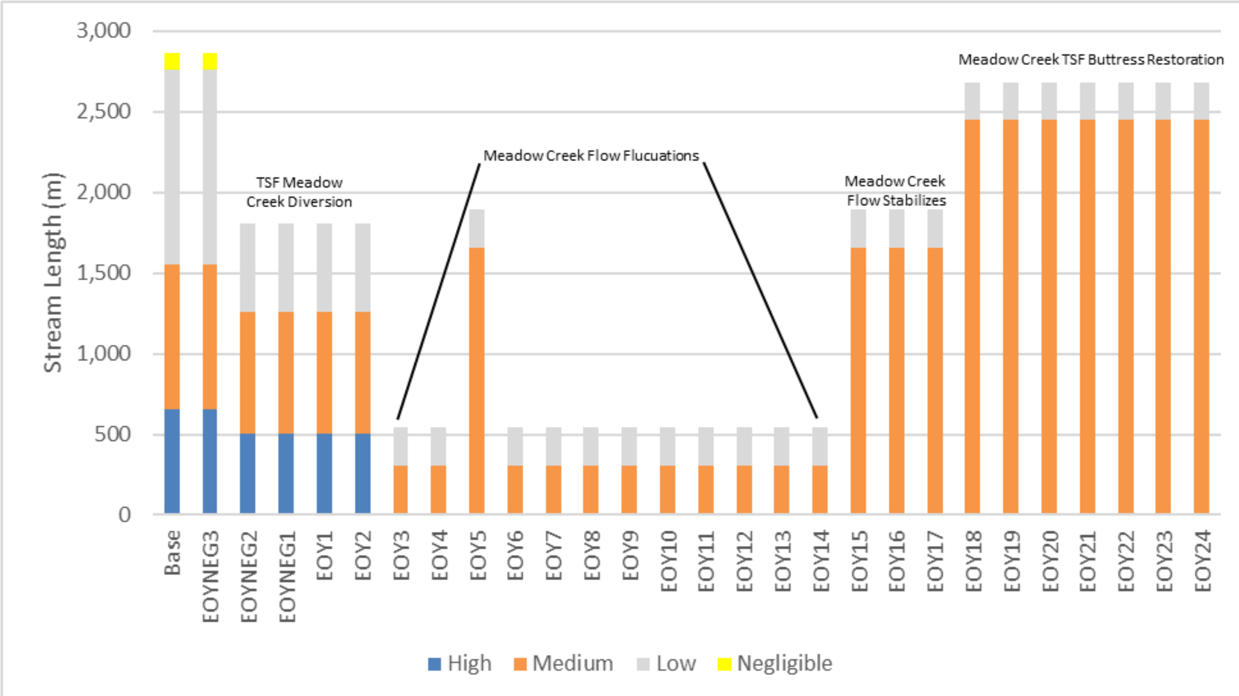


Figure 7-6 Chinook Salmon Intrinsic Potential Habitat in Meadow Creek for 28 Years (Mine Years - 4 to 24)

Overall, the SGP area gains a length of 0.28 km with Chinook salmon IP habitat by the end of the life of the mine. Meadow Creek has a net loss of 0.18 km while all other areas have no overall change or have a slight increase. The total changes to IP habitat are as follows: medium IP habitat is increased by 77 percent (1.34 km), less than 1 percent (0.01 km) of low IP habitat is lost, 100 percent (0.66 km) of high IP habitat is lost, and 31 percent (0.40 km) of negligible IP is lost. This equates to a 2 percent (0.28 km) gain of the total IP habitat for Chinook salmon. Although there is a loss of IP habitat in Meadow Creek, there is an overall long-term minor, permanent, increase in IP habitat and a small addition of new low IP habitat on the East Fork SFSR between the YPP and Sugar Creek.

It is important to note that under baseline conditions, Chinook salmon do not volitionally occur upstream from the YPP lake cascade barrier. The effects of the SGP on Chinook salmon IP habitat are expected to be moderate and localized impacts during the mining years, but minor, permanent, and localized benefits post-closure.

Critical Habitat

Critical Habitat for Chinook salmon in the active mine area would be impacted by various activities including active mining, diversions, barrier removal, and stream restoration. The impacts would be related to physical stream channel changes, accidental hazardous material spills, and changes in WCIs – most importantly barriers, stream flow, and water temperature. Chinook salmon Critical Habitat outside the mine site also would be directly affected by culvert installations and would be at risk of accidental hazardous materials spills in the streams adjacent to the access roads.

Access road culvert replacements and new culverts would cause temporary disturbances of Critical Habitat and increase the risk of erosion and sedimentation. The transportation of hazardous materials on access roads and throughout the mine site would increase the risk of spills adjacent to Critical Habitat or in streams/rivers that flow into Critical Habitat in the East Fork SFSR, Johnson Creek, and streams adjacent to Warm Lake Road (CR 10-579). A total of 18 km of Chinook salmon Critical Habitat along the Burntlog Route would be at risk. Impacts to Critical Habitat resulting from risks of erosion and sedimentation, hazardous materials, and risk of spills are described in **Section 7.2.3.2** in each respective topic area.

An analysis of modeled Critical Habitat currently blocked due to passage barriers indicates that the largest impacts to Critical Habitat for Chinook salmon would come from barrier removal. Nearly 26 km of modeled Critical Habitat are blocked above the YPP cascade barrier, with just over 23 km upstream from the box culvert in the East Fork SFSR under baseline conditions. These barriers would be removed by Mine Year -1 to provide upstream access for Chinook salmon. Activities on Meadow Creek would eliminate potential access to much of the stream, including over 6.6 km of modeled Critical Habitat.

The project activities would affect water temperatures in the mine site area, which are described in Impacts to Chinook Salmon – Water Temperature. These effects would be the same effects to Critical Habitat.

It is important to note that under baseline conditions, Chinook salmon do not volitionally occur upstream from the YPP lake cascade barrier. Overall, there would be a localized, permanent, major beneficial effect on access to Critical Habitat for Chinook salmon.

Integration of Effects

The combination of physical stream channel changes, direct effects to individuals, and changes to many of the WCIs (e.g., temperature, stream flow) would affect Chinook salmon and habitat in the analysis area under the 2021 MMP. SGP activities that would potentially cause these impacts include, but are not limited to, new road construction, transportation including hazardous materials, stream diversions, and construction and operation activities at the mine site. These effects may cause injury or mortality to individuals and temporarily or permanently displace Chinook salmon from several mine site streams during certain periods when habitat conditions become unsuitable. This would cause a temporal loss of habitat.

A summary of the overall net effects to Chinook salmon habitat and specific points regarding the impacts are provided below.

- Changes to water chemistry would primarily have minor effects but would have an unknown level of beneficial effects through the reduction of arsenic and antimony.

- Alterations of the physical structures of the East Fork SFSR and Meadow Creek would result in a net benefit to Chinook salmon. The construction of the fishway, with a later restoration of the East Fork SFSR, would provide volitional access to nearly 9 km of spawning habitat and nearly 20 km of rearing habitat that was only accessible when fish were transplanted by IDFG. Additional enhancements to the East Fork SFSR and Meadow Creek would provide additional habitat benefits.

- While there is a modeled loss of thermally suitable habitat for adult migration of Chinook salmon, this is primarily caused by water temperatures below the temperature criteria, which would not result in impaired movement. Spawning, both upstream and downstream from the YPP and juvenile rearing downstream from the YPP would experience a slight decrease in thermally-suitable habitat downstream from YPP. However, the expansion of habitat availability through the addition of the fishway and the subsequent stream channel restoration provides access to an additional 6 km of spawning habitat and nearly 17 km of rearing habitat.

- Changes in flows would result in a net decrease in productivity between baseline conditions and post-closure conditions. Activities during mine operations would result in reductions as described in **Table 7-11** in flows and in Chinook salmon flow-based productivity in the East Fork SFSR between Meadow Creek and Sugar Creek, and in Meadow Creek. The predicted average decreases in Chinook salmon productivity during mine operations compared to baseline conditions would be greater than 10 percent in the East Fork SFSR between YPP and Sugar Creek and nearly 9 percent in lower Meadow Creek, and over 5 percent in the East Fork SFSR near Stibnite. There would, as a result, be a net decrease in flow-productivity, particularly for the spawning life stage caused by a reduction in flow. In subsequent years, closure and post-closure periods, would have negligible to minor changes in productivity.

- The removal of barriers would provide access to upstream habitat not previously volitionally accessed. This would result in a net benefit to Chinook salmon. A new barrier would be constructed in Meadow Creek along the TSF; however, this is not a section of Meadow Creek in which Chinook salmon are able to volitionally reach.

- There would be a slight net increase in IP habitat for Chinook salmon. Post-closure, there would be a net increase of approximately 0.28 km (2 percent) of useable habitat in the headwaters of the East Fork SFSR. This is a change from approximately 11.15 km at baseline to 11.42 km in Mine Year 23. The majority of the usable IP habitat identified in the analysis area is habitat not previously volitionally accessed.

- There would be a net increase in access to Chinook salmon Critical Habitat. While construction and mining activities would affect individual fish and may affect the habitat through the introduction of sediment and contaminants, there would be an increase in access to upstream habitat that was not previously volitionally accessible.

Following closure and reclamation, the overall net effect from the SGP would be a net increase in available habitat, however, flows and temperatures make the additional habitat less optimal.

7.2.3.5 Impacts to Steelhead

Steelhead would be affected by the 2021 MMP through changes in water temperature and flow, which affects other factors such as productivity, intrinsic potential, and Critical Habitat. The effects to steelhead are described below.

Water Temperature

As described in **Section 6.3.2.4**, water temperature is an important factor affecting the survival of each steelhead life stage. The accepted stream temperature thresholds/ranges for life stages of steelhead were compiled from regulatory standards and other relevant literature (ESS 2022b). The technical memorandum presents quantification of baseline habitat availability (in relation to stream temperature) for steelhead and analyzes the likely effects of changes to stream temperatures on available habitat as a result of implementation of the SGP. The following is a summary of the analysis and potential impacts from water temperature changes in streams at the mine site.

Table 7-13 presents the length of intrinsic potential habitat that fall within the temperature threshold categories for steelhead life stages. Length of habitat for steelhead egg incubation/emergence and juvenile rearing are based the amount of habitat with suitable thermal conditions using the summer maximum temperatures. The other life stages are outside the summer – fall modeled parameters, and therefore are not included in the analysis. Detailed data for steelhead under the 2021 MMP are presented in the update of ESS 2022b.

As shown in **Table 7-13**, there would be no reduction in habitat that meets the thermal requirements for steelhead. Relative to baseline conditions:

- There would be no loss of suitable conditions for egg incubation/emergence.
- There would be a net increase in suitable rearing habitat during operations and post-closure, even with a loss of suitable rearing habitat conditions downstream from the YPP lake cascade barrier.

Creeks in the mine site area do experience significant seasonal and diurnal variations, and for mobile life stages (i.e., adults and juveniles), if MWMT are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges. Through stream restoration and enhancement actions, stream cover and instream structures may provide thermal refugia.

It is important to note that under baseline conditions, steelhead do not volitionally occur upstream from the YPP lake cascade barrier. Based on modeled results, the effects of the SGP on steelhead caused by changes to temperature-based suitable habitat are expected to be moderate, permanent, and localized, with beneficial effects resulting from increased access to habitats not previously accessible.

Table 7-13 Length of Stream Habitat that Meets the Optimal Thermal Requirements for Steelhead Under the 2021 Modified Mine Plan

Life Stage	Baseline (km)	Mine Year 6 (km)	Mine Year 12 (km)	Mine Year 18 (km)	Mine Year2 2 (km)	Mine Year2 7 (km)	Mine Year 32 (km)	Mine Year 52 (km)	Mine Year 112 (km)	Change from Baseline to 112 (km)
Below Yellow Pine Pit Cascade Barrier										
Incubation/ Emergence	0	0	0	0	0	0	0	0	0	0
Juvenile Rearing	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Total Available Habitat	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Above Yellow Pine Pit Cascade Barrier										
Incubation/ Emergence	0	0	0	0	0	0	0	0	0	0
Juvenile Rearing	0	8.52	9.35	9.91	9.91	9.28	10.0 7	10.0 7	10.0 7	+10.07
Total Available Habitat	0	8.52	9.35	9.91	9.91	9.28	10.0 7	10.0 7	10.0 7	+10.07

Note: Results based on usable IP habitat
km = kilometer

Flow Productivity

A flow-productivity model was developed to examine the effects of predicted flow changes associated with the 2021 MMP on steelhead productivity (see **Section 6.3.2.5** for additional detail on the model**)**. Annual flow productivity was determined as the long-term percent change from the existing or baseline conditions for each mine year. To analyze the altered stream flow across the project area, flow-productivity outputs were used from three of the USGS stream flow gages (East Fork SFSR above Sugar, East Fork SFSR at Stibnite, East Fork SFSR above Meadow) and the lower Meadow Creek (MC-6).

Table 7-14 and **Figure 7-7** shows the average steelhead productivities for each stream flow site over pertinent periods throughout mine operations and post-closure. The greatest, negative percent changes in flow-productivity averaged over the long-term period (Mine Years -2 to 20) are in the East Fork SFSR upstream from Sugar Creek (-11.2percent) and in Meadow Creek (-13.6 percent). Most of the steelhead productivity on the East Fork SFSR upstream from Sugar Creek is greatly impacted by mine operations that alter streamflow over the life of the mine. Similarly, most of the productivity in Meadow Creek is greatly impacted by changes in stream flow caused by mine operations in Meadow Creek. The East Fork SFSR above Meadow Creek is less impacted by changes in stream flow over the long-term. Similarly, most of the steelhead productivity throughout the mine area is minimally affected by altered stream flow post-closure.

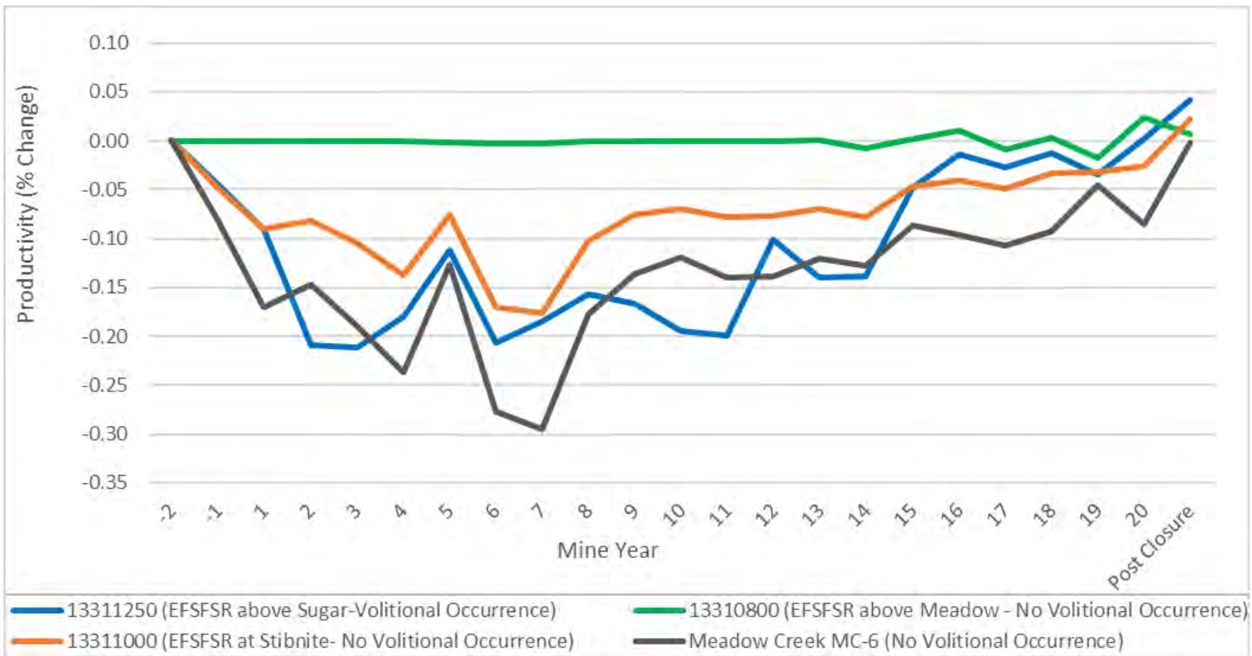


Figure 7-7 Percent Change in Steelhead Productivity from Baseline Conditions by Mine Year and Location (USGS Gaging Stations and MC-6)

Table 7-14 Percent Change in Steelhead Productivity Relative to Baseline Productivity by Mine Year and Location

Period	Mine Year	East Fork SFSR above Meadow Creek (USGS Gage 13310800	East Fork SFSR at Stibnite (USGS Gage 13311000)	East Fork SFSR above Sugar Creek (USGS Gage 13311250)	Meadow Creek (MC-6)
Baseline Productivity		1.24	1.24	1.24	1.24
Mine Years -2 to 20 Percent Change from Baseline	-2	0%	0%	0.1%	0.0%
	-1	0%	-4.8%	-4.4%	-8.1%
	1	0%	-9.0%	-9.0%	-17.0%
	2	0%	-8.2%	-20.9%	-14.7%
	3	0%	-10.4%	-21.1%	-19.0%
	4	0%	-13.8%	-18.0%	-23.6%
	5	-0.2%	-7.5%	-11.2%	-12.6%
	6	-0.3%	-17.1%	-20.7%	-27.6%
	7	-0.3%	-17.6%	-18.5%	-29.5%
	8	-0.1%	-10.2%	-15.7%	-17.7%
	9	0%	-7.6%	-16.7%	-13.6%
	10	0%	-7.0%	-19.4%	-11.9%
	11	0%	-7.8%	-20.0%	-14.0%
	12	0%	-7.7%	-10.1%	-13.8%
	13	0%	-7.0%	-14.0%	-12.1%
	14	-0.8%	-7.9%	-13.8%	-12.7%
	15	0.2%	-4.6%	-4.8%	-8.6%
	16	1.0%	-4.0%	-1.4%	-9.6%
	17	-0.9%	-4.9%	-2.7%	-10.7%
	18	0.3%	-3.3%	-1.2%	-9.2%
	19	-1.8%	-3.2%	-3.4%	-4.6%
	20	2.4%	-2.6%	0.2%	-8.5%
Mine Years -2 to 20 Productivity (Percent Change from Baseline)	Minimum	1.21 (-1.8%)	1.02 (-17.6%)	0.98 (-21.1%)	0.88 (-29.5%)
	Mean	1.24 (0.0%)	1.14 (-7.6%)	1.10 (-11.2%)	1.02 (-13.6%)
	Maximum	1.26 (2.4%)	1.24 (0.0%)	1.24 (0.2%)	1.24 (0.0%)
Mine Years 21 to 112 Productivity (Percent Change from Baseline)	Mean	1.24 (0.7%)	1.27 (2.3%)	1.29 (4.2%)	1.24 (-0.2%)

The Mine Years–2 to 20 were selected because stream flows equilibrate at year 20. Therefore, the post-closure value represents an average annual percent change in productivity for Mine Years 21 through 112.
% = percent; East Fork SFSR = East Fork South Fork Salmon River; USGS = U.S. Geological Survey

Changes in steelhead productivity also occur from Mine Years 3 to 8, where productivity fluctuates in the East Fork SFSR above Meadow Creek, East Fork SFSR above Sugar Creek, and Meadow Creek locations (**Table 7-14**, **Figure 7-7**). The negative percent changes in productivity occur during periods of mine operations that results in dewatering. The increase in productivity in Mine Year 5 is due to reductions of water abstraction during operations from dewatering and subsequent filling of the Hangar Flats pit and dewatering of the YPP.

It is important to note that under baseline conditions, steelhead do not volitionally occur upstream from the YPP lake cascade barrier. However, at mine year -1, the diversion tunnel is constructed allowing for volitional passage, thus increasing the amount of habitat available to steelhead. At the Meadow Creek, East Fork SFSR at Stibnite, and East Fork SFSR above Sugar Creek sites, the effects of the SGP on steelhead productivity are expected to be moderate, long-term (occur during mine operations), and localized. For the East Fork SFSR above Meadow Creek site, the effects of the SGP on steelhead productivity are expected to be minor, long-term (occur during mine operations), and localized. Permanent effects from changes in productivity, that occur during the post-closure are negligible across the mine site.

Intrinsic Potential

An IP model was developed to evaluate segments of stream within the SGP area to determine the watershed's capacity to provide quality habitat for steelhead (see **Section 6.3.1.1** and ESS 2022d for additional information).

For steelhead, habitat assessed for IP was categorized into 1 of 3 rankings including high, medium, and low. Throughout the construction period and life of the mine, the length of each ranking of IP habitat were determined. **Table 7-15** summarizes the years in which there is a large change in IP and includes total IP habitat length in the baseline conditions and at the end of the mine life. Additionally, **Figure 7-8** shows all steelhead IP habitat within the analysis area broken down by year and includes key SGP events that effect the amount and quality of IP habitat.

Table 7-15 Stream Length with Intrinsic Potential Habitat for Steelhead Throughout the Mine Life

IP Rating	Intrinsic Potential Habitat (km)						
	Baseline	Mine Year					Net Loss/ Gain
		-2	3	11	18	23 to 112	
East Fork SFSR and Tributaries Upstream from the Yellow Pine Pit Cascade Barrier							
High	2.16	2.16	2.16	2.16	2.16	2.16	0
Medium	0	0	0	0	0	0	0
Low	2.91	2.88	2.88	3.45	3.45	3.45	+0.54
Total IP Habitat	5.07	5.04	5.04	5.61	5.61	5.61	+0.54
Total Length Habitat Evaluated	29.01	28.35	28.35	28.92	29.34	29.97	+0.96
Meadow Creek and East Fork Meadow Creek							
High	2.18	1.30	1.89	1.86	2.65	3.21	+1.03
Medium	0.60	0.46	0	0	0	1.27	+0.67
Low	0.87	0.09	0.03	0.03	0.03	0.03	-0.84
Total IP Habitat	3.65	1.85	1.89	1.89	2.68	4.51	+0.86
Total Length Habitat Evaluated	16.93	15.75	15.53	15.53	16.30	17.51	+0.58
East Fork SFSR and Tributaries between Yellow Pine Pit and Sugar Creek							
High	0.18	0.12	0.12	0.12	0.12	0.12	-0.06
Medium	0	0	0	0	0	0	0
Low	0.72	0.23	0.23	1.14	1.14	1.14	+0.42
Total IP Habitat	0.90	0.35	0.35	1.26	1.26	1.26	+0.36
Total Length Habitat Evaluated	4.34	4.47	4.47	3.45	3.45	3.45	-0.89
East Fork SFSR Downstream from Sugar Creek							
High	0.03	0.03	0.03	0.03	0.03	0.03	0
Medium	0	0	0	0	0	0	0
Low	1.02	1.02	1.02	1.02	1.02	1.02	0
Total IP Habitat	1.05	1.05	1.05	1.05	1.05	1.05	0
Total Length Habitat Evaluated	1.11	1.11	1.11	1.11	1.11	1.11	0
Headwaters East Fork SFSR Subwatershed							
Total IP Habitat Below YPP	1.95	1.40	1.40	2.31	2.31	2.31	+0.36
Total IP Habitat Above YPP	8.72	6.90	6.94	7.51	8.30	10.13	+1.51
Total IP Habitat	10.67	8.30	8.34	9.82	10.61	12.44	+1.77

East Fork SFSR = East Fork South Fork Salmon River; IP = Intrinsic Potential; km = kilometer

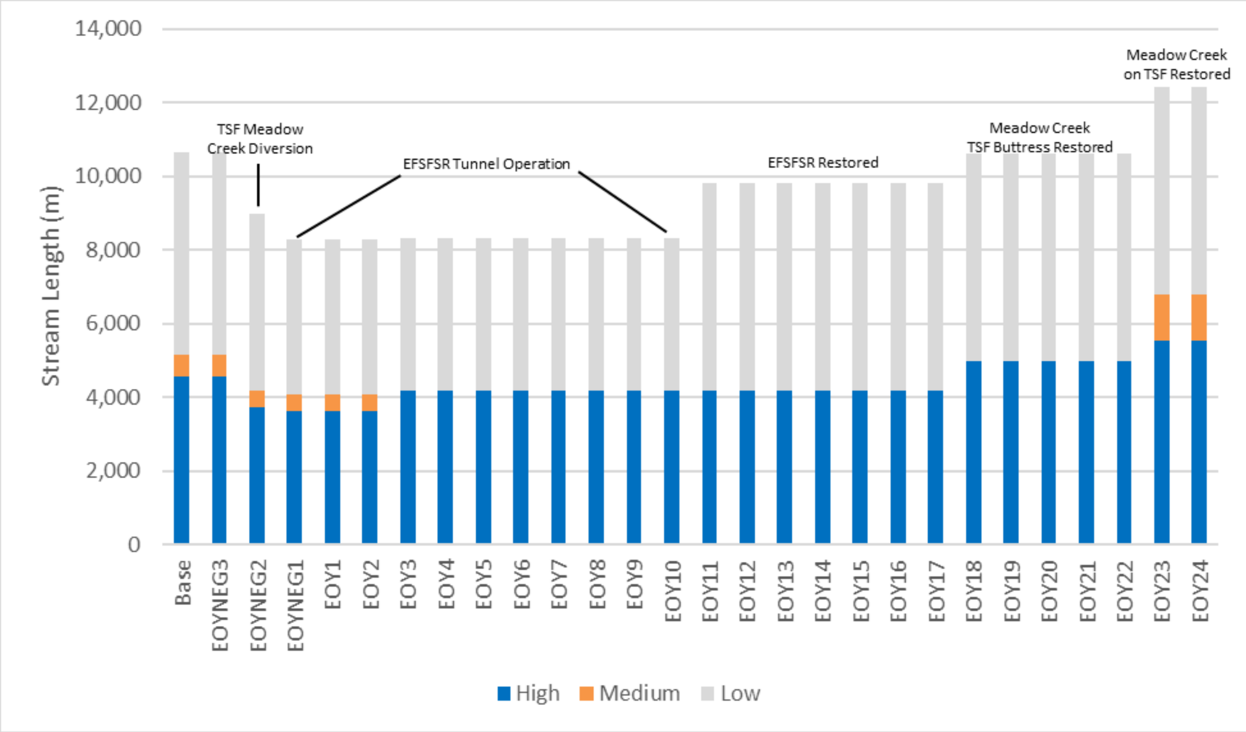


Figure 7-8 Steelhead Intrinsic Potential Habitat in the Mine Site Area Over 28 Years (Mine Years -4 to 24)

Throughout the life of the mine, most of the changes to IP habitat for steelhead result in moderate positive or negative impacts. In Mine Year -1 when the diversion of Meadow Creek occurs, Meadow Creek would lose some high, and most medium, and low-quality IP habitat. Additionally, in Mine Year -1, the YPP fish tunnel construction causes a slight decrease of IP habitat in the East Fork SFSR and tributaries between YPP and Sugar Creek. In Mine Year 3, all medium quality IP habitat is lost; however, 0.59 km of high IP habitat in lower Meadow Creek is added due to an increased bankfull width. Physical modification of ground surface in the vicinity of the East Fork SFSR causes a loss of low IP habitat just upstream from Midnight Creek. In Mine Year 11, the East Fork SFSR regains some low IP habitat above Midnight Creek due to reclamation starting and physical modifications of ground surface in the vicinity of East Fork SFSR end. By Mine Year 18, Meadow Creek gains back high IP habitat due to dewatering pumping stopping. Finally, at Mine Year 23, Meadow Creek regains additional medium and high-quality IP habitat.

As mentioned previously, IP does not factor in the actual species presence or physical barriers, but only whether the stream segments are considered usable IP habitat. It is important to note that under baseline conditions, steelhead do not occur upstream from YPP and there is a physical barrier to fish in Meadow Creek. While there is 10.67 km of IP habitat in baseline conditions, only 1.95 km or 18.2 percent of that is in stream habitat in which steelhead do currently occur. However, by Mine Year -1 the fishway construction would allow steelhead access to East Fork SFSR and its tributaries upstream from the YPP. By Mine Year 23, 1.77 km of IP habitat would be gained from baseline, providing 12.44 km of potential rearing and spawning habitat above and below YPP for steelhead. Within this 12.44 km of IP habitat, a physical barrier blocks 2.62 km of the 4.51 km of IP habitat in Meadow Creek so it would still be inaccessible to steelhead (**Figure 7-9**).

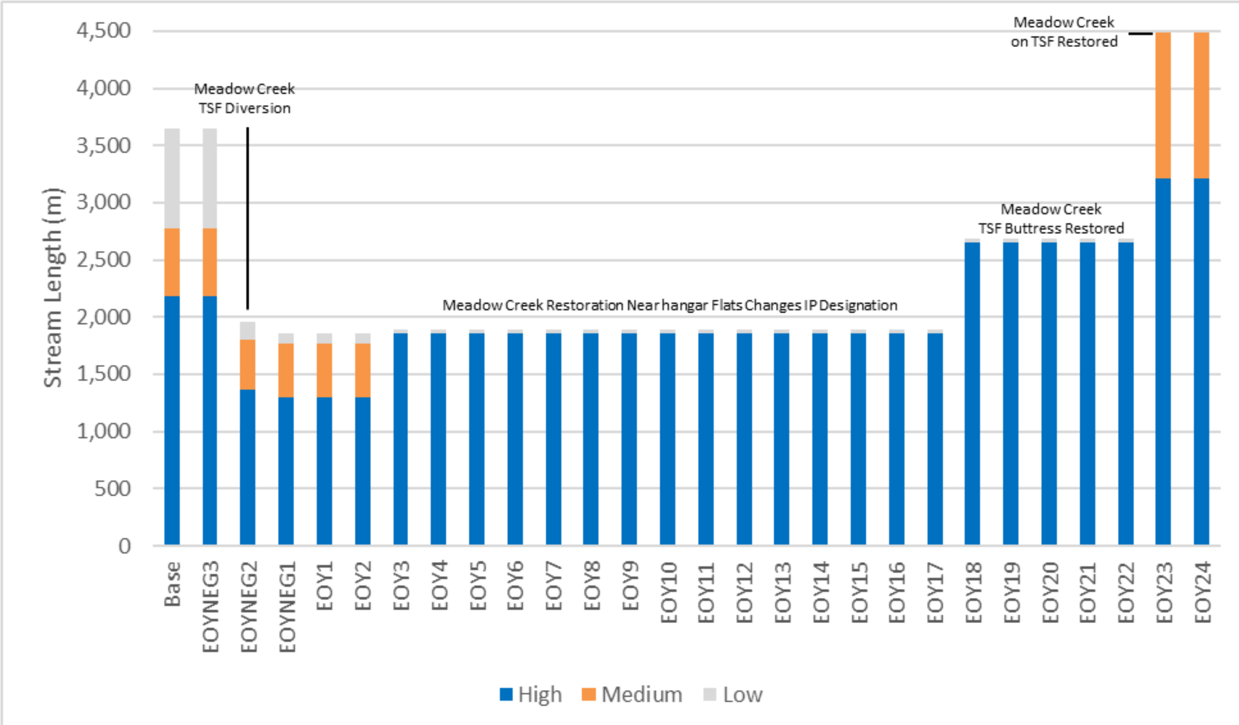


Figure 7-9 Steelhead Intrinsic Potential Habitat in Meadow Creek for 28 Years (Mine Years -4 to 24)

Overall, the SGP area gains 1.77 km of steelhead IP habitat by Mine Year 23. Within that gain of IP habitat, high quality IP habitat increased by 18 percent, medium quality IP habitat increased by 112 percent, and low-quality IP habitat increased by 2 percent relative to baseline conditions. This equates to an overall 16.5 percent gain in IP habitat for steelhead. The long-term changes in IP habitat for steelhead have a moderate positive impact in lower Meadow Creek and East Fork SFSR between Meadow Creek and YPP and a major negative impact in upper Meadow Creek and East Fork SFSR between YPP and Sugar Creek. The permanent changes in IP habitat for steelhead have a moderate positive impact. While permanent impacts are mostly positive due to IP habitat improvements in Meadow Creek, there is a moderate permanent impact in upper Meadow Creek.

It is important to note that under baseline conditions, steelhead do not volitionally occur upstream from the YPP lake cascade barrier. Once the fishway construction and subsequent channel restoration is completed, steelhead would be able to access habitat upstream from YPP except for part of Meadow Creek upstream from a barrier. Overall, the SGP is expected to result in moderate, permanent, and localized benefits to steelhead IP habitat.

Critical Habitat

There is no steelhead trout Critical Habitat upstream from the YPP cascade barrier, but there is Critical Habitat below the barrier. Impacts from SGP activities at the mine site and those caused by the access roads, transmission lines, or off-site facilities could impact steelhead Critical Habitat. Access road culvert replacements and new culverts would cause temporary disturbances of Critical Habitat and increase the risk of erosion and sedimentation. The transportation of hazardous materials on access roads and throughout the mine site would increase the risk of spills adjacent to Critical Habitat or in streams/rivers that flow into Critical Habitat in the East Fork SFSR, Johnson Creek, and streams adjacent to Warm Lake

Road (CR 10-579). A total of 18 km of steelhead Critical Habitat along the Burntlog Route could be affected.

The gradient barrier at the YPP lake cascade is currently restricting access for steelhead trout to habitat upstream. However, no Critical Habitat is identified for steelhead trout upstream from the barrier. The removal of the YPP barrier at Mine Year -1, would provide access to fish to naturally move upstream. This would create a gain in quantity and quality of available habitat regardless of the lack of identified Critical Habitat for steelhead trout upstream from the YPP barrier.

Overall, the effects of the SGP are expected to result in minor, long-term, and localized impacts to the steelhead Critical Habitat.

Integration of Effects

The combination of physical stream channel changes (e.g., diversions and new construction), direct effects to individuals, and changes to many of the WCIs (e.g., water temperature, streamflow) would affect steelhead and habitat in the mine area under the 2021 MMP. SGP activities that would potentially cause these impacts include, but are not limited to, new road construction, transportation including hazardous materials, stream diversions, and construction and operation activities at the mine site. These effects may cause injury or mortality to individuals and temporarily or permanently displace steelhead from several mine site streams during certain periods when habitat conditions become unsuitable. This would cause a temporal loss of habitat.

A summary of the overall net effects to steelhead habitat and specific points regarding the impacts are provided below.

- Changes to water chemistry would primarily have minor effects but would have an unknown level of beneficial effects through the reduction of arsenic and antimony.

- Alterations of the physical structures of the East Fork SFSR and Meadow Creek would result in a net benefit to steelhead. The construction of the fishway, with a later restoration of the East Fork SFSR, would provide volitional access to nearly 9 km habitat that was not previously accessible. Additional enhancements to the East Fork SFSR and Meadow Creek would provide additional habitat benefits.

- There is a modeled increase in thermally-suitable habitat for juvenile rearing. There is no thermally-suitable habitat for egg incubation and emergence under either baseline conditions or the 2021 MMP, so no net loss. Additionally, steelhead would have access to upstream spawning and rearing habitat, which were not previously accessible.

- Changes in flows would result in a net decrease in productivity between baseline conditions and post-closure conditions. Activities during mine operations would result in major reductions in flows and in steelhead flow-based productivity in the East Fork SFSR between Meadow Creek and Sugar Creek, and in Meadow Creek. There would be a net decrease in steelhead habitat in Meadow Creek, but most flows would return to near baseline conditions in the East Fork SFSR after mine closure and post-closure. In subsequent years, closure and post-closure periods, would have negligible to minor changes in productivity.

- The removal of barriers would provide access to upstream habitat not previously volitionally accessed. This would result in a net benefit to steelhead. A new barrier would be constructed in Meadow Creek along the TSF; however, this is not a section of Meadow Creek in which steelhead are able to volitionally reach.

- There would be a slight net increase in IP habitat for steelhead. Post-closure, there would be a net increase of approximately 1.77 km (16.5 percent) of useable habitat in the headwaters of the East Fork SFSR. This is a change from approximately 10.67 km at baseline to 12.44 km in Mine Year 23. The majority of the usable IP habitat identified in the analysis area is habitat not previously volitionally accessed.
- There would no change in access to steelhead Critical Habitat because there is no assumed Critical Habitat upstream from the YPP lake. Following the establishment of passage into the upper watershed, NMFS may designate Critical Habitat in the upper watershed.

Following closure and reclamation, the net effect would be an increase in both the quantity and quality of habitat for steelhead trout.

7.2.3.6 Impacts to Bull Trout

Bull trout would be affected by the 2021 MMP through changes in water temperature and flow, which affects other factors such as habitat through weighted usable area, occupancy probability, and Critical Habitat. The effects to bull trout are described below.

Water Temperature

As described in **Section 6.3.4.2**, water temperature is an important factor affecting the survival of each bull trout life stage. The accepted stream temperature thresholds/ranges for life stages of bull trout were compiled from regulatory standards and other relevant literature (ESS 2022b). The technical memorandum presents quantification of baseline habitat availability (in relation to stream temperature) for bull trout and analyzes the likely effects of changes to stream temperatures on available habitat as a result of implementation of the SGP. The following is a summary of the analysis and potential impacts from water temperature changes in streams at the mine site.

Table 7-16 presents the length of streams that have positive bull trout occupancy probability that fall within the temperature threshold categories for bull trout life stages. Length of habitat for bull trout juvenile rearing are based the amount of habitat with suitable thermal conditions using the summer maximum temperatures; while spawning and incubation/emergence apply the fall maximum temperature. Detailed data for bull trout under the 2021 MMP are presented in the update of ESS 2022b.

As shown in **Table 7-16**, all life stages experience a reduction in habitat that meets the thermal requirements for bull trout. These reductions are either due to water temperatures that are too high or too low for the specific life stage, or due to limited access to suitable habitat (e.g., Meadow Creek). Relative to baseline conditions:

- There would be a net decrease in thermally suitable conditions for spawning because water temperatures are higher than the thermal requirements. While there is a decrease in the amount of thermally suitable spawning habitat that is considered functioning at risk or functioning at unacceptable risk, there is also a decrease in spawning habitat functioning appropriately.
- There would be a net decrease in thermally suitable habitat functioning appropriately for egg incubation/emergence during operations and post-closure primarily due to the loss of access to the upper Meadow Creek.
- There would be a net decrease in thermally suitable juvenile rearing habitat functioning appropriately during operations through post-closure primarily due to the loss of access to the upper Meadow Creek.

Table 7-16 Length of Stream Habitat Under the Watershed Condition Indicator Categories for Water Temperatures for Bull Trout Under the 2021 Modified Mine Plan

Life Stage	Baseline (km)	Mine Year								Change from Baseline to 112 (km)
		Mine Year 6 (km)	Mine Year 12 (km)	Mine Year 18 (km)	Mine Year 22 (km)	Mine Year 27 (km)	Mine Year 32 (km)	Mine Year 52 (km)	Mine Year 112 (km)	
Below Yellow Pine Pit Cascade Barrier										
Spawning – FA	0	0	0	0	0	0	0	0	0	0
Spawning – FR	0	0	0	0	0	0	0	0.05	0.05	+0.05
Spawning - FUR	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.61	1.61	-0.35
Incubation/Emergence - FA	0	0	0	0	0	0	0	0	0	0
Incubation/Emergence - FUR	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Juvenile Rearing - FA	0	0	0	0	0	0	0	0	0	0
Juvenile Rearing - FR	0	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	+1.66
Juvenile Rearing - FUR	2.01	0	0	0	0	0	0	0	0	-2.01
Total Available Habitat	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Above Yellow Pine Pit Cascade Barrier										
Spawning – FA	1.62	1.42	2.61	1.42	1.42	1.42	1.42	1.42	1.42	-0.20
Spawning – FR	7.76	6.28	8.24	5.55	6.18	6.34	6.34	6.34	6.34	-1.42
Spawning - FUR	14.82	8.64	5.85	10.78	10.15	8.29	8.29	8.29	8.29	-6.52
Incubation/Emergence - FA	0	0	0	0	0	0	0	0	0	0
Incubation/Emergence - FUR	24.2	16.34	16.70	17.75	17.75	16.05	16.05	16.05	16.05	-8.15
Juvenile Rearing - FA	12.16	10.35	9.90	7.60	7.88	7.76	7.76	7.76	7.76	-4.4
Juvenile Rearing - FR	9.60	5.99	6.55	9.45	9.62	5.36	5.60	7.22	8.29	-1.31
Juvenile Rearing - FUR	2.43	0	0.25	0.69	0.25	2.93	2.68	1.07	0	-2.43
Total Available Habitat	24.2	16.34	16.70	17.75	17.75	16.05	16.05	16.05	16.05	-8.15

Note: Results based on usable habitat for occupancy potential
FA = functioning appropriately; FR = functioning at risk; FUR = functioning at unacceptable risk; km = kilometer;

Creeks in the mine site area do experience significant seasonal and diurnal variations, and for mobile life stages (i.e., adults and juveniles), if MWMT are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges. Through stream restoration and enhancement actions, stream cover and instream structures may provide thermal refugia.

Creeks in the mine site area do experience significant seasonal and diurnal variations, and for mobile life stages (i.e., adults and juveniles), if water temperatures are above the thresholds, fish may avoid areas within streams if they are able, such as finding thermal refuges. It is important to note that bull trout do not necessarily currently occur in areas that are considered lost habitat due to thermal conditions. However, based on modeled results, the effects of the SGP on bull trout caused by changes to thermally suitable habitat are expected to be major, permanent, and localized.

Weighted Usable Area (PHABSIM)

A PHABSIM model was developed to predict how bull trout habitat changes based upon changes in stream flow associated with different stream reaches throughout the SGP (see **Section 6.3.3.5** for additional detail). The PHABSIM data are approximately 30 years old and originated from another project. They represent available data that provide reference information and should not be viewed as directly transferable to the project site. Although the PHABSIM results do not explicitly predict changes in habitat associated with changes in flow related to the proposed project, they do provide data on how the model predicted similar reductions in flow at similar-sized creeks in close proximity would affect habitat for the different life stages of bull trout. The general relationship between the predicted changes in streamflow and the impact to habitat (i.e., WUA) at the mine site is a general decrease in streamflow results in a general decrease in habitat for the adult and juvenile bull trout life stages.

Under the 2021 MMP, the largest impacts on low-flow discharge would be in Meadow Creek between Year 2 and Year 8. Over this time period, flows are predicted to decrease between 11 percent and 36 percent (**Table 7-8**; mean = 18 percent and median = 20 percent). Since Meadow Creek is a small stream, it is represented by Summit Creek (Stream Index 1; **Table 6-20**). For Summit Creek, the PHABSIM results indicated an 87 percent reduction in discharge from 7.8 cfs to 1.0 cfs which would result in a 90 percent reduction in adult bull trout habitat. Juvenile bull trout results were slightly lower with an 89 percent reduction in juvenile bull trout habitat. The predicted reduction in adult habitat at Summit Creek associated with a reduction in flow from 7.8 cfs to 4.4 cfs (44 percent) was predicted to equate with a 42 percent decline in adult bull trout habitat and similarly a 41 percent reduction in juvenile bull trout habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size. For Meadow Creek, the impacts on bull trout habitat are major, long-term, and localized.

For the East Fork SFSR above Sugar Creek site, which is represented by Sugar Creek (Stream Index 2; **Table 6-20**), flows are predicted to decrease between Mine Years 1 and 14 ranging from 7 percent to 25 percent (**Table 7-8**; mean = 16 percent and median = 16 percent). For Sugar Creek, the PHABSIM results indicated a 90 percent reduction in discharge from 9.9 cfs to 1.0 cfs which would result in an 88 percent reduction in adult bull trout habitat. Juvenile bull trout habitat reduction results were slightly lower with a –87 percent reduction. The predicted reduction in adult habitat at Sugar Creek associated with a decrease in flow from 7.8 cfs to 4.4 cfs (44 percent) was predicted to equate to a 37 percent decline in adult bull trout habitat and similarly a 33 percent reduction in juvenile bull trout habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size. For East Fork SFSR above Sugar Creek, the impacts on bull trout habitat are major, long-term and localized.

For the East Fork SFSR at Stibnite site, which is represented by East Fork SFSR downstream from Sugar Creek (Stream Index 3; **Table 6-20**), flows are predicted to decrease between Mine Years 2 and 8 ranging from 6 percent to 20 percent (**Table 7-8**; mean = 10 percent and median = 11 percent). For East Fork SFSR downstream from Sugar Creek, the PHABSIM results indicated a 60 percent reduction in discharge from 63 cfs to 25 cfs which would result in a 49 percent reduction in adult bull trout habitat. Juvenile bull trout habitat reduction results were slightly lower with a 45 percent reduction in juvenile bull trout habitat. The predicted reduction in adult habitat at Sugar Creek associated with a decrease in flow from 63 cfs to 44 cfs (30 percent) was predicted to equate to a 15 percent decline in adult bull trout habitat. Juvenile bull trout habitat reduction results were slightly lower with an 11 percent reduction in habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size. For the East Fork SFSR at Stibnite site, the impacts on bull trout habitat are moderate, long-term and localized. Analysis of relevant PHABSIM modeling from the region indicates SGP discharge impacts on physical habitat would be major, long-term, and localized.

Occupancy Probability

The OM is a tool used to determine the probability of a fish species occupying a particular stream reach (occupancy probability) and to predict changes in the probability given changes to site physical characteristics (Isaak et al. 2015, 2017). An OM was developed to quantify potential occupancy probability for bull trout (See **Section 6.3.3.5** and ESS 2022f for additional information). The OM calculates occupancy probabilities based on the combination of three independent variables important to bull trout: stream flow, stream temperature, and channel slope. The continuous range of occupancy probabilities are represented as percentages, from 0 percent to 100 percent for each reach. **Table 7-17** presents the OM-derived distance-weighted average occupancy probabilities for bull trout by stream reach under the 2021 MMP for six different time periods: Baseline (existing conditions), Mine Year 6 (approximately halfway through mine operations), Mine Year 12 (near the end of mine operations), Mine Year 18 (beginning of the closure and reclamation), Mine Year 27 (post-closure where water temperatures are the highest) and Mine Year 112 (post-closure).

Stream channel alterations in the East Fork SFSR and Meadow Creek would impact occupancy probabilities for bull trout in the mine area. The largest increase in bull trout occupancy probability occurs in the East Fork SFSR between Sugar Creek and the YPP lake in Mine Year 6 but decrease in Mine Year 12 and Mine Year 18 and starts to increase to Mine Year 112 (**Table 7-17**). The increase in Mine Year 6 in the East Fork SFSR is primarily caused by a decrease in average water temperatures between mid-July and late September. Water temperatures have higher maximums, but also lower minimums during this period. During this time period, less water from Meadow Creek is flowing into the East Fork SFSR, which affects the daily temperature moderation. As a result, the lower average temperature results in a higher occupancy probability for bull trout in the East Fork SFSR between the YPP lake and Sugar Creek. The East Fork SFSR upstream from the YPP lake and the Meadow Creek drainage all have increased occupancy probabilities for bull trout over time.

Table 7-17 Distance Weighted Average of Occupancy Probabilities (in Percent) for Bull Trout Under the 2021 Modified Mine Plan

Stream Reach	Baseline	Mine Year 6	Mine Year 12	Mine Year 18	Mine Year 27	Mine Year 112
East Fork SFSR upstream from Meadow Creek	8.4%	9.6%	9.5%	8.5%	9.8%	9.7%
Meadow Creek and East Fork Meadow Creek	5.7%	6.9%	6.7%	7.8%	5.7%	8.7%
East Fork SFSR between Meadow Creek and YPP	10.1%	12.4%	15.2%	13.8%	13.1%	14%
East Fork SFSR Between YPP and Sugar Creek	15.3%	22.6%	12.4%	12.3%	13.3%	16.1%

% = percent; East Fork SFSR = East Fork South Fork Salmon River; YPP = Yellow Pine pit

A distance-weighted average method was used to represent the average occupancy probability for each stream segment. To produce the distance-weighted average, the occupancy probability of each OM reach was multiplied by the proportion of the reach's stream length to the total length of each stream segment that has some likelihood of being occupied by bull trout. The length of potential habitat available for bull trout are presented in **Table 7-18**.

Table 7-18 Length of Available Habitat for Potential Occupancy for Bull Trout Under the 2021 Modified Mine Plan

Stream Reach	Baseline (km)	Mine Year 6 (km)	Mine Year 12 (km)	Mine Year 18 (km)	Mine Year 27 (km)	Mine Year 112 (km)
East Fork SFSR upstream from Meadow Creek	13.1	13.9	13.1	13.1	13.9	13.1
Meadow Creek and East Fork Meadow Creek	13.1	7.1	6.8	7.4	15.2	14.0
East Fork SFSR between Meadow Creek and YPP	6.5	5.6	7.8	6.9	7.4	8.1
East Fork SFSR Between YPP and Sugar Creek	1.2	0.5	0.7	0.7	0.7	0.7

East Fork SFSR = East Fork South Fork Salmon River; km = kilometer; YPP = Yellow Pine pit

The largest decreases of available potential habitat for bull trout and westslope cutthroat trout relative to baseline conditions would occur in the Meadow Creek drainage. During this period, the main activities that contribute to the loss of potential habitat in these areas are the diversion of Meadow Creek around the TSF footprint; the construction of the rock drain on East Fork Meadow Creek and the East Fork SFSR fish tunnel; and dewatering of the YPP lake, all occurring in Mine Year -1. The length of available habitat in these areas would increase at Mine Year 18 following restoration of Meadow Creek along the TSF.

Mine actions, stream enhancement, and restoration implemented by Mine Year 18 would remove all major fish passage blockages. Any remaining available habitat blockages would occur only in non-enhanced reaches and the Meadow Creek TSF high-gradient areas where fish cannot naturally access the available habitat. The approximately upper 10 km of Meadow Creek would remain blocked in perpetuity due to the high-gradient stream segments flowing off the TSF, however, there is still potentially usable bull trout habitat with occupancy potential that does get factored into the modeled results.

Overall, the SGP is expected to result in minor, permanent, and localized benefits to occupancy probability and the available habitat for occupancy potential for bull trout.

Critical Habitat

Critical habitat for bull trout in the active mine area would be impacted by various activities including active mining, diversions, barrier removal, and stream restoration. An analysis of designated Critical Habitat currently blocked due to passage barriers indicates that the largest impacts to Critical Habitat for bull trout would come from barrier removal. Nearly 20 km of Critical Habitat are blocked for migratory bull trout above the YPP under baseline conditions but are occupied by non-migratory bull trout. This barrier would be removed before mine operations begin (Mine Year -1) to allow access for fluvial and adfluvial bull trout above these barriers. An existing barrier to bull trout in Meadow Creek upstream from East Fork Meadow Creek would be removed but would be replaced by a pipeline along the TSF during operations and then a gradient barrier post-closure. This barrier would block passage to the headwaters of Meadow Creek, but would not eliminate suitable habitat for any bull trout currently present. Overall, the effects of the SGP on bull trout access to Critical Habitat within the mine area would include a combination of beneficial and detrimental impacts and be major, permanent, and localized.

Integration of Effects

The combination of physical stream channel changes, direct effects to individuals, and changes to many of the WCIs would affect bull trout in the mine area. Some SGP activities may improve access to habitat from baseline conditions. Despite some improvement to access, there remain some potential effects associated with the 2021 MMP that may cause injury or mortality to individuals and permanent displace bull trout from the analysis area.

Post-closure, a net decrease in quality and quantity of bull trout habitat would occur despite removal of passage barriers and an increase of lake habitat for bull trout including:

- Changes to water chemistry would primarily have minor effects but would have an unknown level of beneficial effects through the reduction of arsenic and antimony.
- The loss of the YPP lake would result in a net long-term impact to bull trout, but a permanent negligible net change once the Stibnite Lake is constructed by Mine Year 11. The construction of the fishway, and subsequent channel restoration of the East Fork SFSR, would provide volitional access to habitat that was not previously accessible to the adfluvial population, which may provide additional spawning habitat. Additional enhancements to the East Fork SFSR and Meadow Creek would provide additional habitat benefits.
- There would be a net loss in bull trout thermally suitable habitat due to water temperatures exceeding the thermal requirements for spawning, incubation/emergence and rearing, primarily in Meadow Creek.
- Changes in flows would result in a net decrease in bull trout habitat in Meadow Creek and in the East Fork SFSR, but most flows would return to near baseline conditions, particularly in the East Fork SFSR after mine closure and post-closure.
- The removal of barriers would provide access to upstream habitat not previously volitionally accessed. This would result in a benefit to bull trout. A new barrier would be constructed in Meadow Creek along the TSF, which would result in blockage. Overall, there would be a net increase in accessibility to habitat for bull trout.
- There would be a minor net increase in occupancy potential for bull trout.
- There would be a net loss in Critical Habitat for bull trout in upper Meadow Creek because of the diversion around the TSF, and later by the completion of the TSF, which would become a gradient barrier to upstream and downstream fish passage.

7.2.3.7 Westslope Cutthroat Trout

Westslope cutthroat trout would be affected by the 2021 MMP through changes in water temperature and flow, which affects other factors such as habitat through weighted usable area and occupancy probability. The effects to westslope cutthroat trout are described below.

Water Temperature

As described in **Section 6.3.4.2**, water temperature is an important factor affecting the survival of each westslope cutthroat trout life stage. The accepted stream temperature thresholds/ranges for life stages of cutthroat trout were compiled from regulatory standards and other relevant literature (ESS 2022b). The technical memorandum presents quantification of baseline habitat availability (in relation to stream temperature) for westslope cutthroat trout and analyzes the likely effects of changes to stream temperatures on available habitat as a result of implementation of the SGP. The following is a summary of the analysis and potential impacts from water temperature changes in streams at the mine site.

Table 7-19 presents the length of streams that have positive westslope cutthroat trout occupancy probability that fall within the temperature threshold categories for westslope cutthroat trout life stages. Length of habitat for westslope cutthroat trout egg incubation/emergence and juvenile rearing are based the amount of habitat with suitable thermal conditions using the summer maximum temperatures. The other life stages are outside the summer – fall modeled parameters, and therefore are not included in the analysis. Detailed data for westslope cutthroat trout under the 2021 MMP are presented in the update of ESS 2022b.

As shown in **Table 7-19**, there are slight decreases in suitable habitat conditions for egg incubation/emergence during operations, but an increase for post-closure conditions. Relative to baseline conditions:

- There would be a decrease in thermally suitable condition for egg incubation/emergence due to higher water temperatures during operations and the early period of the post-closure, but after Mine Year 27, water temperatures begin to decrease, resulting in a net increase in thermally suitable conditions for egg incubation/emergence upstream from the YPP lake cascade barrier.

- There would be a decrease in thermally suitable rearing habitat during operations and early post-closure, but after Mine Year 22, water temperatures begin to decrease, resulting in a net increase in thermally suitable rearing habitat upstream from the YPP lake cascade barrier.

Based on modeled results, the effects of the SGP on westslope cutthroat trout caused by changes to thermally suitable habitat are expected to be minor, long-term, and localized.

Weighted Usable Area (PHABSIM)

A PHABSIM model was developed to predict how westslope cutthroat trout habitat changes based upon changes in streamflow associated with different stream reaches throughout the SGP (see **Sections 6. 3.3.5** and **6.3.4.3**). The limitations and functions of PHABSIM are described in **Section 7.2.3.6**.

Under the 2021 MMP, the largest impacts on low-flow discharge for the project site would be at Meadow Creek between Year 2 and Year 8. Over this time period, flows are predicted to decrease between 11 percent and 36 percent (**Table 7-8**; mean = 18 percent and median = 20 percent). Since Meadow Creek is a small stream, it is comparable to Summit Creek (Stream Index 1; **Table 6-20**). For Summit Creek, the PHABSIM results indicated an 87 percent reduction in discharge from 7.8 cfs to 1 cfs which would result in a 99 percent reduction in adult cutthroat trout habitat. Effects on the habitat for the cutthroat spawning life stage were about half as large. The predicted reduction in adult habitat at Summit Creek associated with a reduction in flow from 7.8 cfs to 4.4 cfs (44 percent) was predicted to equate to a 56 percent decline in adult cutthroat habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size. For Meadow Creek, the impacts on cutthroat trout habitat are major, long-term and localized.

Table 7-19 Length of Stream Habitat that Meets the Optimal Thermal Requirements for Westslope Cutthroat Trout Under the 2021 Modified Mine Plan

Life Stage	Baseline (km)	Mine Year 6 (km)	Mine Year 12 (km)	Mine Year 18 (km)	Mine Year 22 (km)	Mine Year 27 (km)	Mine Year 32 (km)	Mine Year 52 (km)	Mine Year 112 (km)	Change from Baseline to 112 (km)
Below Yellow Pine Pit Cascade Barrier										
Incubation/ Emergence	0	0	0	0	0	0	0	0	0	0
Juvenile Rearing	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Total Available Habitat	2.01	1.48	1.66	1.66	1.66	1.66	1.66	1.66	1.66	-0.35
Above Yellow Pine Pit Cascade Barrier										
Incubation/ Emergence	0.85	0.78	0.78	0.37	0.37	0.37	2.11	2.11	2.11	+1.26
Juvenile Rearing	20.91	17.33	17.69	18.74	19.15	23.40	21.65	21.65	21.65	+0.74
Total Available Habitat	24.20	18.11	18.47	19.52	19.52	23.77	23.77	23.77	23.77	-0.73

Note: Note: Results based on usable habitat for occupancy potential
km = kilometer

For the East Fork SFSR above Sugar Creek site, which is represented by Sugar Creek (Stream Index 2; **Table 6-20**), flows are predicted to decrease between Year 1 and Year 14 ranging from 7 percent to 25 percent (**Table 7-8**; mean = 16 percent and median = 16 percent). For Sugar Creek, the PHABSIM results indicated a 90 percent reduction in discharge from 9.9 cfs to 1.0 cfs which would result in a 99 percent reduction in adult cutthroat trout habitat. Juvenile cutthroat trout habitat loss results were slightly lower, while effects on cutthroat fry habitat were about half as large. The predicted reduction in adult habitat at Sugar Creek associated with a decrease in flow from 9.9 cfs to 5.4 cfs (46 percent) was predicted to equate to a 53 percent decline in adult cutthroat trout habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size. For the East Fork SFSR above Sugar Creek, the impacts on cutthroat trout habitat are major, long-term and localized.

For the East Fork SFSR at Stibnite site, which is represented by East Fork SFSR Downstream from Sugar Creek (Stream Index 3; **Table 6-20**), flows are predicted to decrease between Year 2 and Year 8 ranging from 6 percent to 20 percent (**Table 7-8**; mean = 10 percent, median = 11 percent). For East Fork SFSR Downstream from Sugar Creek, the PHABSIM results indicated a 60 percent reduction in discharge from 63 cfs to 25 cfs which would result in a 67 percent reduction in adult cutthroat trout habitat. No habitat data were available for juvenile cutthroat trout habitat, but the effects on cutthroat fry habitat were much lower with a 24 percent decrease. The predicted reduction in adult habitat at Sugar Creek associated with a decrease in flow from 63 cfs to 44 cfs (30 percent) was predicted to equate to a 32 percent decline in adult cutthroat trout habitat and only a 6 percent reduction in cutthroat fry habitat. There were no PHABSIM results provided for smaller decreases in discharge at low flows for this stream size or for the cutthroat trout juvenile life stage. For the East Fork SFSR at Stibnite site, the impacts on cutthroat trout habitat are moderate, long-term and localized.

Analysis of relevant PHABSIM modeling from the region indicates the effects of SGP discharge impacts on physical habitat could be moderate to major, long-term, and localized.

Occupancy Probability

Occupancy probability and stream length with occupancy probability was calculated in the same manner for westslope cutthroat trout as described for bull trout (see **Section 7.2.3.6**).

Stream channel alterations in the East Fork SFSR and Meadow Creek would impact occupancy probabilities for westslope cutthroat trout in the mine area. The largest increase in westslope cutthroat trout occupancy probability occurs in the East Fork SFSR between Sugar Creek and the YPP lake in Mine Year 6 but decrease in Mine Year 12 but increases again by Mine Year 112 (**Table 7-20**). The increase in Mine Year 6 in the East Fork SFSR is caused by a decrease in average water temperatures between mid-July and late September. Water temperatures have higher maximums, but also lower minimums during this period. During this time period, less water from Meadow Creek is flowing into the East Fork SFSR, which affects the daily temperature moderation. As a result, the lower average temperature results in a higher occupancy probability for westslope cutthroat trout in the East Fork SFSR between the YPP lake and Sugar Creek. The East Fork SFSR upstream from the YPP lake and the Meadow Creek drainage all have increased occupancy probabilities for westslope cutthroat trout over time.

Table 7-20 Distance Weighted Average Occupancy Probability (in Percent) of Westslope Cutthroat Trout under the 2021 Modified Mine Plan

Stream Reach	Baseline	Mine Year 6	Mine Year 12	Mine Year 18	Mine Year 27	Mine Year 112
East Fork SFSR upstream from Meadow Creek	64.3%	64.4%	64.8%	64.4%	64.4%	64.8%
Meadow Creek and East Fork Meadow Creek	63.9%	64.6%	64.6%	65.1%	64.5%	66.3%
East Fork SFSR between Meadow Creek and YPP	64.2%	65.0%	66.5%	65.7%	65.6%	65.4%
East Fork SFSR Between YPP and Sugar Creek	68.0%	70.2%	65.5%	65.7%	65.6%	67.7%

% = percent; East Fork SFSR = East Fork South Fork Salmon River; YPP = Yellow Pine pit

With the occupancy probability identified in each system, the length of habitat that has an occupancy probability in each stream was calculated. The length of potential habitat available for westslope cutthroat trout are presented in **Table 7-21**.

Table 7-21 Length of Available Habitat for Potential Occupancy for Westslope Cutthroat Trout Under the 2021 Modified Mine Plan

Stream Reach	Baseline (km)	Mine Year 6 (km)	Mine Year 12 (km)	Mine Year 18 (km)	Mine Year 27 (km)	Mine Year 112 (km)
East Fork SFSR upstream from Meadow Creek	13.1	13.9	13.1	13.1	13.9	13.1
Meadow Creek and East Fork Meadow Creek	13.1	7.1	6.8	7.4	15.2	14.0
East Fork SFSR between Meadow Creek and YPP	6.7	5.6	7.8	6.9	7.4	8.1
East Fork SFSR Between YPP and Sugar Creek	1.2	0.5	0.7	0.7	0.7	0.7

EFMC = East Fork Meadow Creek; East Fork SFSR = East Fork South Fork Salmon River; YPP = Yellow Pine pit

The largest decreases of available potential habitat for westslope cutthroat trout relative to baseline conditions would occur in the Meadow Creek drainage. During this period, the main activities that contribute to the loss of potential habitat in these areas are the diversion of Meadow Creek around the TSF footprint; the construction of the rock drain on East Fork Meadow Creek and the East Fork SFSR fish tunnel; and dewatering of the YPP lake, all occurring in Mine Year -1. The length of available habitat in these areas would increase at Mine Year 18 following restoration of Meadow Creek along the TSF.

Mine actions, stream enhancement, and restoration implemented by Mine Year 18 would remove all major fish passage blockages. Any remaining available habitat blockages would occur only in non-enhanced reaches and the Meadow Creek TSF high-gradient areas where fish cannot naturally access the available habitat. The approximately upper 10 km of Meadow Creek would remain blocked in perpetuity due to the high-gradient stream segments flowing off the TSF. Based on the current known extent westslope cutthroat trout occupancy, fish in the upper headwaters of Meadow Creek would remain isolated.

Overall, the SGP is expected to result in minor, permanent, and localized benefits to occupancy probability and the available habitat for occupancy potential for westslope cutthroat trout.

Integration of Effects

The combination of physical stream channel changes, direct effects to individuals, and changes to many of the WCIs would negatively affect westslope cutthroat trout in the analysis area through the loss of suitable habitat. Despite some improvement to access, there remain potential effects which may cause injury or mortality to individuals and/or displacement of westslope cutthroat trout.

Following reclamation, the net effect would be a minor loss of both quantity and quality of habitat for westslope cutthroat trout including:

- Changes to water chemistry would primarily have minor effects but would have an unknown level of beneficial effects through the reduction of arsenic and antimony.
- Habitat enhancements to the East Fork SFSR and Meadow Creek would provide benefits to westslope cutthroat trout habitat.

- The primarily net reduction in water temperatures in the East Fork SFSR and Meadow Creek would provide a net minor benefit for westslope cutthroat trout. There is a slight modeled decrease in temperature-suitable habitat for all life stages.

- Changes in flows would result in a net decrease in westslope cutthroat trout habitat in Meadow Creek, but most flows would return to near baseline conditions in the East Fork SFSR after mine closure and post-closure. Habitat quantified by WUA available to westslope cutthroat trout based on PHABSIM model results show low reductions in WUA post-closure, with a negligible net decrease in westslope cutthroat trout habitat.

- The removal of barriers would have negligible effects on westslope cutthroat trout. A new barrier would be constructed in Meadow Creek along the TSF, which would result in blockage, which may result in isolation of fish in the headwaters.

- There would be a minor net increase in occupancy potential for westslope cutthroat trout.

The 2021 MMP may indirectly impact westslope cutthroat trout individuals but would not likely contribute to a trend towards ESA listing or loss of viability of the species within the planning area.

7.2.4 Johnson Creek Route Alternative

7.2.4.1 Direct Impacts to Individuals

Spill Risk

All vehicle trips would traverse the Johnson Creek Route under this alternative, resulting in greater use of the Johnson Creek Route access roads. The potential location and extent of accidental spills would therefore differ compared to the 2021 MMP. The Johnson Creek Route is located in close proximity to streams (i.e., within 100 feet) for 6.5 miles or 18 percent of its approximately 36-mile length, so the potential for fuel and hazardous chemical spills impacting surface water quality is higher than for travel on the Burntlog Route which is within 100 feet of a stream for 1.69 miles or four percent of its length. There is also an approximately five-mile segment of Warm Lake Road within 100 feet of Warm Lake Creek that would be travelled under this alternative, same as the 2021 MMP. Overall design features proposed by Perpetua, design features required by the Forest Service, and permit stipulations and regulatory requirements from state and federal agencies (including use of USDOT-certified containers and USDOT-registered transporters) would reduce the risk of spills and promote effective response should a spill occur.

The effects of spills associated with the Johnson Creek Route alternative on surface water and potentially on fish and aquatic habitat would be minor to major, temporary, and localized depending on the spill location.

7.2.4.2 Impacts to Watershed Condition Indicators

Sediment and Turbidity

The number of streams crossed along the Johnson Creek Route (43) would be reduced compared to the 2021 MMP. However, the Johnson Creek Route would be widened and upgraded under this alternative to accommodate approximately 60 vehicle trips per day for the duration of the operating period. Therefore, surface water quality impacts from erosion and sedimentation during access road construction could increase during the construction activities and would require implementation of sediment and erosion BMPs.

Use of the Johnson Creek Route for site access would avoid construction-related impacts from sedimentation at 21 different streams compared to the 2021 MMP. These streams include Burntlog Creek, East Fork Burntlog Creek, the East Fork SFSR, Johnson Creek, Landmark Creek, Peanut Creek, Rabbit Creek, Riordan Creek, Trapper Creek, and 12 unnamed waterbodies.

During mine construction, the number of daily vehicle trips to the SGP would be comparable between the alternatives. The number of daily vehicle trips also would be the same during mine operations and reclamation; however, all vehicle trips would traverse the Johnson Creek Route under this alternative, resulting in greater use of the Johnson Creek Route access roads, and more fugitive dust generation and greater wear and tear on the road surface. In addition, use of the Johnson Creek Route would require two additional years of construction. The resulting surface water quality impacts from erosion and sedimentation would therefore differ in location and extent compared to the 2021 MMP but would be similar in magnitude because the number of vehicle trips to the SGP would remain the same.

Prevention of these types of impacts would be achieved through proper road design, construction, grade control, fugitive dust control and, in the winter months, snow removal and “sanding” using gravel and coarse sand with minimal fines to avert slippery conditions and reduce off-site sedimentation during the spring runoff season (**Tables 2-2** and **2-3**).

Overall, based on identified maintenance activities, design features proposed by Perpetua, design features required by the Forest Service, and permit stipulations from state and federal agencies, traffic-related dust and erosion/sedimentation would be within the normal range of properly maintained NFS roads. The duration for traffic-related dust and erosion/sedimentation would last throughout the entire period of use of the Johnson Creek Route (approximately 40 years); however, the potential for these effects would be incrementally reduced during closure and reclamation (when average annual daily traffic would be reduced). Due to the nature of airborne dust and sediment transport by streams, the geographic extent of the impact could be hundreds of feet to miles, depending on many site- and event-specific factors, but it is expected that effects would be limited to within the subwatersheds of the analysis area.

The effects of the Johnson Creek Route Alternative of sedimentation would be moderate, long-term, and localized.

Chemical Contaminants

The water quality effects of the Johnson Creek Route Alternative and 2021 MMP are comparable with regard to contact water, water treatment, groundwater chemistry, surface water chemistry, stream temperature, and impaired water bodies. The change in site access does result in some differences in effects of sedimentation and fuels and hazardous chemicals as noted above.

7.3 Cumulative Effects

7.3.1 Past, Present, and Reasonably Foreseeable Activities Relevant to Cumulative Effects Analysis

The cumulative effects analysis area for fish and aquatic habitat consists of all of the watercourses and waterbodies in the Hydrologic Unit Code 6th field (10-digit code watersheds that overlap potential SGP disturbance areas (**Figure 5-1**).

Cumulative effects consider past, present, and reasonably foreseeable activities and their potential effects with respect to fish and aquatic habitat when combined with the potential direct and indirect impacts of the SGP. Past and present actions that have, or are currently, affecting fish and aquatic habitat include past and current mining activities (including exploration), infrastructure projects, ongoing Forest Service management projects, recreation, fishing, transportation projects, water diversions, hydropower projects, and wildland fires.

Reasonably foreseeable future actions that could cumulatively contribute to fisheries and aquatic habitat impacts in the analysis area include:

- East Fork South Fork Restoration and Access Management Plan,
- Granite Goose Landscape Restoration Project,
- Payette National Forest Resilience and Fuels Reduction Prescribed Fire Project;
- Southwest Idaho Resilient Landscape Project;
- South Fork Plunge Watershed Restoration Project;
- Profile Creek Culvert Replacement Project;
- Stallion Gold Horse Heaven Exploration Project, and

Figure 7-10 shows the general locations of past, present, and reasonably foreseeable future actions that are relevant to the cumulative effects analysis.

7.3.2 No Action Alternative

The existing baseline conditions of fish and aquatic habitat in and adjacent to the mine site are expected to improve due to the removal of legacy mining materials that are in contact with surface waters in Meadow Creek and the East Fork SFSR under the ASAOC Phase I. The ASAOC is a separate action and not tied to the permitting of the SGP. Although impacts would likely be reduced due to a reduction of mine waste available for contact with surface water, elevated arsenic and antimony concentrations would persist as a cumulative impact with inputs from other historical sources (e.g., SODA) and inputs from natural sources that would continue to cause contaminant loading to the environment and influence Meadow Creek and East Fork SFSR stream flow concentrations. These actions are consistent with standard EPA presumptive remedies for this type of site.

Cumulative impacts to fisheries also could occur at the SGP area due to continuing surface exploration for the Golden Meadows Exploration Project. These previously approved activities include construction of several temporary roads (approximately 0.32 mile of temporary roads) to access drill sites (total of 28 drill sites), drill pad construction (total of 182 drill pads), and drilling on both Forest Service and private lands at and in the vicinity of the SGP. The continuation of approved exploration activities at the SGP by Perpetua could cumulatively increase stream sediment levels resulting from surface disturbance and erosion; however, this increase would be incremental because of the limited activity and disturbance area. Exploration activities also could cause cumulative surface water quality impacts through accidental spills of diesel, gasoline, and jet fuel stored at the SGP in aboveground tanks. Similarly, exploration activities associated with the Stallion Gold Horse Heaven Exploration Project could contribute as well.

7.3.3 2021 Modified Mine Plan

These actions would occur in the same watershed and are expected to have similar types of impacts to fish and aquatic habitat as described for the 2021 MMP, such as increases in sediment and stream temperatures, stream flow reductions, and stream channel changes. However, because these projects appear to be at a smaller scale than the SGP, their impacts also would be at a smaller scale. These projects also could have beneficial effects on fish and aquatic habitat in the long-term and are summarized below.

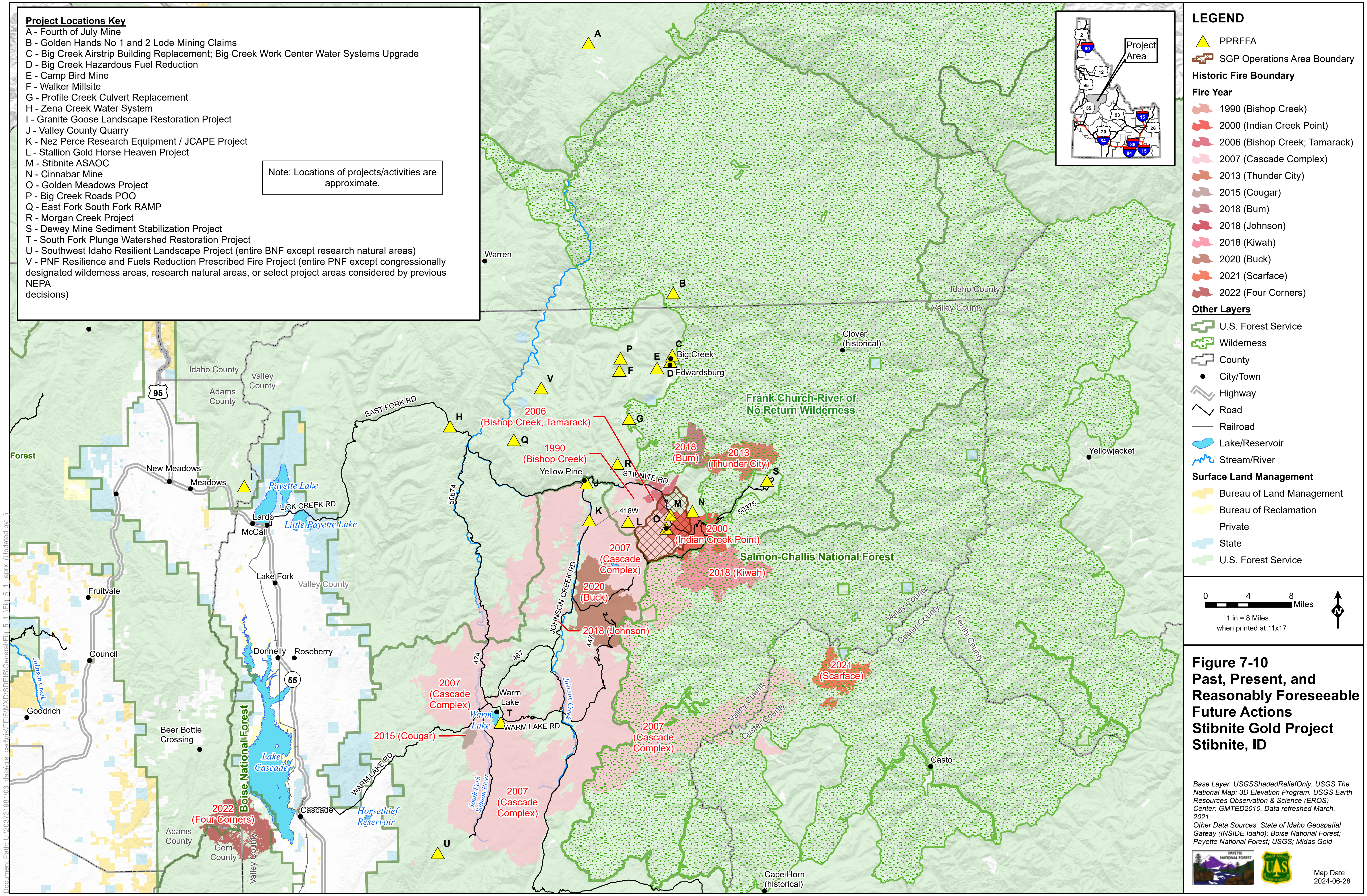


Figure 7-10
Past, Present, and Reasonably Foreseeable Future Actions
Stibnite Gold Project
Stibnite, ID

Base Layer: USGSShadedReliefOnly: USGS The National Map: 3D Elevation Program. USGS Earth Resources Observation & Science (EROS) Center: GMTED2010. Data refreshed March, 2021.
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Payette National Forest; USGS; Midas Gold

Map Date: 2024-06-28

The present South Fork Restoration and Access Management Plan and the reasonably foreseeable East Fork South Fork Restoration and Access Management Plan, Payette National Forest Resilience and Fuels Reduction Prescribed Fire Project, Southwest Idaho Resilient Landscape Project, South Fork Plunge Watershed Restoration Project; Profile Creek Culvert Replacement Project include numerous actions related to watershed reclamation within the SFSR watershed and is therefore expected to have a long-term beneficial effect on habitat conditions for fish. Further, the Profile Creek Culvert Replacement Project would replace a culvert at Profile Creek on Profile Gap Road NFSR 340 with a 90-foot bridge for aquatic organism passage. Cumulative effects from large-scale management of Forest vegetation could include short-term disturbance of fish habitats and increases in sediment; but would be beneficial in the long-term. **Table 7-22** provides a general description of effects on fish and aquatic resources from the other types of projects that are expected to occur in the analysis area.

The impacts from the specific reasonably foreseeable future projects and other future projects or activities would likely be short duration and are planned at a smaller scale. However, when combined with the potential impacts and duration of the 2021 MMP, the duration and scale of cumulative impacts on fish and aquatic habitat would be larger because all these projects would occur during the same time period. The resulting cumulative effect on fish and aquatic habitat in the analysis area would be temporal losses or degradation of habitat and behavioral disturbances, along with some long-term beneficial effects from habitat improvements.

Table 7-22 Cumulative Effects on Fish and Aquatic Habitat from Other Future Projects or Activities

Cumulative Project Type	Effects on Fish and Aquatic Habitat
Mineral exploration and mining activities	Currently planned or future mine development would affect fish and habitat during development through direct disturbance of habitat, increase sediment, changes in stream flow and temperature.
Closure and reclamation projects	Projects within fish habitat that are currently, or in the future, undergoing reclamation would likely improve fish habitat because these projects involve the removal of some infrastructure and reclamation of native habitats.
Transportation projects	Road maintenance, bridge or culvert replacement, and improvement projects are likely in the analysis area. Installation or improvement of culverts or bridges may impact fish habitat due to construction-related effects such as erosion and sediment in streams. Maintenance of existing roadways and culverts/bridges would create short-term impacts, while new roadways and culverts/bridges could have impacts for a longer period.
Recreation and tourism effects	Recreational activities such as fishing would continue to affect fish in the future. Fishing activities could decrease localized fish populations. These are regulated by the IDFG and would not lead to cumulative impacts when combined with impacts from the SGP.

7.3.4 Johnson Creek Route Alternative

The effects discussed for the 2021 MMP for the SGP and reasonably foreseeable future actions would also occur under the Johnson Creek Route Alternative. The use of the Johnson Creek Road rather than the construction of the Burntlog Route would increase the risk of spills and sedimentation in Johnson Creek. Therefore, the potential for cumulative effects to fish and aquatic habitat from the Johnson Creek Route Alternative would be greater in degree with regards to spills and sediment compared to the 2021 MMP but would be comparable with regard to other effects.

7.4 Short-term Uses and Long-term Productivity

7.4.1 No Action Alternative

Under the No Action Alternative, there would be no open pit mining or removal of legacy waste material at the SGP beyond the Phase I ASAOC activity. Consequently, no short-term use would occur that would affect fisheries resources, and no change in long-term productivity would occur.

7.5 Mitigation and Monitoring

Mitigation measures required by the Forest Service would represent reasonable and effective means to reduce the impacts identified in the previous section or to reduce uncertainty regarding the forecasting of impacts into the future. These mitigation measures would be in addition to the Forest Service requirements and environmental design features (**Section 2.4**) accounted for in the preceding impact analysis. Mitigation measures addressing water quality effects (e.g., stream water temperature) would mitigate certain impacts to fish.

Contingent Stream Temperature Reduction

Issue: Long-term performance of stream temperature reduction measures may have the potential to not fully achieve the forecasted stream temperature results. For example, the restored stream channel across the closed TSF may experience different consolidation, hydrologic, and/or re-vegetation performance compared to model forecasts that would affect its viability for reducing stream temperature as well as maintaining a physically and chemically stable closure for the TSF.

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. When shade is assumed to be 40 percent of design, predicted stream temperatures remain elevated in the TSF area and near existing conditions in downstream areas without realizing the benefit of the restored stream channel over the TSF on reducing stream temperatures below the existing condition.

Without this temperature reduction, stream temperatures downstream of the Yellow Pine pit area could also be greater than existing conditions.

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 main stream system. In addition, these diversions would not be affected by TSF consolidation or implementation of stream channel restoration. Therefore, these surface flow diversions would not be removed/reclaimed and continue to be utilized to divert flows in part of in whole until:

1. TSF consolidation appropriate for stream channel restoration could be verified via consolidation monitoring and re-modeling for the as-built tailings facility,
2. Stream restoration design and implementation could be re-assessed 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 would need adjustment to accommodate the gradients of the post-consolidation TSF surface, and
3. Achievement of design shading effects of riparian plants on stream temperatures could be re-assessed prior to construction by measuring the success of establishing riparian plantings at

locations outside the TSF footprint (e.g., Hangar Flats pit diversion corridor, TSF Buttress, across the Yellow Pine pit backfill or others) or a TSF-analogous test plot location utilizing the design cover materials and thicknesses.

Operational period maintenance practices for the diversions would 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 would be collected to confirm the performance of the temperature reduction measures. In an event where monitoring data indicated that acceptable stream temperatures would not be attained, the ditch and pipeline diversions would be re-commissioned and utilized to convey surface flows in part or in whole until an effective planting design would be developed and implemented.

Effectiveness: This monitoring and mitigation measure would be effective in reducing stream temperatures to predicted levels. However, it could delay the reclamation of surface water diversion ditches and pipelines for a period of several years, until stream temperature reductions could be achieved by shading, channel reconfiguration, or other means. This could delay the placement of up to 33,000 BCY of growth media. Any extended usage of the operational period diversion may also affect the implementation of approximately 121 acres of riparian planting and wetlands restoration plus the establishment of potential fish habitat on the reclaimed TSF area. However, the stream temperatures could be more conducive to fish occupancy in reaches of the East Fork SFSR in the mine site area.

Water Resource Monitoring Plan

Issue: As with any predictive model, limitations to long-term water chemistry modeling may result in underestimation of the nature and/or extent of surface water and groundwater quality impacts.

Monitoring Measure - Water Resource Monitoring Plan Implementation: Because construction, operation, and closure of the proposed Project has potential to impact surface or groundwater resources, a focused Water Resources Monitoring Plan for the approved project would be developed by Perpetua. As the mine owner/operator, Perpetua would be responsible for the implementation of the Water Resources Monitoring Plan for any approved action incorporating the confirmation of predicted surface water and groundwater chemistry plus surface water temperature. The plan would include mined development rock and ore, surface water, groundwater, and meteorological monitoring requirements. Monitoring results would be provided to the Forest Service on a quarterly basis and summarized in an annual report. Perpetua would 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 would be reviewed and approved by the Forest Service 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.

Effectiveness: This monitoring measure would provide for identification of potential impacts to groundwater and surface water resources as a result of mine-related water management activities. Implementation of this monitoring measure in conjunction with associated mitigation measures is anticipated to mitigate any impacts that deviate outside model uncertainty to surface water and groundwater resources resulting from mine-related water management during the construction, mining, and closure periods. If such deviation is observed, actions may consist of additional investigation and evaluation, including additional monitoring as necessary, to determine effective management practices and prevent adverse impacts.

Geochemical and Temperature Modeling

Issue: Despite the best efforts at calibration and validation predictive modeling of groundwater and surface water chemistry and temperature entails uncertainty and future field conditions may vary form model predictions.

Monitoring Measure - Updated Geochemical and Temperature Modeling: Geochemical modeling and/or temperature modeling would be updated as necessary (at the request of the Forest Service) if monitoring results obtained from the Water Resources Monitoring Plan or other data collection indicate a change in water quality conditions that would significantly influence prediction and recognition of potential mine impacts. The Forest Service's review of quarterly and annual monitoring results compared to predicted conditions would provide early warning of potentially unanticipated, undesirable impacts to water resources to allow for implementation of appropriate mitigation measures. Implementation of these mitigation measures would reduce or eliminate potential impacts to water quality.

Effectiveness: Implementation of this monitoring measure is expected to be effective in sustaining predictive models as usable evaluation tools that reflect site conditions and monitoring data for the purpose of predicting impacts and developing effective management practices.

Streamflow Temperature

Issue: Riparian vegetation planting along restored stream channels may not provide enough shade to limit temperatures at the degree and timing forecast in the site closure plan.

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 would 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 an 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.

Effectiveness: Implementation of additional shading measures and low-flow piping would reduce the MWMT temperatures. The extent to which these reductions would achieve targeted temperatures would be subject to further monitoring with additional measures if warranted to achieve temperature targets in the Project area streams available for volitional fish passage.

Water Quality Sampling

Issue: Water quality sampling and analyses may be too infrequent to detect changes in water chemistry that could cause or contribute to impairments of beneficial use or violations of surface water quality standards.

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 SGP components could have rapidly changing analyte concentrations, water quality samples would 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, would be reviewed and compared to previously collected data, baseline concentrations, and other permit conditions. Higher frequency water quality sampling and analyses would be applied to:

- Discharges from the start-up or resumption of mine water treatment plants following an extended shut-down (pH, specific conductivity, WAD cyanide, organic carbon, arsenic, antimony, and mercury) until results meet IPDES permit limits or the results of monitoring are considered sufficient based on Forest Service review in consultation with applicable state regulatory agencies, and

- 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 Forest Service review in consultation with applicable state regulatory agencies.

Effectiveness: Higher frequency water quality sampling (with corresponding turnaround analysis time) from Project components with potentially rapidly changing analyte concentrations would allow for detection of and water management response to short-term variations in water quality that could affect surface water quality compared to forecast conditions.

7.5.1 2021 Modified Mine Plan

Mining by its nature is a short-term land use with its effects on long-term productivity dependent on the success of its closure and reclamation activities. Construction and operation of the proposed mine would result in short-term impacts to fish and associated habitat. During construction and operations, some sections of fish habitat would be removed from the footprint of the proposed mine site. Changes to fish habitat include diverting the East Fork SFSR around YPP and subsequently backfilling and constructing a stream channel atop the pit at closure. In the long-term restoring fish passage upstream from the YPP would result in an increase in available habitat for anadromous and resident fish in the analysis area.

Short-term changes to fish habitat in Meadow Creek include diverting a portion of the creek just south of the proposed Hangar Flats open pit, and the loss of habitat where the TSF and TSF Buttress would be located. The short-term loss of habitat would negatively affect fish populations in Meadow Creek over the life of the mine. Closure and reclamation would restore habitat over time.

7.5.2 Johnson Creek Route Alternative

Under the Johnson Creek Route Alternative, the effects of short-term use and long-term productivity would be the same as that described for the 2021 MMP because the impacts to fish and aquatic habitat are primarily associated with activity at the mine site.

7.6 Irreversible and Irretrievable Commitments of Resources

7.6.1 No Action Alternative

Under the No Action Alternative there would be no irreversible or irretrievable commitment of fish and aquatic habitat resources.

7.6.2 2021 Modified Mine Plan

Irreversible Commitments – A commitment of resources is irreversible when the impacts of the proposed action or alternatives would limit the future options for use of the resource. This applies primarily to non-renewable resources or to processes or resources that are renewable over long periods of time.

The direct mortality of fish would be an irreversible impact that could occur under the 2021 MMP. Although fish exclusion barriers and trap and transfer activities would be incorporated to minimize fish mortality, incidental injury or mortality is expected to occur. These losses of fish in the mine site would be considered irreversible. Species subject to potential irreversible losses include Chinook salmon, steelhead trout, bull trout, and cutthroat trout.

Irretrievable Commitments – A commitment of resources is irretrievable when the impacts of the action alternatives would result in a loss of production, harvest, or use of renewable resources. An irretrievable commitment of resources occurs when a resource that is renewable over a relatively short period of time is consumed during the life of the SGP and is therefore unavailable for other uses until the use ceases and it is renewed and once again available. It is the temporal loss of resources that is considered irretrievable.

This includes resources that are renewable over a short time, such as riparian vegetation and streams. While the loss of the resource itself is reversible (through mitigation), the temporal loss of the use of the resource or habitat is irretrievable. The SGP would cause a temporal loss of fish habitat for fish species inhabiting certain stream reaches.

Portions of Meadow Creek upstream from the southern extent of the TSF would be irretrievable and unavailable to downstream fish within Meadow Creek during construction and operations. During construction and operations, the presence of the TSF and TSF Buttress would essentially isolate any populations of bull trout and westslope cutthroat trout which are known to inhabit the upper reaches of Meadow Creek. After closure and reclamation, restoration of Meadow Creek over the TSF/TSF Buttress would restore habitat, but a fish barrier would remain in place and access to upstream habitat would keep the upstream populations isolated.

The loss of existing fish habitat in the YPP lake may constitute as an irretrievable commitment of resources.

7.6.3 Johnson Creek Route Alternative

Under the Johnson Creek Route Alternative, the irreversible and irretrievable commitment of fish and aquatic resources would be the same as that described for the 2021 MMP because the impacts to fish and aquatic habitat are primarily associated with activity at the mine site.

7.7 Summary

For fish and aquatic habitat, the important factors involve the removal and placement of barriers such as the Yellow Pine Pit and TSF/TSF Buttress (which affect species differently), the modifications in surface water management and flows at the mine site, fish access through the East Fork SFSR fishway, and stream channel restoration effects on stream temperature. The principal difference between alternatives is associated with the risk of transportation-related spills along access routes. Under the 2021 MMP, during construction, 11.5 miles of the transportation route would be within 100 feet of streams but would be reduced to 6.69 miles of route within 100 feet of streams once the Burntlog Route was constructed. The Johnson Creek Route Alternative would have 11.5 miles of transportation route within 100 feet of streams for the duration of the SGP.

Reclamation and stream restoration activities post-closure generally improve habitat conditions compared to the operational period as flows and channels are re-established. However, stream temperatures are increased in restored stream channels until revegetation establishes to provide riparian shading for the streams.

Individual fish would be affected by dewatering, salvage, and relocation due to modification of stream channels and dewatering of the existing Yellow Pine pit lake. Fish salvage would be required for dewatering and all in-water work at stream crossings in all fish-bearing water bodies. Management of individuals affected would be conducted under the Fisheries and Aquatic Resources Mitigation Plan and Fishway Operations Management Plan.

Alterations to mine area surface streams including the elimination of the Yellow Pine pit lake, construction of the East Fork SFSR fish tunnel, and removal of existing barriers would alter fish occupancy and available habitat during construction and operations primarily by allowing fish access to portions of the East Fork SFSR and relocating the barrier on Meadow Creek upstream.

During operations summer maximum stream water temperatures in Meadow Creek and the East Fork South Fork would decrease due to diversion of Meadow Creek around the TSF and TSF Buttress. Upon closure and routing of Meadow Creek to the restored stream channel on top of the reclaimed TSF, summer maximum stream temperatures would increase due to the time needed for revegetation to result in riparian shading of the stream. Over time, summer maximum stream temperatures would decline to near or below baseline conditions.

Changes in water chemistry due to mining activities would not negatively affect fish because predicted concentrations for key constituents are comparable or lower than existing conditions. Effects of spills, sedimentation, and turbidity on water quality would be managed through Forest Service requirements and project design features to minimize these effects.

Stream flow reductions would affect fish productivity during operations, but productivity would return toward existing conditions as stream flows recover over time. Post-closure stream flows and productivity would decrease in Meadow Creek and the East Fork SFSR upstream from Meadow Creek by approximately 1 percent and 2 percent, respectively due to hydrological and physical changes associated with the project. Flows and productivity in the East Fork SFSR downstream from Meadow Creek would return to existing conditions post-closure.

The combination of physical stream channel changes, direct effects to individuals, and changes to many of the WCIs (e.g., temperature, stream flow) would affect Chinook salmon and habitat in the analysis area. SGP activities that would potentially cause these impacts include, but are not limited to, new road construction, transportation including hazardous materials, stream diversions, and construction and operation activities at the mine site. These effects may cause injury or mortality to individuals and temporarily or permanently displace Chinook salmon from several mine site streams during certain periods when habitat conditions become unsuitable. This would cause a temporal loss of habitat. Following closure and reclamation, the overall net effect from the SGP would be a net increase in available habitat; however, flows and temperatures would make the additional habitat less optimal.

There would be similar operational period effects on steelhead trout, bull trout, and westslope cutthroat trout. Effects for trout species differ from Chinook salmon following closure and reclamation, as there would be a net increase in both the quantity and quality of habitat for steelhead trout and net decreases in both quantity and quality of habitat for bullhead trout and westslope cutthroat trout.

Table 7-23 provides a summary comparison of fish and aquatic resource impacts by issues.

Table 7-23 Comparison of Fisheries and Aquatic Habitat Impacts by Alternative

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
The SGP may cause changes in fish habitat in the analysis area that may affect aquatic species, including federally listed fish species and aquatic habitat (e.g., Critical Habitat within and downstream from the SGP area.	Direct Impacts to Individuals	No mining related activities.	No change from Baseline	Individuals would be affected by dewatering, salvage, and relocation due to modification of stream channels and the dewatering of the Yellow Pine Pit lake.	Same as 2021 MMP.
	Altered Physical Stream Structure	No mining related activities.	No change from Baseline	Diversion of stream channels, elimination of the Yellow Pine Pit lake, the fish tunnel, and new barriers would affect fish occupancy and habitat during construction and operations.	Same as 2021 MMP.
	Changes to Water Temperature WCI	No mining related activities.	No change from Baseline	During operations summer maximum stream water temperatures in Meadow Creek and the East Fork South Fork would decrease by up to 3.7°C due to diversion of Meadow Creek around the TSF and TSF Buttress. Upon closure and routing of Meadow Creek to the restored stream channel on top of the reclaimed TSF, summer maximum stream temperatures would increase by up to 6.8°C due to the time needed for revegetation to result in riparian shading of the stream. Over time, summer maximum stream temperatures would decline to near or below baseline conditions except for the Meadow Creek upstream from East Fork Meadow Creek which would remain 1.1°C above existing conditions.	Same as 2021 MMP.

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Sediment and turbidity from construction of temporary roads and transmission lines	No mine-related traffic on existing Forest Service Roads	No change from Baseline	Access road roads would cross 43 streams and transmission lines would cross 37 streams. **Construction:** 6.5 miles (18% of routes) would be within 100 feet of streams. **Operations:** 1.56 miles (4% of routes) would be within 100 feet of streams. Sedimentation and fugitive dust predicted to be within normal range of properly maintained Forest Service roads.	Same as 2021 MMP except 6.5 miles of stream would be within 100 feet of streams during operations.
	Change in Access to fish habitat through culverts from road construction	Use of existing roads and culverts	No change from Baseline	Culvert replacements on the Burntlog Route may increase or re-establish habitat access for native and non-native species.	No change from Baseline
	Change in amount of stream habitat by barrier removal and new barriers	Existing barriers in place	No change from Baseline	Removal of the box culvert in the East Fork SRSR would provide additional access to around 6 km of IP habitat for Chinook salmon and steelhead, with the removal of the barrier at the YPP lake cascade adding more than an additional 2.5 km for Chinook salmon. Removal of these barriers will provide access to nearly 33 km of habitat for bull trout and westslope cutthroat trout. Removal of barriers in the downstream end of Fiddle Creek would provide an additional 2 km of habitat for bull trout and westslope cutthroat trout. Creation of a partial gradient barrier in East Fork Meadow Creek would provide additional access to habitat for bull trout and westslope cutthroat trout. The removal and addition of barriers in Meadow Creek would ultimately result in a reduction in access to the Meadow Creek headwaters.	Same as 2021 MMP.

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Changes to Chemical Contaminants Associated with Spills	No mining related activities.	No change from Baseline	Effects of spills would be managed via application of Forest Service requirements and project design features to minimize effects.	Same as 2021 MMP. Effects from spills would be potentially more significant because 6.5 miles of the permanent access road would be within 100 feet of streams during operations.

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Changes to Chemical Contaminants Associated with Mining Activity	**TSF Area** Aluminum: No exceedance Copper: No exceedance Antimony: 0.001 mg/L to 0.025 mg/L Arsenic: 0.004 mg/L to 0.075 mg/L Mercury: 1 ng/L to 2 ng/L **East Fork SFSR Downstream from SGP** Aluminum: No exceedance Copper: No exceedance Antimony: 0.0052 mg/L to 0.025 mg/L Arsenic: 0.014 mg/L to 0.076 mg/L Mercury: 3.2 ng/L to 9.6 ng/L	No change from Baseline	**TSF Area** Aluminum: No exceedance Copper: No exceedance Antimony: 0.001 mg/L to 0.014 mg/L Arsenic: 0.001 mg/L to 0.018 mg/L Mercury: 1 ng/L to 2 ng/L **East Fork SFSR Downstream from SGP** Aluminum: No exceedance Copper: No exceedance Antimony: 0.003 mg/L to 0.016 mg/L Arsenic: 0.010 mg/L to 0.066 mg/L Mercury: 3.0 ng/L to 10.0 ng/L Increased seasonal peaks in mercury concentrations would be 1 to 3 ng/L above existing conditions in the mine area but below applicable water quality standards (12 ng/L). The effects of mercury concentrations on methylated mercury concentrations in the mine site area are comparable to existing conditions based on site-specific ratios of methylmercury to mercury concentrations (up to 2%). Effects of differences in peak mercury concentrations on downstream mercury methylation have not been quantified.	Same as 2021 MMP.

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Changes in Stream Flow	No mining related activities.	No change from Baseline	East Fork SFSR Upstream from Sugar Creek: Up to 24.8% reduction in flow during operations. No reduction in flow post-closure. East Fork SFSR at Stibnite: Up to 20.4% reduction in flow during operations. No reduction in flow post-closure. East Fork SFSR Upstream from Meadow Creek: Up to 3.8% reduction in flow during operations. Up to 2% reduction in flow post-closure. Meadow Creek: Up to 36.4% reduction in flow during operations. Less than 1% reduction in flow post-closure.	Same as 2021 MMP
	Suitable Habitat Based on Optimal Thermal Requirements for Chinook Salmon	Below Yellow Pine Pit: Adult Migration (15-19˚C): 0 km Adult Migration (12-17˚C): 2.01 km Spawning (13˚C): 0 km Spawning (4-14˚C): 2.01 km Incubation: 0 km Juvenile Rearing: 2.01 km Total Available: 2.01 km Above Yellow Pine Pit: Adult Migration (15-19˚C): 2.43 km	No Change from Baseline	**Middle of Operations:** Below Yellow Pine Pit: Adult Migration (15-19˚C): 0 km Adult Migration (12-17˚C): 1.48 km Spawning (13˚C): 0 km Spawning (4-14˚C): 1.48 km Incubation: 0 km Juvenile Rearing: 1.48 km Total Available: 1.48 km Above Yellow Pine Pit: Adult Migration (15-19˚C): 0.25 km Adult Migration (12-17˚C): 3.35 km Spawning (13˚C): 0.28 km Spawning (4-14˚C): 6.85 km Incubation: 3.50 km Juvenile Rearing: 10.94 km Total Available: 10.94 km **Post-Closure:** Below Yellow Pine Pit:	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
		Adult Migration (12-17˚C): 7.48 km Spawning (13˚C): 1.51 km Spawning (4-14˚C): 10.92 km Incubation: 3.44 km Juvenile Rearing: 10.92 km Total Available: 10.92 km		Adult Migration (15-19˚C): 0 km Adult Migration (12-17˚C): 1.66 km Spawning (13˚C): 0 km Spawning (4-14˚C): 1.66 km Incubation: 0.73 km Juvenile Rearing: 1.66 km Total Available: 1.66 km <u>Above Yellow Pine Pit:</u> Adult Migration (15-19˚C): 0 km Adult Migration (12-17˚C): 6.57 km Spawning (13ºC): 0 km Spawning (4-14ºC): 10.07 km Incubation: 7.39 km Juvenile Rearing: 18.97 km Total Available: 18.97 km	
	Chinook Salmon Flow Productivity	<u>East Fork SFSR Upstream from Sugar Creek:</u> 1.06 <u>East Fork SFSR at Stibnite:</u> 1.06 <u>East Fork SFSR Upstream from Meadow Creek:</u> 1.06 <u>Meadow Creek:</u> 1.06	No change from Baseline	<u>East Fork SFSR Upstream from Sugar Creek:</u> Up to 21.4% reduction during operations. No reduction post-closure. <u>East Fork SFSR at Stibnite:</u> Up to 17.7% reduction during operations. No reduction post-closure. <u>East Fork SFSR Upstream from Meadow Creek:</u> Up to 3.9% reduction during operations. Up to 1.8% reduction post-closure. <u>Meadow Creek:</u> Up to 28.6% reduction during operations. Less than 1% reduction post-closure.	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Chinook Salmon Intrinsic Potential	11.15 km	No change from Baseline	**Operations:** Loss of 3.34 km (30 percent). **Closure:** Gain of 0.28 km (2 percent).	Same as 2021 MMP.
	Chinook Salmon Critical Habitat	East Fork SFSR above Yellow Pine Pit: 25.88 km Meadow Creek: 6.81 km	No change from Baseline	**Operations:** Above Yellow Pine Pit: 25.9 km **Closure:** Above Yellow Pine Pit: 25.9 km	Same as 2021 MMP.
	Suitable Habitat Based on Optimal Thermal Requirements for Steelhead	Below Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 2.01 km Total Available: 2.01 km Above Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 0 km Total Available: 0 km	No Change from Baseline	**Middle of Operations:** Incubation: 0 km Juvenile Rearing: 1.66 km Total Available: 1.66 km Above Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 8.52 km Total Available: 8.52 km **Post-Closure:** Incubation: 0 km Juvenile Rearing: 1.66 km Total Available: 1.66 km Above Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 10.07 km Total Available: 10.07 km	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Steelhead Flow Productivity	East Fork SFSR Upstream from Sugar Creek: 1.24 East Fork SFSR at Stibnite: 1.24 East Fork SFSR Upstream from Meadow Creek: 1.24 Meadow Creek: 1.24	No change from Baseline	East Fork SFSR Upstream from Sugar Creek: Up to 21.1% reduction during operations. No reduction post-closure. East Fork SFSR at Stibnite: Up to 17.6% reduction during operations. No reduction post-closure. East Fork SFSR Upstream from Meadow Creek: Up to 1.8% reduction during operations. No reduction post-closure. Meadow Creek: Up to 29.5% reduction during operations. Less than 1% reduction post-closure.	Same as 2021 MMP
	Steelhead Intrinsic Potential	10.67 km	No change from Baseline	**Operations:** Loss of 2.33 km (22 percent) **Closure:** Gain of 1.77 km (17 percent).	Same as 2021 MMP.
	Steelhead Critical Habitat	No Critical Habitat at mine site. Critical Habitat in proximity to access routes could be affected by spills.	No change from Baseline	No change from Baseline for mine site area. See above for spills summary.	Same as 2021 MMP. See above for spills summary.

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Suitable Habitat Based on Optimal Thermal Requirements for Bull Trout	Below Yellow Pine Pit: Spawning - FA: 0 km Spawning - FR: 0 km Spawning - FUR: 2.01 km Incubation - FA: 0 km Incubation - FUR: 0 km Juvenile Rearing - FA: 2.01 km Juvenile Rearing - FR: 0 km Juvenile Rearing - FUR:2.01km Total Available: 2.01 km Above Yellow Pine Pit: Spawning - FA: 1.62 km Spawning - FR: 7.76 km Spawning - FUR: 14.82 km Incubation - FA: 0 km Incubation - FUR: 24.20 km Juvenile Rearing - FA:12.16 km Juvenile Rearing - FR: 9.60 km Juvenile Rearing – FUR: 2.43 km Total Available: 24.20 km	No Change from Baseline	**Middle of Operations:** Below Yellow Pine Pit: Spawning - FA: 0 km Spawning - FR: 0 km Spawning - FUR: 1.48 km Incubation - FA: 0 km Incubation - FUR: 1.48 km Juvenile Rearing - FA: 0 km Juvenile Rearing - FR: 1.48 km Juvenile Rearing - FUR: 0 km Total Available: 1.48 km Above Yellow Pine Pit: Spawning - FA: 1.42 km Spawning - FR: 6.28 km Spawning - FUR: 8.64 km Incubation - FA: 0 km Incubation - FUR: 16.34 km Juvenile Rearing - FA: 10.35 km Juvenile Rearing - FR: 5.99 km Juvenile Rearing - FUR: 0 km Total Available: 16.34 km **Post-Closure:** Below Yellow Pine Pit: Spawning - FA: 0 km Spawning - FR: 0.05 km Spawning - FUR: 1.61 km Incubation - FA: 0 km	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
				Incubation - FUR: 1.66 km Juvenile Rearing - FA: 0 km Juvenile Rearing - FR: 1.66 km Juvenile Rearing - FUR: 0 km Total Available: 1.66 km <u>Above Yellow Pine Pit:</u> Spawning - FA: 1.42 km Spawning - FR: 6.34 km Spawning - FUR: 8.29 km Incubation - FA: 0 km Incubation - FUR: 16.05 km Juvenile Rearing - FA: 7.76 km Juvenile Rearing - FR: 8.29 km Juvenile Rearing - FUR: 0 km Total Available: 16.05 km	
	Bull Trout Distance Weighted Average Occupancy Probabilities	<u>East Fork SFSR between YPP and Sugar Creek:</u> 15.3% <u>East Fork SFSR between Meadow Creek and YPP:</u> 10.0% <u>East Fork SFSR Upstream from Meadow Creek:</u> 8.4% <u>Meadow Creek:</u> 5.7%	No change from Baseline	<u>East Fork SFSR between YPP and Sugar Creek:</u> 12.4% - 22.6% during operations. 16.1% post-closure. <u>East Fork SFSR between Meadow Creek and YPP:</u> 12.4% - 15.2% during operations. 14% post-closure. <u>East Fork SFSR Upstream from Meadow Creek:</u> 8.5% - 9.6% during operations. 9.7% post-closure. <u>Meadow Creek:</u> 6.7% - 7.8% during operations. 8.7% post-closure.	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Bull Trout Length of Available Habitat for Potential Occupancy	East Fork SFSR between YPP and Sugar Creek: 1.2 km East Fork SFSR between Meadow Creek and YPP: 6.5 km East Fork SFSR Upstream from Meadow Creek: 13.1 km Meadow Creek: 13.1 km	No change from Baseline	East Fork SFSR between YPP and Sugar Creek: 0.5 – 0.7 km during operations. 0.7 km post-closure. East Fork SFSR between Meadow Creek and YPP: 5.6 – 7.8 km during operations. 8.1 km post-closure. East Fork SFSR Upstream from Meadow Creek: 13.1 – 13.9 km during operations. 13.1 km post-closure. Meadow Creek: 6.8 - 7.4 km during operations. 14.0 km post-closure.	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Suitable Habitat Based on Optimal Thermal Requirements for Westslope Cutthroat Trout	Below Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 2.01 km Total Available: 2.01 km Above Yellow Pine Pit: Incubation: 0.85 km Juvenile Rearing: 20.91 km Total Available: 24.20 km	No Change from Baseline	**Middle of Operations:** Below Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 1.48 km Total Available: 1.48 km Above Yellow Pine Pit: Incubation: 0.78 km Juvenile Rearing: 17.33 km Total Available: 18.11 km **Post-Closure:** Below Yellow Pine Pit: Incubation: 0 km Juvenile Rearing: 1.66 km Total Available: 1.66 km Above Yellow Pine Pit: Incubation: 2.11 km Juvenile Rearing: 21.65 km Total Available: 23.77 km	Same as 2021 MMP

Issue	Indicator	Baseline Conditions	No Action	2021 MMP	Johnson Creek Route Alternative
	Westslope Cutthroat Trout Distance Weighted Average Occupancy Probabilities	East Fork SFSR Upstream from between YPP and Sugar Creek: 68.0% East Fork SFSR between Meadow Creek and YPP: 64.2% East Fork SFSR Upstream from Meadow Creek: 64.3% Meadow Creek: 63.9%	No change from Baseline	East Fork SFSR Upstream from between YPP and Sugar Creek: 65.5% - 70.2% during operations. 67.7% post-closure. East Fork SFSR at Stibnite: 65.0% - 66.5% during operations. 65.4% post-closure. East Fork SFSR between Meadow Creek and YPP: 64.4% - 64.8% during operations. 64.8% post-closure. Meadow Creek: 64.6% - 65.1% during operations. 66.3% post-closure.	Same as 2021 MMP
	Westslope Cutthroat Trout Length of Available Habitat for Potential Occupancy	East Fork SFSR between YPP and Sugar Creek: 1.2 km East Fork SFSR between Meadow Creek and YPP: 6.7 km East Fork SFSR Upstream from Meadow Creek: 13.1 km Meadow Creek: 13.1 km	No change from Baseline	East Fork SFSR between YPP and Sugar Creek: 0.5 – 0.7 km during operations. 0.8 km post-closure. East Fork SFSR between Meadow Creek and YPP: 5.6 – 7.8 km during operations. 8.1 km post-closure. East Fork SFSR Upstream from Meadow Creek: 13.1 – 13.9 km during operations. 13.1 km post-closure. Meadow Creek: 6.8 - 7.4 km during operations. 14.0 km post-closure.	Same as 2021 MMP

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Life History, Ecology and Population Status of Migratory Bull Trout (*Salvelinus confluentus*) in the Flathead Lake and River System, Montana

Abstract

Life history, ecology, and population trends of migratory bull trout (*Salvelinus confluentus*) were investigated in the Flathead Lake and River system of northwest Montana and southeast British Columbia. We conducted these studies to obtain information to manage the species in light of threats posed by timber harvest, hydropower development, and a proposed coal mine. We estimated that about half the adult bull trout in Flathead Lake embarked on a spawning migration from May through July, swimming 88-250 km to reach tributaries of the North and Middle Forks of the Flathead River. Bull trout entered the tributaries when water temperatures dropped below 12°C, and spawned from late August through early October after water temperatures were below 9°C. They spawned in areas of tributaries with low gradient, loosely compacted gravel, groundwater influence, and cover. After spawning, females left the tributaries and returned to the lake sooner than males. Most spawners were six or seven years old and they averaged 628 mm in length. Juveniles were found close to the substrate in streams with summer maximum temperatures less than 15°C. Juveniles migrated out of the tributaries to the river system from June through August, at age I (18%), II (49%), III (32%), and IV (1%). Population status was monitored through redd counts and estimates of juvenile abundance in natal tributaries. The population may be limited by quantity and quality of rearing and spawning habitat, and spawning escapement. Specific requirements for spawning and rearing habitat, and general sensitivity of each life stage, make the bull trout an excellent indicator of environmental disturbance.

Introduction

The bull trout (*Salvelinus confluentus*) is the largest species of fish native to the Flathead drainage, attaining a length of nearly one meter and a weight of 10 kg. The bull trout inhabiting the inland waters of northwestern North America is considered a separate species from the smaller, coastal Dolly Varden (*Salvelinus malma*) (Cavender 1978). The bull trout population in the Flathead system is largely migratory, growing to maturity in lakes and migrating through the river system and into the tributaries to spawn. Juveniles live in tributary streams from one to four years before migrating to the lakes.

Much information has been published concerning the life history of coastal Dolly Varden (e.g., Blackett 1968, Armstrong and Morton 1969, Armstrong and Morrow 1980, Balon 1980). Published information on the bull trout is limited. McPhail and Murray (1979), Leggett (1969), and Allan (1980) studied various aspects of the life history of bull trout in British Columbia and Alberta. Gould (1987) described the characteristics of larval bull trout.

The Montana Department of Fish, Wildlife and Parks has studied the bull trout population in the Flathead drainage since 1953 (Block 1955, Hanzel 1976). More intensive work was undertaken from 1979-1984 during the EPA-sponsored Flathead River Basin Studies (Graham *et al.* 1980, Fraley *et al.* 1981, Shepard *et al.* 1982, 1984b, Graham *et al.* 1982, Fraley and Graham 1982, Graham and Fredenberg 1982, Leathe and Graham 1982). We studied bull trout age and growth both in the lake and in the river system, harvest by anglers, the adult spawning migration, spawning site selection and use, and the densities, habitat selection, and emigration of juveniles growing in tributaries. Methods included tagging, gillnetting, stream trapping and electrofishing, creel survey, otolith and scale analysis, redd counts, and substrate analysis (Graham and Fredenberg 1982, Shepard and Graham 1983).

In this paper we summarize our findings on the life history, ecology, and population status of adfluvial bull trout in the Flathead Lake and inlet river system and compare our information to the results of other investigators.

Study Area

The Flathead Lake and River system is a headwater drainage of the Columbia River Basin (Figure 1). Flathead Lake is a large oligomesotrophic lake with a surface area of 476 km² and a mean depth of 32.5 m (Potter 1978). The upper 3 m of Flathead Lake is regulated by Kerr Dam, constructed on the outlet in 1938. The Flathead River enters the north end of the lake. This study

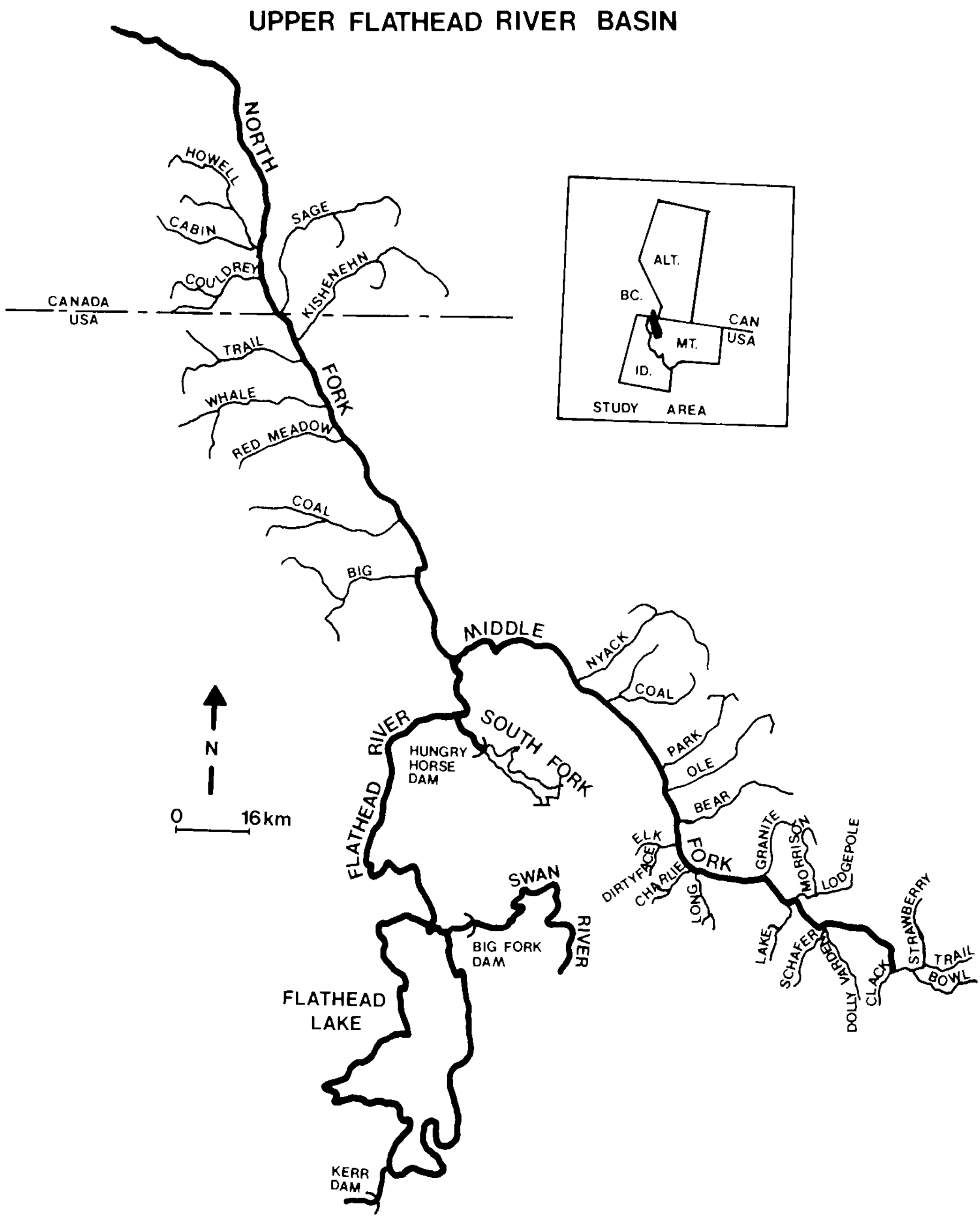

Figure 1. The upper Flathead River Basin. The 28 tributaries shown were used by spawning bull trout.

was conducted in the upper Flathead Basin which includes Flathead Lake and the river system upstream from Flathead Lake.

The South, Middle and North forks drain areas of approximately equal size in portions of the Great Bear and Bob Marshall wildernesses, Glacier National Park and the Flathead National Forest. The upper North Fork drains southern British Columbia. The South Fork is regulated by Hungry Horse Dam, located 8 km above its mouth. The Swan River enters Flathead Lake near the mouth of the Flathead River. Bull trout coexist with 23 other species of fish in the Flathead Lake and River system (Leathe and Graham 1982).

Most bull trout that spawn in the North and Middle Fork drainages mature in Flathead Lake, but fish maturing in large lakes of Glacier National Park may spawn in some tributaries. There are a few populations of bull trout in tributaries of the North Fork that spend their entire lives in the streams.

Bull trout originally used the tributaries of all forks of the Flathead and the Swan rivers. The construction of Bigfork Dam in 1902 blocked bull trout migrations into the Swan River. Limited numbers of bull trout move downstream from the Swan drainage via a marginal fish ladder, as evidenced by tag returns. Hungry Horse Dam, a 164.6-m structure which was closed in 1951, blocked all movements of bull trout into the South Fork drainage and probably resulted in a substantial reduction of the population in Flathead Lake.

The 28 tributaries used by spawning bull trout in the North and Middle Fork drainages (Figure 1) are characterized by gravel-rubble substrate, low flows of 0.057-1.70 m^3/sec, and maximum summer water temperatures less than 15°C.

Results and Discussion

Life History

Lake Residence

Bull trout populations residing in Flathead Lake were found to include recently arrived juveniles from the Flathead River system, subadult fish less than about 450 mm in length, and mature fish five to six years or more in age. Most bull trout in Flathead Lake matured at age VI. A similar age of maturity was reported for bull trout in Arrow Lakes, British Columbia (McPhail and Murray 1979).

The diet of bull trout in the lake consisted almost exclusively of fish. Whitefish species and yellow perch (*Perca flavescans*) were the most important food items, followed by kokanee (*Oncorhynchus nerka*) and nongame species (Table 1). Small bull trout have been found to feed incidentally on *Mysis* in Flathead Lake. *Mysis relicta* was discovered in Flathead Lake in 1981 and densities increased dramatically through 1986. Kokanee were the major food item for bull trout in Pend Oreille Lake, Idaho (Jeppson and Platts 1959), while whitefish were the major food in Upper Priest Lake (Bjornn 1961).

The annual growth increment for bull trout in Flathead Lake, based on analysis of scales, ranged from 60-132 mm (Table 2). Back calculations of length at annulus formation were made from 1,813 scale samples. Aging was checked with otoliths from 451 of the fish. Agreement of aging between otoliths and scales ranged from 100 percent for fish zero to three years of age, to 52 percent for older, mature fish. Growth of lake-resident fish was relatively constant after age IV. Growth rates of bull trout in Flathead Lake were similar to those reported for Priest and Upper Priest Lakes, Idaho (Bjornn 1961).

Not all mature bull trout spawned annually. Adult-size fish were relatively less abundant in the lake during the summer and fall, as compared to the spring. It appeared that 38 to 69 percent (average 57%) left the lake each spring and summer to spawn. The frequency of successive year spawning varied by age and sex (Leathe and Graham 1982). Alternate year spawning has been reported for inland Dolly Varden char (Armstrong and Morrow 1980).

Upstream Migration

Bull trout maturing in Flathead Lake began their spawning migration into the river system during April and moved slowly upstream, arriving in the North and Middle forks during late June and July. They traveled more than 250 km to spawn in some North Fork tributaries in British Columbia. The shortest distance traveled from Flathead Lake was 88 km to the mouth of Canyon Creek in the North Fork drainage. Observations and tag returns from 1974-1982 indicated that adult bull

TABLE 1. Composition by number, weight, and frequency of occurrence and calculated index of relative importance (IRI, George and Hadley 1979) for major food items in the stomachs of 95 bull trout collected between November and January, 1979, 1980 and 1981 in Flathead Lake.

Item	Number	(%)	Wet weight -g.	(%)	Index of Relative Importance (IRI)
Pygmy whitefish	5	(2.4)	37.0	(4.0)	3.2
Lake whitefish	1	(0.5)	104.1	(11.2)	4.3
Mountain whitefish	1	(0.5)	24.3	(2.6)	4.4
Unidentified whitefish	11	(5.3)	281.2	(30.3)	15.0
Total whitefish	18	(8.7)	446.6	(48.1)	23.5
Kokanee	2	(1.0)	82.8	(8.9)	4.0
Unidentified trout/salmon	2	(1.0)	13.2	(1.4)	1.5
Total trout/salmon	4	(1.9)	96.0	(10.3)	5.1
Sculpin	3	(1.5)	7.6	(0.8)	1.8
Redside shiner	5	(2.4)	15.0	(1.6)	2.0
Peamouth	1	(0.5)	3.6	(0.4)	0.7
Sucker	2	(1.0)	74.4	(8.0)	3.7
Yellow perch	83	(40.3)	105.1	(11.3)	24.6
Total nongame	94	(45.6)	205.7	(22.1)	31.0
Unidentified fish	90	(43.7)	181.1	(19.5)	41.4

TABLE 2. Back calculated lengths at annulus formation of bull trout in the upper Flathead Basin (n in parentheses). Calculations were made based on methods in Hesse (1977).

Drainage	Total length (mm) at annulus								
	I	II	III	IV	V	VI	VII	VIII	IX
Adults and Juveniles									
Upper Flathead (1968-81)	66 (1,813)	121 (1,538)	196 (1,161)	292 (927)	385 (669)	475 (349)	566 (129)	657 (32)	731 (4)
Flathead Lake (1968-8I)	68 (931)	129 (931)	204 (928)	291 (853)	384 (603)	472 (291)	566 (102)	658 (28)	731 (4)
North Fork of the Flathead River drainage (1975-81)	73 (533)	117 (306)	165 (60)	301 (12)	440 (8)	538 (7)	574 (3)	— —	— —
Middle Fork of the Flathead River drainage (1980-81)	52 (349)	100 (300)	165 (172)	297 (61)	399 (57)	488 (50)	567 (24)	655 (4)	
Juveniles Only									
North Fork drainage	73 (525)	117 (298)	155 (52)	228 (4)	—	—	—	—	—
Coal Creek	75 (145)	124 (62)	202 (23)	323 (14)	—	—	—	—	—
Red Meadow Creek	65 (145)	113 (113)	168 (29)	360 (7)	—	—	—	—	—
Trail Creek	74 (473)	119 (264)	158 (46)	228 (4)	—	—	—	—	—
Whale Creek	56 (52)	98 (34)	139 (6)	—	—	—	—	—	—

trout remained at the mouths of spawning tributaries for two to four weeks during which time feeding was thought to be limited.

Based on observations at stream trapping sites, adult bull trout entered tributary streams at night from July through September; the majority entered in August. Because most bull trout moved through the traps in pairs, we believe bull trout formed pairs near the mouth of the spawning tributary. Bull trout which entered the spawning tributaries were generally not in final spawning condition, but held in the tributaries for up to a month or more in deeper holes or near log or debris cover before spawning. Similar prespawning behavior and spawning timing was reported for bull trout in Mackenzie Creek (McPhail and Murray 1979) and John Creek (Leggett 1969) in British Columbia.

Most bull trout spawners in the North and Middle Forks were six or seven years of age (Table 3) whereas most spawners in the Swan system were five or six years old (Leathe and Enk 1985).

TABLE 3. Age of bull trout spawners in the Flathead system.

Stream	Percent by Age				
	5	6	7	8	9
North Fork Flathead River 1954 (N = 41)	24	39	34	3	0
Middle Fork Flathead River 1981 (N = 31)	10	48	35	10	0
Swan River 1983 (N = 57)	33	35	23	9	<1
Swan River 1984 (N = 76)	43	37	17	3	0

Spawning

Most bull trout spawned during September and early October in the Flathead River system, as did adfluvial bull trout in Idaho (Heimer 1965) and British Columbia (McPhail and Murray 1979). Initiation of spawning in the Flathead appeared to be related largely to water temperature, although photoperiod and streamflow probably also played a part. Spawning began when water temperatures dropped below 9-10°C. McPhail and Murray (1979) reported that 9°C was the threshold temperature for the initiation of spawning in Mackenzie Creek, British Columbia.

Bull trout spawners selected areas in the stream channel characterized by gravel substrates, low compaction and low gradient (Table 4). Groundwater influence and proximity to cover also were important factors influencing spawning site selection. These relatively specific requirements resulted in a restricted distribution of spawning in the Flathead drainage. Bull trout from Flathead Lake spawned in only 28 percent of the 750 km of available stream habitat according to basin-wide surveys from 1980-1982.

TABLE 4. Mean measurements of physical habitat variables in 34 stream reaches where no redds were located, 29 reaches where redd frequency averaged 1.2 redds/km (low), and 31 reaches where redd frequency averaged 6.9 redds/km (high).

Parameter	Redd frequency categories		
	None	Low	High
Stream order	3.0	3.1	3.6
D-90 (cm; the size of material larger than 90% of the substrate)	51	37	33
Gradient (percent)	3.2	1.8	1.5
Boulder (percent of substrate)	16	12	10
Gravel-Cobble (combined percent of substrate)	54	62	62
High quality pool (percent of stream)	5	7	8
Overhang cover (percent)	14	10	11
Total cover (percent)	16	15	13

Average length of adult spawners in the Flathead River system was 628 mm (Table 5). The female chose a spawning site and constructed the redd, while the male defended the area. Male bull trout in Trail Creek, a North Fork tributary,

TABLE 5. Average total lengths of adult bull trout spawners in the Flathead drainage.

Stream	Year	Average Length (mm)	Number of Fish
North Fork	1979	638	36
	1977	645	32
	1953	617	165
Middle Fork	1980	618	35
	1957	622	87
Both Forks	1975	628	46

remained near the redd an average of two weeks after spawning. Bull trout redds in the Flathead drainage averaged 2.0 m long x 1.0 m wide, and sometimes overlapped. Block (1955) observed one male spawn with three females in succession; the size of the redd expanded each time. McPhail and Murray (1979), Leggett (1969), and Block (1955) provided detailed descriptions of spawning behavior and spawning site activities. After spawning, the spent adults moved out of the tributaries and downstream to the lake, possibly feeding on mountain whitefish (*Prosopium williamsoni*) during the journey.

Fecundity varied with fish size, averaging 5,482 eggs per female for a sample of 32 adults averaging 645 mm. One female bull trout weighed 15 pounds and contained 12,000 eggs. Bull trout in Arrow Lakes, British Columbia, were smaller and contained fewer than 2,000 eggs per female (McPhail and Murray 1979). The sex ratio of bull trout spawners averaged 1.4 females per male in Trail Creek in the North Fork drainage, and 1.37 females per male in the Swan drainage.

Incubation and Emergence

After deposition by early October, bull trout embryos incubated in the redd for several months before hatching in January. The alevins then remained in the gravel and absorbed the yolk sac, with the first fry appearing in electrofishing samples in mid April. Emergence occurred approximately 200 days after egg deposition. Newly emerged fry averaged 23-28 mm and more than doubled their length during the first summer of growth (see Table 2).

Weaver and White (1985) found that incubation time was dependent on temperature. Bull trout eggs required 113 days (340 temperature units) to 50 percent hatch in Coal Creek, a tributary of the North Fork of the Flathead River. The fry emerged from the gravel 223 days (635 temperature units) after egg deposition. Intergravel temperatures during the incubation period (October-March) in Coal Creek ranged from 1.2-5.4°C. Survival to emergence in Coal Creek averaged 53 percent. McPhail and Murray (1979) reported the best survival of bull trout embryos at 2-4°C.

Juvenile Occurrence and Emigration

Juvenile bull trout were present in about half of the stream reaches surveyed during studies in the upper Flathead River Basin. Juveniles were present in many reaches that were not used by adult spawners; they apparently swam upstream to these sections to grow. Distribution also was influenced by water temperature as juvenile bull trout were rarely observed in streams with summer maximum temperatures exceeding 15°C. Oliver (1979), Allan (1980) and Pratt (1984) also reported that bull trout distribution was affected by temperature.

Young-of-the-year bull trout were generally found in side channel areas and along the stream margins in Flathead tributaries. Blackett (1968) reported a similar habitat preference for juvenile Dolly Varden char in southeast Alaskan streams. McPhail and Murray (1979) found young-of-the-year bull trout in areas of low velocity near stream edges.

Densities of bull trout juveniles in Flathead tributaries were greatest in pools, and lower but generally similar in runs, riffles and pocketwater habitat. Juvenile bull trout were found closely associated with stream substrate. Pratt (1984) studied microhabitat preferences in the Flathead drainage and reported that juvenile bull trout (less than 100 mm) usually remained near the stream bottom, close to streambed materials and submerged fine debris. Juveniles 100 mm or longer also remained near cover, including larger instream debris. As the juvenile bull trout grew, they became less associated with the streambed.

During stream residence, juvenile bull trout were opportunistic feeders, mainly ingesting aquatic invertebrates (especially Diptera and Ephemeroptera) in similar percentages as they were available in the stream (Fraley *et al.* 1981). Bull trout larger than 110 mm also ate small trout and sculpin.

Snorkeling estimates of juvenile bull trout densities in Flathead drainage tributaries averaged 1.5 fish/100 m^2 of stream surface area (range: 0.1-7.1). Juvenile bull trout are difficult to observe because of their close association with the stream bottom, so these numbers are probably underestimates. Electrofishing estimates ranged as high as 15.5 fish/100 m^2 in certain streams.

Most juvenile bull trout in the Flathead drainage remained in the tributaries for one to three years before emigrating to the river system. Of 246 juvenile bull trout captured in downstream migrant traps placed in three tributaries to the North and Middle forks, about half (49%) were age II, a third (32%) age III, and 18 percent age I (Table 6). Only 1 percent of the emigrants were age IV. The ages of emigrating juveniles were similar in Idaho and British Columbia (Bjornn 1961, Oliver 1979, McPhail and Murray 1979). The average lengths at annulus formation of Age I, II, and III juvenile bull trout in tributaries of the North Fork Flathead were 73, 117 and 155 mm, respectively (Table 2).

TABLE 6. Percent and number of age I, II, III and IV bull trout emigrating from tributary streams.

Location	Years of migration sampling	Age Classes			
		I	II	III	IV
Red Meadow Cr.	1973, 79	6 (3)	76 (42)	18 (10)	0 (0)
Trail Creek	1977, 79	34 (41)	43 (52)	19 (23)	3 (4)
Geifer Creek	1981	0 (0)	37 (26)	63 (45)	0 (0)
All Sites	(%) (number)	18 (44)	49 (120)	32 (78)	1 (4)

Emigration of juveniles from the tributaries into the Flathead River system took place largely from June through August (Table 7), similar to the emigration period reported for the Wigwam drainage, British Columbia (Oliver 1979). After juvenile bull trout entered the river system they appeared to move rapidly downstream into the main stem Flathead River, arriving below the South Fork during August and September. Although juvenile bull trout were captured by electrofishing in the main stem throughout the year, their numbers peaked during the fall months (McMullin and Graham 1981). Snorkel observations indicated that some juveniles lived along the shallow margins of the Middle and North forks. Residence in the lower Flathead River before entry into Flathead Lake has not been well documented.

Trends in Spawner Abundance

Drainage-wide counts of bull trout redds in 1980 (568), 1981 (714), 1982 (1138), and 1986 (814) were used to index the number of adfluvial bull trout which successfully spawned in the river-tributary system. We converted the redd counts to approximate fish numbers by making the following assumptions: 1) 75 percent of all redds were located, and 2) an average of 3.2 spawners entered the tributary for each completed redd. From partial trapping results on several tributaries in 1977-1981, we estimated a spawner:redd ratio of 3.2:1. In 1953, 55 bull trout entered Trail Creek and constructed 18 redds for a spawner:redd ratio of 3.2:1 (Block 1955). During 1954, 160 bull trout constructed 48 redds in Trail Creek, yielding a ratio of 3.3:1. Based on these assumptions, we calculated that an average of 3,450 bull trout successfully spawned annually in the Flathead drainage during our period of record.

Bull trout spawned in 28 tributaries to the North and Middle forks (see Figure 1), but only a small percentage of the stream reaches were used for spawning. Important spawning tributaries in the North Fork were Howell, Trail, Whale, Big and Coal creeks. Major spawning tributaries in the Middle Fork were Morrison-Lodgepole, Granite, Ole, Trail and Dolly Varden creeks. The portion of the drainage in Canada supported 23-31 percent (mean 29%) of the spawning in the North Fork drainage during the 1980-82 period. Howell Creek supported 13-19 percent (mean 16%) of all North Fork spawning.

Monitoring of bull trout spawning at selected sites indicated that escapement was highest in 1982 (Table 8). These sites are considered representative of the drainage, and comprised 32, 30, 31, and 43 percent of the total drainage-wide counts in 1980, 1981, 1982, and 1986, respectively. Monitoring areas reflected drainage-wide trends.

Juvenile bull trout densities have been used as an index of population status. Juvenile bull trout populations in sections of Coal and Morrison creeks have been monitored for a six-year period (Table 9). Numbers of juvenile bull trout in these sections were highest in 1987 for both streams. Continued population estimates in these streams will provide valuable baseline information for future monitoring.

Sampling for bull trout in Flathead Lake indicated that the population had been relatively stable through 1981. Average catches of bull trout in sinking nets were 1.2 to 2.1 fish per net

TABLE 7. Number of stream trapping days, number of juvenile bull trout passed downstream through traps, and number of trapped juvenile bull trout per trap day by month from North Fork tributaries during 1976 to 1980 and Middle Fork tributaries during 1981.

	June	July	August	September	October
North Fork tributaries (1976-1980)					
Trap days	42	443	424	264	131
Number of fish	42	709	340	116	6
Fish/trap day	1.00	1.60	0.80	0.44	0.04
Middle Fork tributaries (1981)					
Trap days	43	74	62	14	—
Number of fish	60	28	19	8	—
Fish/trap day	1.40	0.38	0.26	0.57	—

TABLE 8. Bull trout redd counts for selected areas of tributaries chosen for monitoring in the Flathead Drainage.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
North Fork:										
Big	10	20	18	41	22	9	9	12	22	19
Coal	38	34	23	60	73	61	40	13	48	52
Whale	35	45	98	211	141	133	94	90	143	136
Trail	34[a]	31[a]	78	94	56	32	25	69	64	62
Total North Fork	117	130	217	406	292	235	168[b]	184	277	269
Middle Fork:										
Morrison	25[a]	75	32[a]	86	67	38	99	52	49	50
Granite	14	34	14[a]	34	31	47	24	37	34	32
Lodgepole	32	14	18	23	23	23	20	42	21	19
Ole		19	19	51	35	26	30	36	45	59
Total Middle Fork	71	142	83	194	156	134	173[b]	167	149	160
Total Drainage Monitoring Areas	188	272	300	600	448	369	341	351	426	429

[a]Counts may be underestimated due to incomplete survey.
[b]High flows may have obliterated some of the redds.

TABLE 9. Juvenile bull trout densities in sections of a North Fork tributary (Coal Creek) and a Middle Fork tributary (Morrison Creek) from 1980-1985.

	Date	Population Estimate (Number/150 m section)	95% Confidence Interval
Coal Creek (at Deadhorse Bridge)	08/05/82	130	±36
	03/23/83	99	±33
	08/31/84	89	±27
	08/26/85	167	±66
	08/12/86	149	±45
	09/01/87	179	±55
Morrison Creek	09/23/80	91	±48
	09/01/82	93	± 5
	08/18/83	62	±11
	09/25/85	93	±27
	08/27/86	114	±15
	08/25/87	138	±10
	08/30/88	126	±23

in 1967-1970, 2.2 to 2.9 fish per net in 1980-81 (Leathe and Graham 1982). Average length of bull trout sampled in Flathead Lake increased by 24 mm from 1967 to 1980. A larger percentage of the fish were greater than 500 mm in the 1980-81 sampling period. The percentage of trophy fish (greater than 634 mm) was similar in both sampling periods. Migrating spawners, captured in the river system, were similar in size from 1953 through 1981 (see Table 5).

Sensitivity to Environmental Disturbance

All bull trout life stages are sensitive to environmental disturbances. The population in the Flathead system is threatened by several major forms of resource development. The proposed Cabin Creek coal mine in the North Fork drainage in British Columbia received preliminary approval by the Canadian government and was referred by the U.S. and Canadian governments to an International Joint Commission for review (Flathead International Study Board 1988). This mining activity could harm bull trout spawning and rearing habitat in the upper North Fork and in Howell Creek, the major spawning tributary in the Canadian portion of the drainage. The major concerns are increased sedimentation, alteration of flow and water quality degradation (Biological Resources Committee 1987). In addition, timber harvest and road construction in both the North and Middle Fork drainages are potential threats to bull trout spawning and rearing habitat.

Increased fishing pressure is often associated with resource development. Because of the restricted distribution of bull trout spawning in the basin and the limited size of the known annual escapement (3,000-4,000 individuals), harvest of fish by anglers could reduce the population. Any increase in harvest by anglers in a particular area or subbasin could result in a loss of recruitment from that site, in turn reducing the overall population in Flathead Lake.

The long overwinter incubation and development phase for bull trout embryos and alevins (223 days in Coal Creek) leaves them particularly vulnerable to increases in fine sediments and degradation of water quality. In laboratory experiments, survival was shown to be inversely related to the percent fine material (<6.35 mm) in the gravels (Weaver and White 1985). Survival to emergence ranged from nearly 50 percent in substrates which contained 10 percent fines, to zero percent in mixtures which contained 50 percent fines. Juvenile bull trout could be affected by streambed changes because of their close association with the substrate. Shepard *et al.* (1984a) found a significant relationship ($r^2 = 0.40$, $P < .01$) between substrate score (a measure of unimbedded instream rock cover) and juvenile bull trout densities in tributaries of the Swan River.

As our studies of bull trout in the Flathead River system continue, we hope to define more precisely the factors which negatively affect the population. It is not clear whether the tributaries are at carrying capacity for juvenile bull trout, nor whether juvenile densities are limited by spawner escapement levels. The answer to these questions will require monitoring of the escapement levels and resulting juvenile densities in the tributaries over a longer period of time. McPhail and Murray (1979) suggested that limitations in juvenile rearing habitat may form an "ecological bottleneck," greatly affecting overall population levels of bull trout.

Bull trout in the Flathead River system are dependent on habitat quality and management of the interconnected river, lake, and tributaries. Cumulative losses of spawning and rearing habitat would reduce the bull trout population in Flathead Lake.

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Research Article

Effect of Heavy Metals on Fishes: Toxicity and Bioaccumulation

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ABSTRACT

Heavy metal pollution is a serious problem for the environment due to their toxicity, persistency, bioaccumulation, and bio magnifications property. Heavy metal contamination in the environment can occur from different natural and anthropogenic sources. The natural sources of heavy metals are mainly volcanic eruption and weathering of metal-bearing rocks, while the anthropogenic sources of heavy metals include agricultural and industrial activities, combustion of fossil fuel and gasoline, waste incinerators, mining, etc. The mobilization of these heavy metals to the aquatic ecosystem alters the physicochemical property of water which is hazardous for aquatic organisms. Heavy metals mainly enter the fish body through gills, body surface and digestive tract during ingestion of metal accumulated food materials. Cadmium, chromium, nickel, arsenic, copper, mercury, lead and zinc are the most common heavy metal pollutants that cause severe toxicity in fishes. Development of oxidative stress is the fundamental molecular mechanism of metal toxicity. The stress weakens the immune system, causes tissue and organ damage, growth defect and reduces reproductive ability. The rich source of high-quality protein filled with vitamins and omega-3 fatty acids encourage the human being to uptake fish as a major food source. So, accumulated heavy metals in the fish tissues directly transfer to the human body and cause toxic effects to expedite various diseases. Therefore, it is necessary to discuss the sources of heavy metals and their toxic effect on fish health to enforce the law and legislations regarding their protection in the aquatic environment and also to save human life.

Keywords: Heavy metal; Aquatic ecosystem; Bioaccumulation; Toxicity; Oxidative stress

INTRODUCTION

Environmental pollution is one of the major challenges for human society nowadays [1]. Due to the fast-growing industries, increased energy demand and careless destruction of natural resources from the last few decades environmental pollution is increasing day by day [2]. Different organic and inorganic toxic materials are constantly releasing from various natural and anthropogenic sources in the soil and aquatic ecosystem. Among them, heavy metals are playing a major role in environmental pollution, not only for their toxic nature but also possessing the potentiality of bioaccumulation in the food chain [3]. Heavy metals are mostly releasing from domestic and agricultural waste products, industrial waste materials, combustion of fossil fuels, mining, waste water treatment plants to the natural ecosystem [4].

Since heavy metals are persistent in the natural ecosystem, once enter into the living organism, it can accumulate inside. The heavy metals that contaminate the soil are easily taken up by the plants and lead to different adversity e.g. chlorosis, growth inhibition, defect in water balance and photosynthesis, senescence, and finally death [5]. The soil contamination of heavy metals also affects the microbiological balance and reduced soil fertility [6]. The heavy metals can easily dissolved in the aquatic environment and subsequently enter into the body of aquatic organisms [7]. In the course of the food chain, those metals then enter into the body of higher animals. Bioaccumulation of toxic heavy metals in the different tissues may harm animal health and causes damage to their normal physiological processes [8]. Heavy metal toxicity drastically affects the rate of survivability and reproductive capacity of the organisms. Some of these have been reported to be highly carcinogenic, mutagenic and teratogenic depending on the species, dose and exposure time [9].

Aquatic biota directly exposed to the heavy metals that dissolved in water or present as sediment in the water body [10]. Being the top consumers of the aquatic ecosystem fishes are affected most [11]. Heavy metal toxicity sometimes damages the nervous system of fish that affects the interaction of fish with its environment [12]. Humans are omnivorous and exposed to toxic heavy metals by different food items such as fish, vegetables and cereals. Therefore, the heavy metal contamination in the body of aquatic organisms or plants can biomagnified and persist in the food chain, results in

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transfer to the human body [13]. Heavy metal toxicity has become an important global threat for fish consumers [14].

The present review aims to discuss the bioaccumulation and toxic effect of different heavy metals like Chromium, Cadmium, Copper, Lead, Nickel, Arsenic, Mercury and Zinc on fish health, so that necessary steps can be taken to minimize the impact of these metal elements in our ecosystem.

Chromium (Cr)

Chromium is one of the most common trace elements found in the earth's crust and seawater [15]. This element is not present in the environment as pure metal form, but present in divalent (Cr^{2+}), trivalent (Cr^{3+}) or hexavalent (Cr^{6+}) oxidation states. Among these different forms, Cr^{3+} and Cr^{6+} are the most stable forms [16,17]. Cr^{3+} oxidation state is less toxic due to low membrane permeability, non-corrosiveness nature and minimum power of bio magnifications in the food chain. Cr^{6+} state is more toxic because of its strong oxidative potentiality and ability to cross the cell membrane [18]. In an aquatic ecosystem, chromium toxicity occurs from different anthropogenic sources such as leather tanneries, metal processing, petroleum refining, textile manufacturing, alloy preparation, wood preserving etc. [19,20].

The toxicity of chromium to aquatic organisms is dependent upon various biotic factors like age, developmental phase and type of species; and abiotic factors like pH, temperature and alkalinity of water. Initial exposure of fish to chromium showed different behavioural changes i.e. uneven swimming, mucous discharge, change in body colour, loss of appetite etc., [21]. Chronic exposure of chromium at a concentration of 2-200 μmol/L on Cyprinus carpio showed cytotoxicity, decreased mitogen-induced lymphocyte activation and phagocyte functions [22]. Blood coagulation time was decreased in the Tilapia sparrmanii exposed to chromium, which reflects by internal bleeding with an increase of pH value [23]. Accumulation of chromium in the tissue of Indian major carp Labeo rohita decrease total protein and lipid content in the muscle, liver and gill [24]. The depletion of liver glycogen content was observed in a freshwater teleost Colisa fasciatus, on chromium exposure [25]. In rainbow trout, Salmo gairdneri, Cr^{6+} toxicity showed osmoregulatory and respiratory dysfunction at pH 7.8 and 6.5 [26]. Chronic exposure of chromium to Chinook salmon caused DNA damage, microscopic lesions, physiological abnormalities, and reduction in growth and survival rate [27]. In rainbow trout Salmo gairdneri, embryo hatching and the growth of fish were affected after chromium exposure at a concentration of 2 mg/L [28].

Bioaccumulation of chromium varies differentially in various tissues of fish (Table 1). The highest accumulation of chromium is found in gills, liver and kidney and very low concentration is found in the muscle tissue [29].

Cadmium (Cd)

Cadmium is a trace element present in the earth's crust on an average concentration is about 0.1-0.5 ppm and is commonly found in association with zinc, copper and lead ores. In ocean water, the average concentration is between 5-110 mg/L and in surface water and ground water is usually <1 μg/L [30]. Element form of cadmium is not available in nature. Instead, compound forms e.g. cadmium chloride, cadmium oxide, cadmium sulphide, cadmium carbonate, cadmium nitrate and cadmium cyanide are commonly found [31]. Cadmium is released in the aquatic ecosystem from different natural and anthropogenic sources. Natural sources of cadmium are from the earth's crust and mantle by the volcanic eruption and weathering of rocks. Whereas anthropogenic sources include combustion of fossil fuels, fertilizers, agricultural waste and industrial use (plastic stabilizers, pigment, batteries, electroporating industries) which contaminate the water body [32,33]. The flora and fauna of water body uptake water soluble or sediment form of cadmium compounds, which indirectly enter into the fish body in course of the food chain [34]. Whereas fishes uptake water dissolved free ionic form of cadmium directly through gill, gastrointestinal tract and skin [35].

Cadmium is considered as a nonessential element and causes severe toxicity to fishes. It inhibits the electron transfer chain in mitochondria and stimulates Reactive Oxygen Species (ROS) production [36]. A low level of cadmium exposure induced DNA damage in Cyprinus carpio [37]. Trans-epithelial calcium influx in rainbow trout gill was found to be inhibited by Cd^{+2} [38]. Micro-nucleated and bi-nucleated cells formation in blood, gills and liver were observed in subchronic cadmium chloride exposure in fish [39,40]. Reported histopathological alteration like fatty vacuolation in the liver; necrosis in hepatocytes; congestion of sub mucosal blood vessels in the intestine and glomerular shrinkage and necrosis in kidney tissue of Tilapia (Oreochromis niloticus). Fish exposed to cadmium showed a differential haematological response. After 8 weeks of exposure to 150 μg/L of cadmium in American eel fish (Anguilla rostrata), lead to anaemia due to reduction in haemoglobin and erythrocyte counts. Significant increase in leukocyte and large lymphocytes count was also observed after cadmium exposure [41]. The level of glycogen reserve in muscle and liver was decreased significantly and blood glucose level increased in Cyprinus carpio, exposed to sublethal concentration of cadmium [42]. Cadmium is an endocrine disrupter and an inhibitor of vitellogenesis, observed in rainbow trout Oncorhynchus mykiss [43]. Exposure to cadmium chloride affected the gonad function and sexual maturity in common carp Cyprinus carpio [44]. Cadmium exposure to the larvae of ide Leuciscus idus showed body malformations and reduced embryonic survival rate due to death in newly hatched larvae [45].

Cadmium accumulation is a serious environmental concern because of its slow rate of excretion. The highest level of cadmium bioaccumulation is found in the liver, kidney and gill and lowest level in the skin. Gill is the most efficient organ for cadmium detoxification [46]. Cadmium is considered is one of the most toxic heavy metals for aquatic organisms because of its high rate of bioaccumulation.

Copper (Cu)

Copper pollution in the freshwater ecosystem occurs due to extensive use of fungicides, algaecides and insecticides in the agricultural field and then discharge of the waste materials to the water body. Other than that, copper toxicity also occurs from the electroplating industry, metal refining industry, plastic industry, mining, sewage sludge, atmospheric deposition etc. [47,48].

Copper is an essential trace element and micronutrient, important for the growth and metabolism of living organisms. In fish and other vertebrates, copper is the key constituent of many metabolic enzymes and glycoprotein. It is also essential for haemoglobin synthesis and nervous system function [49,50]. But, at higher

Table 1: Heavy metal bioaccumulation in different tissues or organ of fish-ranked in decreasing order.

Heavy metal	Bioaccumulation in tissue or organ	Fish species	Reference
Chromium	Kidney>heart>muscle>gills	Hydrocynusforskahlii	Murtala et al., 2012
	Kidney>gills>muscle>heart	Hydrocynusbebe occidentalis	Murtala et al., 2012
	Kidney>gills>heart>muscle	Clariasgariepinus	Murtala et al., 2012
	Liver>kidney>gills>muscle	Coregonus lavaretus	Gashkinaet al., 2020
	Gills>muscle>kidney>liver	Cyprinus carpio	Rajeshkumaret al., 2018
	Liver>kidney>gills>intestine>muscle	Pelteobagrusfulvidraco	Rajeshkumaret al., 2018
Cadmium	Gills>liver>muscle	Pleuronectes platessa	Westernhagenet al., 1978
	Gills>intestine>liver	Pleuronectes platessa	Pentreath., 1977
	Gills>liver>intestine	Raja clavata	Pentreath., 1977
	Gills>muscle>heart>kidney	Hydrocynusforskahlii	Murtala et al., 2012
	Gills>heart>muscle	Hydrocynusbebe occidentalis	Murtala et al., 2012
	Kidney>gills>heart	Clariasgariepinus	Murtala et al., 2012
	Kidney>liver>gills>muscle	Coregonus lavaretus	Gashkinaet al., 2020
	Kidney>gills>muscle>intestine>liver	Cyprinus carpio	Rajeshkumaret al., 2018
	Intestine>kidney>muscle>liver>gills	Pelteobagrusfulvidraco	Rajeshkumaret al., 2018
Copper	Kidney>Liver >gills>muscle	Coregonus lavaretus	Gashkinaet al., 2020
	Gills>intestine>kidney>liver>muscle	Cyprinus carpio	Rajeshkumaret al., 2018
	Liver>kidney>muscle>gills>intestine	Pelteobagrusfulvidraco	Rajeshkumaret al., 2018
Lead	Gills>muscle>heart>kidney	Hydrocynusforskahlii	Murtala et al., 2012
	Gills>kidney>heart>muscle	Hydrocynusbebe occidentalis	Murtala et al., 2012
	Gills>liver>kidney>muscle	Coregonus lavaretus	Gashkinaet al., 2020
	Gills>kidney>muscle>liver>intestine	Cyprinus carpio	Rajeshkumaret al., 2018
	Kidney>liver>gills>intestine>muscle	Pelteobagrusfulvidraco	Rajeshkumaret al., 2018
Nickel	Kidney>gills>muscle>heart	Hydrocynusforskahlii	Murtala et al., 2012
	Gills>heart>kidney	Hydrocynusbebe occidentalis	Murtala et al., 2012
	Kidney>heart>muscle>gills	Clariasgariepinus	Murtala et al., 2012
	Kidney>liver>gills>muscle	Coregonus lavaretus	Gashkinaet al., 2020
Arsenic	Liver>gills>blood>muscle>skin>brain	Clariasbatrachus	Kumar et al., 2012
	Stomach>liver>gills>muscle	Oreochromis niloticus	Oliveira et al., 2017
Mercury	Kidney>liver>muscle>gills	Coregonus lavaretus	Gashkinaet al., 2020
	Gills>kidney>muscle>liver>intestine	Cyprinus carpio	Rajeshkumaret al., 2018
	Muscle>liver>kidney>head	Oreochromis niloticus	Bradley et al., 2017
Zinc	Gills>kidney>liver>gut	Pleuronectes platessa	Pentreath 1973
	Liver > kidney> intestine > gill > muscle	Channa punctatus	Muruganet al., 2008

concentration, copper causes toxic effect on living organisms [51]. Copper causes toxicity to freshwater fish at a concentration ranging from 10-20 ppb [52]. Toxicity of copper to aquatic life is dependent on several factors, i.e. water hardness, pH, anions and Dissolved Organic Carbon (DOC). Fish uptake copper mainly through the dietary route or ambient exposure [53]. Exposure to waterborne copper on freshwater fish induced oxidative stress response [54]. Chronic toxicity of copper in fish causes poor growth, shortening of life span, decreased immune response, and fertility problems [55]. Copper toxicity in the gill of teleost fish (Oreochromis niloticus), showed induction in apoptosis [56]. In Cyprinus carpio, copper sulfate exposure showed biochemical and morphological changes in the liver tissue [57]. Micronuclei and binuclei formation was induced in blood erythrocytes, gill epithelial cells and liver cells of fish, after subchronic exposure to copper sulphate. Copper impaired complex fish behaviours such as, social interaction, avoidance of predators and reproductive behaviour that are important for survival. Copper toxicity to Mytilus edulis lead to a decrease in heart rate and cardiac function [58]. Copper exposed Oreochromis mossambicus showed an increase in RBC count, haemoglobin content and hematocrit value [59]. This element is neurotoxic to fish and interferes with the function of olfactory neurons [60]. Copper exposed zebrafish larva became greater sensitive than embryonic and adult stage and showed lateral line dysfunction [61]. The larvae of goldfish Carassius auratus showed a high rate of body deformities and mortality on copper exposure [62]. Copper accumulates at the highest concentration in the liver and less concentration in the gill and body flesh of fish [63]. Bioaccumulation of this trace element influenced the oxidative metabolism, lipid peroxidation and protein content in carp tissue [64].

Lead (Pb)

Lead is considered as one of the most hazardous heavy metals, which is naturally present in the environment, in combination with other elements i.e. PbS, PbSO4 and PbCO3.The concentration of lead in the environment is very much increased by different anthropogenic sources such as metal mining, combustion of coal, oil and gasoline, battery manufacturing, lead-arsenate pesticides, lead-based paint, pigments, food cans etc., [65]. Lead discharge from various industries, agricultural fields, street runoff, lead dust and municipal wastewater that directly come to the aquatic environment and cause toxicity for the aquatic life [66]. The solubility of lead in water is depending upon pH, salinity, hardness etc. Highest solubility of lead is observed in soft and acidic water.

The lethal concentration of lead for fish is 10-100 mg/L [67]. Sublethal concentration of lead exposure causes behavioural change, impotency and growth retardation of fish [68]. Katti reported a change in lipid and cholesterol content in the liver, brain and gonad of Clariasbatrachus, in prolonged exposure to a low concentration of lead nitrate [69]. Histological distortion of gill and liver tissue was observed in African catfish Clariasgariepinus, exposed to lead. Freshwater teleost (Mastacembelus pancalus) showed histological alterations in the ovarian tissue in lead exposure [70]. Necrosis of parenchyma cells, fibrosis of hepatic cords and connective tissue, reduction in growth and body weight, collapsing of blood vessels were also observed in lead-exposed fish [71]. Lead exposure in Nile tilapia (Oreochromis niloticus) showed decreased haemoglobin content, red blood cell count and hematocrit value [72]. Oxidative stress is induced by lead toxicity, which caused synaptic damage and neurotransmitter malfunction in fish [73]. Alteration of the immunological parameters was observed in Tench (Tinca tinca) lethal and sublethal exposure to lead [74].

Lead bioaccumulation in fish mainly occurs in the liver, spleen, kidney and gills [75]. Lead bioaccumulation also affected free locomotion and induced morphological deformities in Chinese sturgeon, Acipenser sinensis [76].

Nickel (Ni)

Nickel is a very abundant trace element found in the environment, present in combination with oxygen or sulphur. Nickel is released into the environment from both natural and anthropogenic sources. The element is discharged from industries during nickel mining and transformation of new nickel into alloys or nickel compounds. Nickel is also released from coal-burning power plants, oil-burning power plants and trash incinerators [77].

Nickel is an essential element for many organisms at low concentration, but at high concentration, it causes toxicity [78]. Nickel toxicity in fishes is dependent upon different physiochemical properties of water like pH, ionic strength, temperature, hardness, Dissolved Organic Carbon (DOC) etc. [79]. Exposure to nickel chloride in Nile tilapia showed abnormal swimming behaviour, rapid opercular movement, respiratory disorder and lesions in the skin. Nile tilapia exposed to nickel also showed a change in blood parameters like, increase of RBC count and a decrease of haemoglobin and WBC counts [80]. Histopathological changes in different tissues like gill, kidney, liver and intestine were observed in nickel exposed freshwater fish Hypophthalmichthys molitrix. The fusion of gill lamellae, necrosis of hepatocytes, blood vessels degeneration, hypertrophy, vacuolation, pyknotic nuclei and lesion were observed in the liver tissue. Hyperplasia and degeneration of tubular cells in kidney tissue were also observed on nickel exposure [81]. In chronic and acute exposure of nickel to freshwater fish Oreochromic niloticus, reduced ATPase activity in the brain [82]. Nickel exposure in freshwater fish Prochilodus lineatus, affected the antioxidant defence system in the liver and induced DNA damage in both blood cells and gills [83]. Short term exposure of a high concentration of nickel resulted in stress reaction of common carp Cyprinus carpio. Alteration of haematological parameters and behavioural changes were also found in Cyprinus carpio, to sublethal concentration of nickel exposure [84]. Nickel toxicity showed some adverse effect on protein metabolism of freshwater fish, Cyprinus carpio. The observed alterations were decrease of structural, soluble and total proteins, increase of free amino acids and protease activity and ammonia in gill and kidney after exposure to a lethal concentration of nickel [85]. Nickel poisoning in fish showed loss of body equilibrium and behavioural changes like surfacing, rapid mouth and operculum movement before death [86].

Nickel accumulates in the blood, kidney, muscle and liver of fish but highest accumulation is observed in the kidney [87]. Bioaccumulation expressed a general decrease of glycogen level in both liver and muscle of Tilapia nilotica. High level of nickel bioaccumulation in Tilapia nilotica, elevated blood cell count, packed cell volume and haemoglobin content and caused lymphopenia and leukopenia.

Arsenic (As)

Arsenic is a ubiquitous element, release in the aquatic environment from various anthropogenic sources including manufacturing companies, smelting operations, power plants etc. Another major source of arsenic from the agricultural field is the use of arsenic pesticides, herbicides and fungicides [88].

Fish are continuously exposed to arsenic-contaminated water through their gill and skin and also by arsenic-contaminated food. Arsenic is present in various forms, i.e. element, trivalent and pentavalent oxidative form. Inorganic arsenic in trivalent oxidation state (arsenites) is very rapidly absorbed into the fish tissue and is more toxic than the pentavalent state (arsenates). The toxic effect of arsenic is dependent upon different abiotic factors of a water body such as pH, temperature, salinity, organic matters, phosphate content, suspended solids as well as other toxic substances [89]. Continuous exposure of freshwater fish to the low concentration of arsenic results in bioaccumulation mostly in the liver and kidney tissue [90]. Arsenic exposure showed histopathological alteration in gills and liver tissue of freshwater fish, tilapia (Oreochromis mossambicus). The alterations in gills were epithelial hyperplasis, lamellar fusion, epithelial lifting and oedema, desquamation and necrosis. The liver histology showed macrophage infiltration, vascularisation, hepatocytes shrinkage, dilation of sinusoids, vascular degeneration, nuclear hypertrophy and focal necrosis [91]. A range of histological alterations was found in the heart of freshwater teleost, Channa punctata including necrosis in the heart tissue [92]. Acute exposure of common Indian catfish Clariasbatrachus to sodium arsenite elicited disturbed haemopoiesis, disruption of the erythrocyte membrane, impaired iron uptake by erythrocytes and haemolysis [93]. Arsenic exposure in the catfish Clariasbatrachus showed a time-dependent change in total leucocyte count and reduction of organo-somatic indices in kidney and spleen. Arsenic also induced alteration in T-cell and B-cell functioning and interfere bacterial phagocytosis function of catfish [94]. Developmental arrest of Japanese medaka (Oryzias latipes) embryo was observed in the sublethal concentration of arsenic toxicity [95]. The induction of stress response proteins were found in rainbow trout Salmo gairdnerii, on arsenic exposure [96]. Arsenic toxicity in zebrafish embryos significantly inhibits genes involved in innate immune responses, which function against viral and bacterial infection [97]. Wanget treated two fish cell lines, JF (fin cells of Therapon jarbua) and TO-2 cells (ovary cells of Tilapia), with sodium arsenite [98]. They observed apoptosis in JF cells probably due to induction of oxidative stress and distortion of the cell cycle in TO-2 cells. In long term exposure of freshwater fish Colisa fasciatus, to arsenic oxide caused impaired ovarian function and reduction in the development of 2nd and 3rd stage oocyte [99]. Bioaccumulation of arsenic affects various physiological systems of fish such as growth, reproduction, gene expression, ion regulation, immune system and histopathology.

Mercury (Hg)

Mercury is considered as one of the most toxic heavy metal found in the environment. Mercury contamination in the environment increased rapidly from the 20th century due to huge industrialization [100]. Mercury ranked third in the list of the hazardous substance of the environment after lead and arsenic by United State Environmental Protection Agency (EPA) and the Agency for Toxic Substances and Disease Registry (ATSDR) [101]. The natural sources of this element are forest fire and volcanic eruption and anthropogenic sources include fungicides, electronic equipment, batteries, paint etc. Burning of fossil fuels and mining also contribute a major role in mercury pollution of our environment [102].

Apart from elementary form, mercury is present in an ionic form which forms a compound with sulphide, chloride or organic acid and organic form, especially methyl mercury [103]. Literature suggests methyl mercury is the most chemically toxic form of mercury and 70-100% of mercury present in the fish body is of methylated form. Methylation of inorganic mercury occurs by microorganisms such as anaerobic sulphate-reducing bacteria, iron reducers, and methanogens [104,105]. Increase in water temperatures attributed to climate change which stimulates the methylation of mercury. Mercury can enter into the fish body by food through the alimentary canal, skin and gills. The acute lethal concentration of inorganic mercury is 0.3-1.0 mg/L for salmonids and 0.2-4 mg/L for cyprinids depending upon the physical and chemical property of water. The acute lethal concentrations of commonly found organic mercury compounds are 0.025-0.125 mg/L for salmonids and 0.20-0.70 mg/L for cyprinids. The maximum admissible concentration of the inorganic form of mercury for salmonids is 0.001 mg/L and for cyprinids is 0.002 mg/L [106]. Mercury is very toxic for fish and at sublethal concentration and causes structural, physiological and biochemical alteration on the fish nervous system. Methyl mercury is considered as the most neurotoxic compound because it can cross the blood-brain barrier due to its lipophilic nature and can accumulate in the nervous system of fish. Mercury can also interfere with the physical property and structural integrity of cell membrane by affecting the configuration of purines, pyrimidines and nucleic acids [107]. Chronic exposure of mercurial compound to the kidney of Clarias batrachus expressed damage and necrosis of kidney tubules [108]. Mercury oxide toxicity on African catfish Clarias gariepinus showed a significant increase of serum cortical, cholesterol, aspartate aminotransferase, alanine aminotransferase, alkaline phosphorous, urea and creatinine levels and a significant decrease in haemoglobin and haematocrit value [109]. The freshwater fish Channa punctatus exposed to 0.3 mg/L of $HgCl_2$ for 7 days showed oxidative damage and up regulation of pro-inflammatory cytokines [110]. Inorganic mercury exposure in zebra fish showed histological alteration and oxidative stress in gonads. Mercury toxicity also disrupted the transcription of Hypothalamic-Pituitary-Gonadal (HPG) axis genes and altered the sex hormone levels of adult zebra fish [111]. The male reproductive system of tropical fish Gymnotus carapo showed sensitivity to Hg toxicity. $HgCl_2$ induced seminiferous tubule disorganization, congestion of blood vessels, interstitial tissue proliferation, and reduction in germ cells and sperm's number of Gymnotus carapo [112].

Mercury has a high affinity to proteins, therefore more than 90% of total mercury accumulates in fish muscle [113]. Rate of methyl mercury excretion from fish body is extremely slow therefore in addition to muscle, high concentration of mercury also found in blood [114]. Additionally, liver also function as the site of storage, detoxification or redistribution of mercury [115].

Zinc (Zn)

Zinc contamination in the environment is increasing because of different anthropogenic sources such as industrial activities, mining, combustion of coal and waste materials, steel processing etc., [116].

Zinc is a ubiquitous trace element and one of the essential micronutrients for living organisms. Zinc is involved in various metabolic pathways such as nucleic acids and protein synthesis, immunity, energy metabolism, cell division and body growth. It acts as a cofactor for many enzymes that aid in metabolism, digestion, nerve function and other processes [117,118]. Deficiency of zinc causes several physiological disorders such as poor pregnancy rate, cardiovascular diseases and cancer; but it becomes toxic in excess amount [119]. Zinc toxicity is also species-specific and varies with different developmental stages of fish. The toxic effect of zinc on aquatic animals depends upon several environmental factors, especially temperature, water hardness, and dissolved oxygen concentration. At an acute toxic concentration of zinc, it kills fish by destroying gill tissue and at the chronic toxic level, it induces stress which results in the death of fish [120].

Fish take zinc through the gastrointestinal tract and gills. The major mechanism of zinc toxicity occurs as the divalent cationic form which disrupts the absorption of calcium ion in the tissue, results in hypocalcaemia and eventually fish death [121]. Zinc sulphate exposed Tilapia nilotica showed slow swimming activity and loss of body equilibrium. The hepatocytes of the liver became vacuolated with frequent necrosis [122]. Zebrafish embryos exposed to different concentrations of ZnCl2 showed a delay in hatching capacity, growth defect and skeletal malformations due to defective calcification [123]. Zinc exposed fish Phoxinus phoxinus showed alteration in movement pattern and behavioural change. These fish become less active, easily frightened and formed denser shoals which mostly stayed close to the bottom [124]. Zinc exposed killifish (Fundulus heteroclitus) led to oxidative stress response by increasing hepatic lipid peroxidation level, which is an oxidative stress biomarker and decrease of liver catalase (CAT) activity [125].

Zinc accumulates in fish through gills and digestive track, however the role of water as a source of zinc is not fully elucidated [126]. Murugan examined the accumulation of zinc in different tissue of Channa punctatus and concluded that zinc deposit at the order of liver>kidney> intestine>gill>muscle [127].

CONCLUSION

Some heavy metals have an essential role in the normal biological processes, and the insufficiency or excess amount can cause a disturbance in the metabolic pathways and serious illness [128]. Essential heavy metals are which have known biological functions (Table 2) [129]. Other group of heavy metals have no biological role and at higher concentrations cause a toxic effect to the tissues [130].

Beyond tolerance level, metal ions induce Reactive Oxygen Species (ROS) production, which causes an oxidative stress response in fishes [131]. Redox-active metals e.g. copper and chromium generate reactive oxygen species through redox cycling. Whereas redox inactive metals e.g. mercury, nickel, lead, arsenic and cadmium bind to the Sulfhydryl groups (SH) of proteins involved in antioxidant defences, thereby impair the defence mechanism [132]. Elevated ROS production in fish causes DNA lesions, oxidation of lipids and proteins and alterations of cellular redox status [133,134].

Antioxidant defences mechanism in fish includes the antioxidant enzyme system and low molecular weight scavengers (Figure 1). Super Oxide Dismutase (SOD), Glutathione Peroxidase (GPX), Catalase (CAT), and Glutathione-S-Transferase (GST) enzymes protect cells from oxidative damage by detoxification of ROS [135]. Whereas low molecular weight protein i.e. Metallothioneins (MTs) reached the cysteine residues that sequester the metals. Different isoforms of MTs bound to various metals with different affinities in fishes [136].

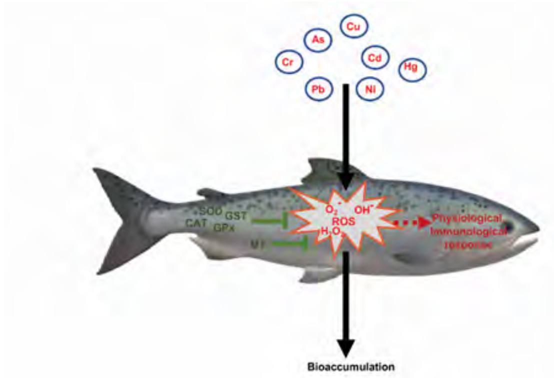

Figure 1: Heavy metals toxicity in fishes. Heavy metals induce oxidative stress by generating reactive oxygen species (ROS). The anti-oxidation defense mechanism (include different enzymes CAT, SOD, GST, GPx and metal scavenging protein MT) involved in detoxification. Severe metal toxicity generates different physiological and immunological responses. In the course of metal toxicity bioaccumulation of metals occurs in different tissue of fishes.

In addition, to detoxify the metals, metallothioneins are the major cause of bioaccumulation of heavy metals in different tissue of fishes [137]. The accumulated heavy metals not only affect the fish population in the aquatic ecosystem but also transfer through the food chain/web to the next tropic level. Trophic transfer of these elements from aquatic to the terrestrial ecosystem has serious implications for human health by promoting different diseases including cancer, neurodegenerative disease, etc. [138,139].

Therefore, this comprehensive study about the heavy metal toxicity on fish health suggests that essential steps should be taken to minimize the toxic impact of heavy metals on human health and the environment. Here, some recommendation is made-

- The level of heavy metal on soil, water and sediment should be monitored regularly. Such data should be used for the assessment of health risk in the human population.
- Agricultural and industrial waste should be decontaminated effectively before discharge into the water body.
- Proper awareness should be provided to the public about the harmful effect of heavy metal toxicity in our environment.
- More scientific research should be encouraged and promoted about the toxicity of heavy metals, their trophic level transfer and their effect on the environment.

AUTHOR CONTRIBUTION

Pramita Garai, Priyajit Banerjee are contributed equally.

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Effects of climate change on snowpack and fire potential in the western USA

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Abstract We evaluate the implications of ten twenty-first century climate scenarios for snow, soil moisture, and fuel moisture across the conterminous western USA using the Variable Infiltration Capacity (VIC) hydrology model. A decline in mountain snowpack, an advance in the timing of spring melt, and a reduction in snow season are projected for five mountain ranges in the region. For the southernmost range (the White Mountains), spring snow at most elevations will disappear by the end of the twenty-first century. We investigate soil and fuel moisture changes for the five mountain ranges and for six lowland regions. The accelerated depletion of mountain snowpack due to warming leads to reduced summer soil moisture across mountain environments. Similarly, warmer and drier summers lead to decreases of up to 25% in dead fuel moisture across all mountain ranges. Collective declines in spring mountain snowpack, summer soil moisture, and fuel moisture across western mountain ranges will increase fire potential in flammability-limited forested systems where fuels are not limiting. Projected changes in fire potential in predominately fuel-limited systems at lower elevations are more uncertain given the confounding signals between projected changes in soil moisture and fuel moisture.

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1 Introduction

In the western US, snow is the primary source of water storage (Cayan 1996). Most of the annual precipitation occurs during the cool season and is returned to the atmosphere in the spring and early summer through evapotranspiration, except at the highest elevations and northern coastal areas, where it is predominantly released as runoff and streamflow (Barnett et al. 2005). This annual cycle makes the region particularly vulnerable to changes in climate, which alter the timing and duration of the snow season, and subsequent water availability throughout the dry summer months. Widespread declines in April 1 snow water equivalent (SWE) have been seen at snow course sites across mountains of the western USA over the past 50 years (e.g., Mote 2006; Hamlet et al. 2005). Declines in snowpack were more pronounced in temperate ranges than the colder, interior ranges, suggesting that the loss in spring snowpack was a result of warming temperatures (Mote et al. 2005). Spring runoff in snowmelt-dominated rivers in the western USA has shifted earlier by 1 to 3 weeks over the past 50 years, which has been attributed to warming temperatures (Stewart et al. 2005) and to decreased mountain precipitation (Kormos et al. 2016).

Projected changes in climate unanimously show continued and accelerated increases in temperature across the western USA through the twenty-first century (Sillmann et al. 2013). Regional changes in precipitation, by contrast, are more uncertain and differ substantially (even by sign) among global climate models (Kharin et al. 2013). Luce et al. (2013) suggested that declines in streamflow in the northwestern USA since 1950 could be attributed to declines in orographic precipitation associated with a reduction in the strength of lower-tropospheric winter westerlies. Lute et al. (2015) found that annual snowfall water equivalent was projected to decline across the western USA by the mid-twenty-first century and that low-snowfall years would become more frequent.

Stewart et al. (2004) among others (e.g., Wood et al. 2004; Lundquist and Flint 2006) have projected that spring runoff timing could shift earlier by more than a month by the end of the twenty-first century, which has strong implications for summer soil moisture. Soil moisture integrates non-linear impacts of temperature, precipitation, vapor pressure deficit, and wind into the moisture content of vegetation and thus may be a proxy for vegetation and duff dryness, making it an important indicator of ecosystem function (e.g., Littell et al. 2008) and of fire potential in flammability-limited forested regimes. Higuera et al. (2015) showed that summer soil moisture explained over 60% of interannual variability in area burned across the Northern Rocky Mountains. Fluctuations in winter snowpack can have a strong impact on the occurrence of large fires (Westerling et al. 2006) in the western USA, as spring snowpack influences soil moisture in the subsequent summer. Similarly, fuel moisture is an important proxy for potential ignition and fire spread and strongly correlates with the amount of area burned (Flannigan et al. 2005; Abatzoglou and Kolden 2013).

The frequency of large fires and area burned in wildland fires over the western USA have increased markedly over the past several decades (Westerling et al. 2006; Dennison et al. 2014; Littell et al. 2009. These trends are projected to continue, with widespread increases in large fire frequency (Westerling et al. 2011a; Stavros et al. 2014) and area burned (Westerling et al. 2011b; Littell et al. 2010; Turner et al. 2016). Although projected changes in wildfire activity across the western USA have been estimated using contemporary climate-fire relationships, it is likely that contemporary climate-fire relationships may be non-stationary under a changing climate (McKenzie and Littell 2016). Past studies (e.g., Littell et al. 2009; Littell and Gwozdz 2011; Abatzoglou and Kolden 2013) have defined two general climate-fire regimes that are applicable to the western USA. Wildfires in primarily lower-elevation rangelands are associated with years of higher fuel abundance that result from increased moisture availability, while wildfires in primarily higher-elevation forested areas are associated with moisture deficits that result in increased fuel aridity (Abatzoglou and Kolden 2013). A long history of fire suppression across parts of the western USA complicates these climate-fire relationships. Despite historical differences in fire suppression and different climate-fire relationships, prior studies have not distinguished between projected changes in fire potential between upland and lowland areas over a domain as large as the western USA.

In this study, our objective is to understand how future changes in climate will affect snowpack, soil moisture, and fuel moisture in upland and lowland regions of the western USA. We focus on the links between hydrologic changes in snowpack and soil moisture, associated both with changing snow processes in the uplands and precipitation changes in the lowlands, and changes in fuel moisture. We also evaluate their combined implications for summer aridity and fire potential. Using an ensemble of ten GCMs allows us to evaluate a broader range of possible outcomes and highlight where projections are consistent (or not) among models. Our intention is not to model changes in fire activity (e.g., burned area, fire frequency), but rather to examine projected changes in fuel aridity metrics that are proximate drivers of interannual variability in fire activity across parts of the region (e.g., Higuera et al. 2015). By the term fire potential, we mean the potential for fire to occur. The vulnerability components of fire risk are beyond the scope of our study.

2 Approach

2.1 Domain

Our domain consists of five mountain regions and six lowland regions in the western USA. The mountain ranges include the Sierra Nevada mountains, Cascades, Northern and Southern Rockies, and White Mountains (Fig. 1). The lowland regions consist of the Great Basin, Coastal North, Coastal South, Northwest Interior, Missouri, and Lower Colorado (Fig. 1). The Missouri, Lower Colorado, and Great Basin regions are defined by USGS Hydrologic Unit Code (HUC) 02 boundaries (Watershed Boundary Dataset for HUC-02s 2015). For Missouri HUC-02, only the area west of 103° is included. The mountain regions were defined as

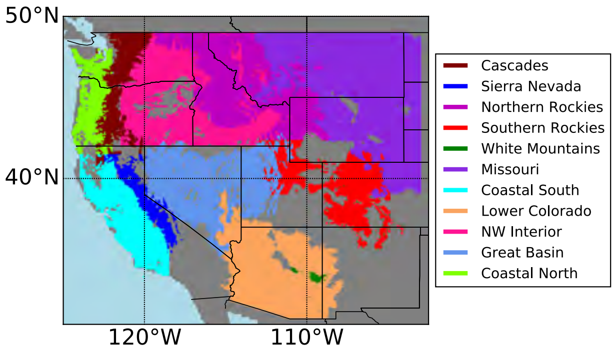

Fig. 1 Map of mountain ranges and lowlands in the western United States included in this study

consisting of the 1/16° latitude-longitude grid cells for which the historical (1970–1999) model-simulated mean April 1 SWE exceeded 10 mm.

2.2 Climate forcing datasets and downscaling

We used meteorological inputs from Livneh et al. (2013) for historical Variable Infiltration Capacity (VIC) model simulations, which we compared to SNOTEL observations (Online Resource 1) and which were also used to define the April 1 SWE threshold for mountain ranges. Our comparison to SNOTEL observations served as a validation for modeled SWE (see Online Resource 1 and Supplementary Materials). Hydrologic simulations were driven by precipitation, maximum and minimum temperature, and wind speed outputs downscaled using the Multivariate Adaptive Constructive Analogues (MACA) statistical downscaling approach (Abatzoglou and Brown 2012). Meteorological inputs used as the training dataset for the MACA downscaling were taken from Livneh et al. (2013) from 1950 to 2011. We used ten GCMs (Online Resource 2), selected from the Coupled Model Intercomparison Project 5 (CMIP5) archive (Taylor et al. 2011) based on their ability to simulate the historical climate in the western USA (Rupp et al. 2013). For each GCM, we used downscaled climate taken from the control forcing (1960–2005) and future forcing (2006–2099) experiments, with the latter including both Representative Concentration Pathways (RCPs) 4.5 and 8.5.

Since Livneh et al. (2013) used a standard lapse rate of −6.5 °C/km over the western USA, this may have introduced biases into our meteorological forcings, particularly over topographically complex regions that have heterogeneous lapse rates, such as on the windward side of the Cascades (Minder et al. 2010), which can significantly impact hydrologic modeling (Mizukami et al. 2013). Behnke et al. (2016) showed, however, that Livneh et al. (2013) is one of the better-performing gridded climate datasets over the contiguous USA (CONUS), despite the lapse rate assumption. While the choice of downscaling approach adds an additional layer of uncertainty (Gutmann et al. 2014), Mizukami et al. (2016) found that the choice of downscaling method resulted in less variability than the choice of hydrologic model. Thus, we expect that the inter-model variation between GCMs in our study is much larger than the spread that would have resulted from using multiple downscaling methods. However, dynamical downscaling methods, in contrast to the statistical downscaling that was used in this study, might have yielded different results.

2.3 Hydrological modeling

The VIC model (Liang et al. 1994) Version 4.1.2.l was run in energy balance mode at a 1/16° spatial resolution and a 3-hour time step over the western USA. Model spin-up was accomplished by running the model with gridded historical inputs from Livneh et al. (2013) for 1950–1959 for all simulations for the control period and with 1995–2005 downscaled output from each GCM (and each scenario) for the future runs. Hydrological fluxes and states were then archived at a daily time step. VIC model parameters were taken from Livneh et al. (2013) and were calibrated to observed and/or naturalized flows in Livneh et al. (2013) for multiple large river basins across the western USA. The VIC model output, as well as the MACA-downscaled GCMs, is archived at the University of Idaho Applied Climate Science Lab at http://climate.nkn.uidaho.edu/IntegratedScenarios/ (Northwest Knowledge Network) and is publicly available.

2.4 Fuel moisture modeling

The US National Fire Danger Rating system (NFDRS) estimates dead fuel moisture (DFM) for different sized fuel classes (Cohen and Deeming 1985). We computed 100 and 1000-hour DFM using regression equations for equilibrium moisture content (EMC) developed by Simard (1968) and used by the NFDRS (Cohen and Deeming 1985; see Supplemental Materials). The 100 and 1000-h DFM correspond to the timescale of exponential decay of DFM with respect to the EMC, with 1000-h fuel representative of larger-diameter fuels that respond more slowly to fluctuations in EMC than 100-h fuels.

2.5 Analysis periods

We partitioned the control and future simulations into four 30-year periods: historical (1970–1999), 2020s (2010–2039), 2050s (2040–2069), and 2080s (2070–2099). We used these periods throughout our study to evaluate projected hydrologic changes during the twenty-first century. We also examined transient changes during the twenty-first century. Climate change results were calculated by comparing future GCM simulations with the control simulation from the same GCM.

3 Results

3.1 Temperature and precipitation projections

Average winter (November–March) temperature increases in all mountain ranges throughout the twenty-first century (Online Resource 3). Warming rates are generally larger over continental areas than maritime areas. For RCP 8.5, temperature increases exceed +4 °C by the 2080s and exceed +5 °C in the Northern and Southern Rockies. The Southern Cascades exhibit the least warming of the five mountain ranges, but still experience an increase of nearly +4 °C in the 2080s.

For most of the mountain ranges and lowland regions, the ensemble mean total winter precipitation increases up to 30% by the 2080s, with the exception of the White Mountains in Arizona and the Lower Colorado, which are projected to experience reductions in winter precipitation in the ensemble mean (Online Resource 4). The southern part of the Lower Colorado basin, in particular, shows a reduction greater than 30% by the 2080s in RCP 8.5. There are large differences between the 2020s, 2050s, and 2080s for RCPs 4.5 and 8.5, with increases becoming larger in the Missouri basin, the southern part of the Northwest Interior and the northern part of the Great Basin. Spring (March–May) ensemble mean precipitation shows a similar pattern in the Northwest Interior and the Missouri basin but shows decreases in the Great Basin.

3.2 Projected changes in snowpack

Shifts in precipitation and temperature impact snowpack across the domain. Figure 2 shows the ensemble mean of simulated SWE aggregated by mountain range as well as the full range and the interquartile range of aggregate SWE predicted by the ensemble of GCMs. Although the magnitude of the decline differs among models, decreasing trends

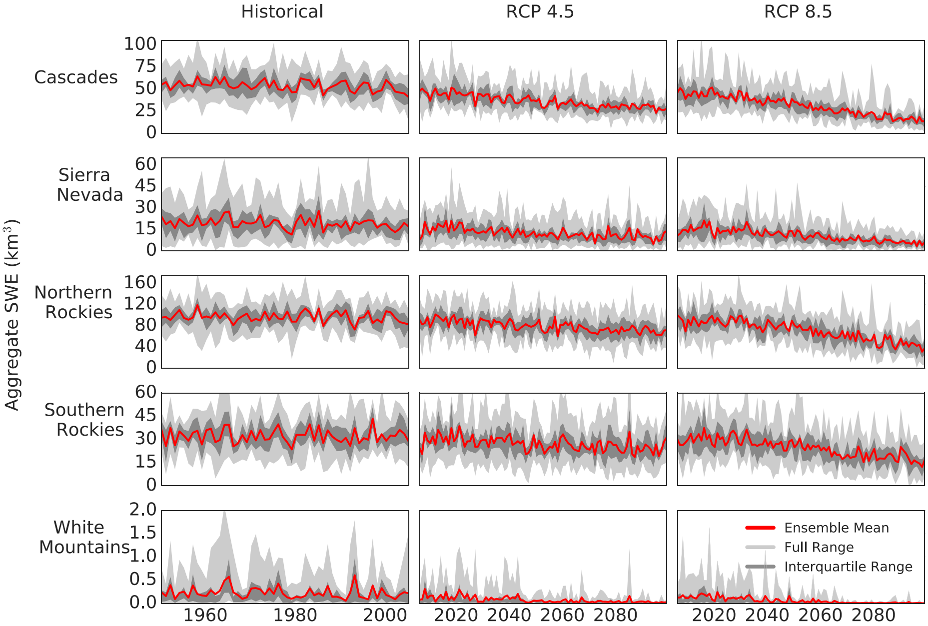

Fig. 2 Simulated April 1 SWE aggregated by volume over each mountain range for the five mountain regions. *Light gray* shows the full range projected by the GCMs, *dark gray* shows the interquartile range, and *red* shows the ensemble mean of the GCMs

are robust across all future simulations for mean April 1 SWE storage (in km^3) between the historical and future periods (Online Resource 6). The greatest relative decline in SWE is projected in the White Mountains, which by the end of the twenty-first century are projected to be nearly free of snow (95% reduction, ensemble mean) or entirely snow-free (maximum projected changes). Although the Northern Rockies also show a large decrease for RCP 8.5, it is substantially smaller in relative terms (48%) than for the Cascades, Sierra Nevada, and White Mountains, which have average projected losses of 65, 65, and 95%, respectively (Online Resource 6). Much of the differential effects of climate change on SWE can be explained in terms of elevation and thus temperature (see Online Resources 8 and 9).

Even though increases in temperature lead to a lower fraction of precipitation falling as snow and earlier melt, the spread in projected changes in precipitation contributes to uncertainty about the magnitude of spring snowpack change in some areas of the western USA. Figure 3 compares the spread in April 1 SWE projections (from all ten GCMs) for RCP 8.5 for the 2050s with the mean change in April 1 SWE (across all ten models) between the future and historic period (1970–1999). A higher value indicates that the range of SWE projections is larger than the mean projected change in SWE. For example, a value of 4 indicates that the range of SWE projections is 4 times greater than the mean projected change in SWE. High ratios occur in parts of the Cascades, Sierras, and much of the Northern and Southern Rockies, while low ratios occur in mid to lower-elevation areas. Luce (2016) used the same metric based on snow simulations at selected SNOTEL sites and found similar results for locations in the Northern and Southern Rockies.

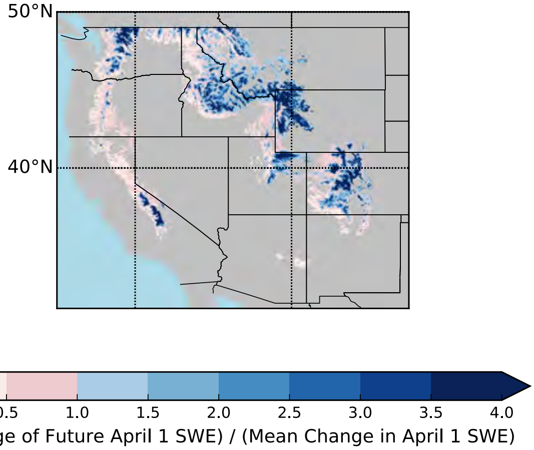

Fig. 3 Uncertainty in projected losses of SWE (absolute value of the difference between maximum and minimum April 1 SWE projected by the GCMs for RCP 8.5 2040–2069 divided by the mean projected change). *Red areas* indicate that the mean projected change is greater than the spread between GCMs. *Blue areas* indicate that the spread is larger than the mean projected change

3.3 Projected changes in soil moisture

Figure 4 shows the ensemble mean total column soil moisture storage for summer (June–August) for the historical period as well as projected changes for the 2050s for RCP 8.5. For each grid cell, the minimum annual average summer soil moisture from the control simulation has been subtracted from each year in the historical and future time periods. For most upland regions, large decreases in summer soil moisture result from earlier snowmelt, reducing soil moisture recharge that historically occurs during late spring and early summer snowmelt. The largest decreases occur in the Sierra Nevada and Southern Cascades, as well as parts of the Northern and Southern Rockies. Absolute declines in soil moisture in these mountain systems are accentuated because they historically have higher summer soil moisture. By contrast, changes in soil moisture for lowland regions are smaller in magnitude and feature differing signals. The largest decrease occurs in the Coastal North, with smaller decreases in the Coastal South and parts of the Lower Colorado and Missouri basins. Soil moisture storage is projected to increase in the Northwest Interior, Great Basin, and the southern part of the Lower Colorado. However, individual GCMs show varied projections for the lowland regions (Online Resource 10). The spread between GCMs for soil moisture in the lowlands is due to the dependence of summer soil moisture on winter, spring, and summer precipitation (Online Resources 4 and 5).

3.4 Projected changes in fuel moisture

Figure 5 shows historical and projected changes in 100-h DFM averaged over June–September, which encompasses much of the primary fire season for the western USA. Historical DFM values are substantially lower at low-elevation sites relative to the uplands as higher elevation areas typically receive more precipitation and have lower temperature and vapor pressure deficits. In the mountain ranges, nearly all areas experience decreases in DFM, from a relatively minor decrease in the 2020s to a much larger relative decrease (greater than 25%) by the 2080s. This pattern is particularly strong in the Cascades and Northern Rockies, areas that were also projected to experience

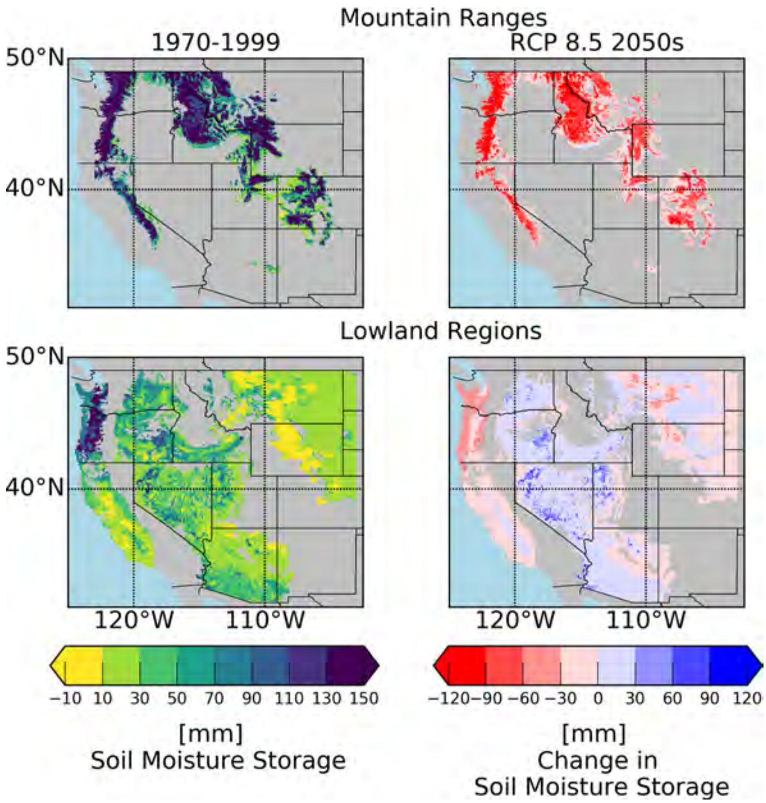

Fig. 4 Ensemble-mean simulated summer (JJA) soil moisture in storage for control simulations (*left column*) and change in storage between RCP 8.5 2040–2069 and the control period (*right column*) for the mountain ranges and lowland regions. The minimum summer soil moisture from the control period has been subtracted from each grid cell for control and future periods

increased aridity during the fire season based on decreasing summer soil moisture. DFM projections for the lowlands are more varied. Most of the lower elevations are projected to see declines in DFM, although at substantially smaller magnitudes than for neighboring higher elevation regions. Portions of the Lower Colorado show increases in DFM by the 2080s, presumably due to increases in summer precipitation in downscaled climate projections. The increasing and decreasing signals observed for 100-h DFM are largely the same for 1000-h DFM (Online Resource 11), with larger decreases in 100-h DFM in the Northwest Interior and Missouri regions.

Projected changes in DFM are not robust across GCMs in all areas. Online Resource 12 shows the number of models with positive changes minus the number of models with negative changes in 100-h DFM for RCP 8.5 in the 2080s. A negative number indicates that a majority of models shows a decrease in DFM, while a positive number indicates an increase in DFM. There is less agreement among models in the Sierra Nevada and Coastal South, as well as the Southern Cascades and the Southern Rockies, with little to no agreement in the southern part of the Coastal South and the Lower Colorado. Results for 1000-h DFM are similar, except with greater agreement for the Great Basin and Lower Colorado regions (Online Resource 13).

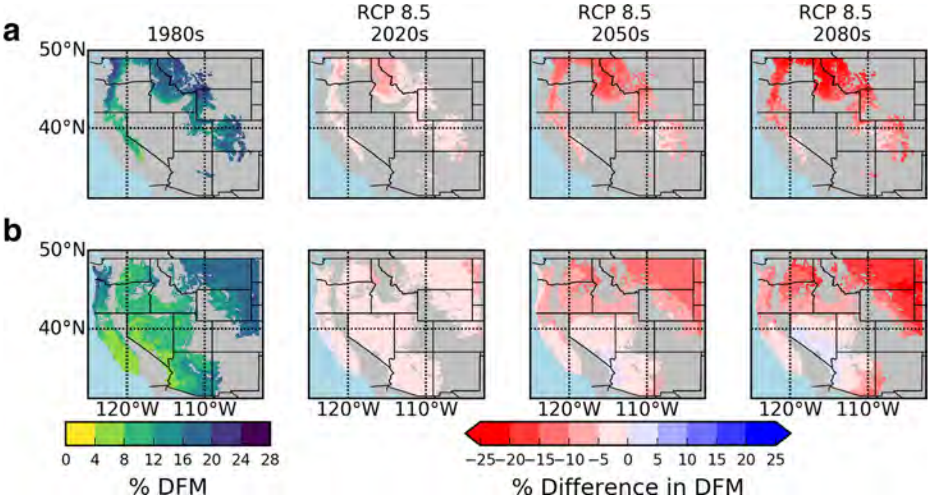

Fig. 5 Ensemble-mean summer (JJAS) 100-h dead fuel moisture (DFM) shown over **a** the five mountain ranges and **b** the six lowland regions, for the control period (1970–1999) and RCP 8.5 2010–2039, 2040–2069, and 2070–2099. For the control period, % DFM is shown, and for future periods, the % difference in DFM. DFM was calculated using the NFDRS algorithm for fuel moisture

4 Discussion

Our projected snowpack changes are generally consistent with previous studies that have examined changing snowpack in the western USA (e.g., Maurer 2007). Our results show relatively large declines in snowpack in all mountain ranges for all future scenarios and GCMs (Online Resource 7). Spring snowpack in mountains near the Pacific Coast is extremely sensitive to warming temperatures, while snowpack in more continental mountain ranges (Northern and Southern Rockies) is more sensitive to changes in precipitation (Online Resource 9), a result that is consistent with Adam et al. (2009) and other recent studies (e.g., Scalzitti et al. 2016; Luce et al. 2014). This sensitivity to warming temperatures explains the strong decline in snowpack in the Cascades and Sierra Nevada that is robust to potential increases in precipitation. The Cascades are projected to lose up to 81% of April 1 SWE storage, or up to 47.3 km^3 of total SWE by the 2080s. The Sierra Nevada are projected to lose up to 76% of SWE storage, or up to 13.4 km^3 of total SWE.

These declines translate into dramatic losses of a key source of water storage for the surrounding regions, many of which primarily rely on snowmelt for water supply. For example, the San Joaquin Basin in California has over 80 dams, with a total storage capacity of about 9.5 km^3 (7.7 million acre-feet) on the San Joaquin, Merced, Tuolumne, and Stanislaus rivers (California Environmental Protection Agency 2011). The maximum projected loss of SWE storage in the Sierra Nevada exceeds the San Joaquin Basin total storage capacity by 40%. Even the average projected loss of SWE storage in the Sierra Nevada for RCP 8.5 in the 2080s (11.3 km^3) exceeds the San Joaquin total storage capacity.

Future projected declines in April 1 SWE translate to declining summer soil moisture for all mountain ranges. Low summer soil moisture, in turn, is closely linked to fire potential and burned area in forested systems like the Northern Rockies (e.g., Higuera et al. 2015). Thus, projected declines of summer soil moisture in the mountain ranges lead to increased drought and are likely to increase the potential for wildfire in systems where large fires have historically coincided with such conditions (e.g., Westerling et al. 2003), but significant uncertainty remains with regard to projected changes in snowpack, soil moisture, and fire potential. Our findings are mostly consistent with previous studies that have identified the Sierra Nevada, Cascades, and Northern Rockies as the most at-risk areas in the western USA for increasing fire activity in a changing climate (Westerling et al. 2011a, b; Barbero et al. 2015; Littell et al. 2010; McKenzie and Littell 2016), with the exception of fire potential projections in the Yellowstone region in Westerling et al. (2011b), which our results contradict.

Summer soil moisture at lower elevations shows a mixed response to climate change. The Northwest Interior, Lower Colorado, and Great Basin are projected to experience increased summer soil moisture, while modest decreases are projected for the Missouri and Coastal North regions. The Coastal South region lacks a strong signal. Summer soil moisture increases in these basins are due to increased spring precipitation (Online Resource 5), which supersedes the effects of warming temperatures (Online Resource 3). There is much larger uncertainty in precipitation than temperature projections (Kharin et al. 2013); hence, the lack of robust agreement for areas where spring snowpack does not strongly influence summer soil moisture. The weaker drought-fire relationships, particularly for rangeland-dominated regimes, and lack of robust changes in soil moisture are less informative for projecting future fire potential in the lowland regions.

Similar differences are apparent in DFM changes between mountains and lowland regions. Decreases in 100-h DFM across mountain ranges, in concert with declines in soil moisture, suggest the potential for increased fire activity. Decreases in DFM in the lowland regions may enhance fire potential in flammability-limited fire regimes, but may not substantially alter fire potential in arid systems. Moreover, the models show a lack of agreement in changes in DFM in areas where the projected change in summer soil moisture lacks a distinct signal, such as in the Coastal South region (Online Resource 10). The confounding signals of increased summer soil moisture and decreased DFM in regions such as the Northwest Interior may have interesting impacts on fire regimes that warrant additional analysis, but are beyond the scope of this study.

5 Conclusions

Projected effects of climate change across the western USA contrast strongly for mountains and lowlands. The water balance of the mountainous portions of the domain is strongly linked to snow accumulation and ablation, which is strongly temperature-sensitive but varies across the domain. Changes in April 1 SWE in the higher-elevation areas of the Northern and Southern Rockies, North Cascades, and Southern Sierra are more uncertain due to larger spread in precipitation projections, whereas in other parts of the mountainous west, temperature projections dominate. Warming temperatures will result in declining snow water storage, and consequently, moisture inputs to the soil column will increase in winter and decrease in spring and summer. The result will be substantial reductions in summer soil moisture storage and increases in water deficit. We project large decreases in DFM in mountain ranges, which would increase fire potential.

The main conclusions of our work are as follows:

- In the five mountain regions, we project large declines in spring snowpack and summer soil moisture, primarily due to warming temperatures. This will result in April 1 SWE

losses by the 2080s of up to 81% for the Cascades and 76% for the Sierra Nevada mountains.
- Ensemble mean summer soil moisture is projected to decrease in the mountain ranges and to increase in lowland regions. In the lowland regions, trends are not robust across GCMs due to differences in precipitation projections.
- Dead fuel moisture content (as represented by 100-h and 1000-h DFM) is projected to decrease in the mountain ranges and mostly increase in the lowland regions (for the ensemble mean). Lowland increases are of much smaller magnitude than the mountain decreases. Changes in fuel moisture content, however, are not robust across the western USA.
- Overall, we conclude that the mountain ranges are on average likely to experience higher fire potential under future climate projections. Other parts of our domain may also experience increased potential, but there is greater uncertainty in the lowland regions, where there is less agreement between GCMs, as well as in the Sierra Nevada, where there is disagreement between soil moisture and fuel moisture projections.

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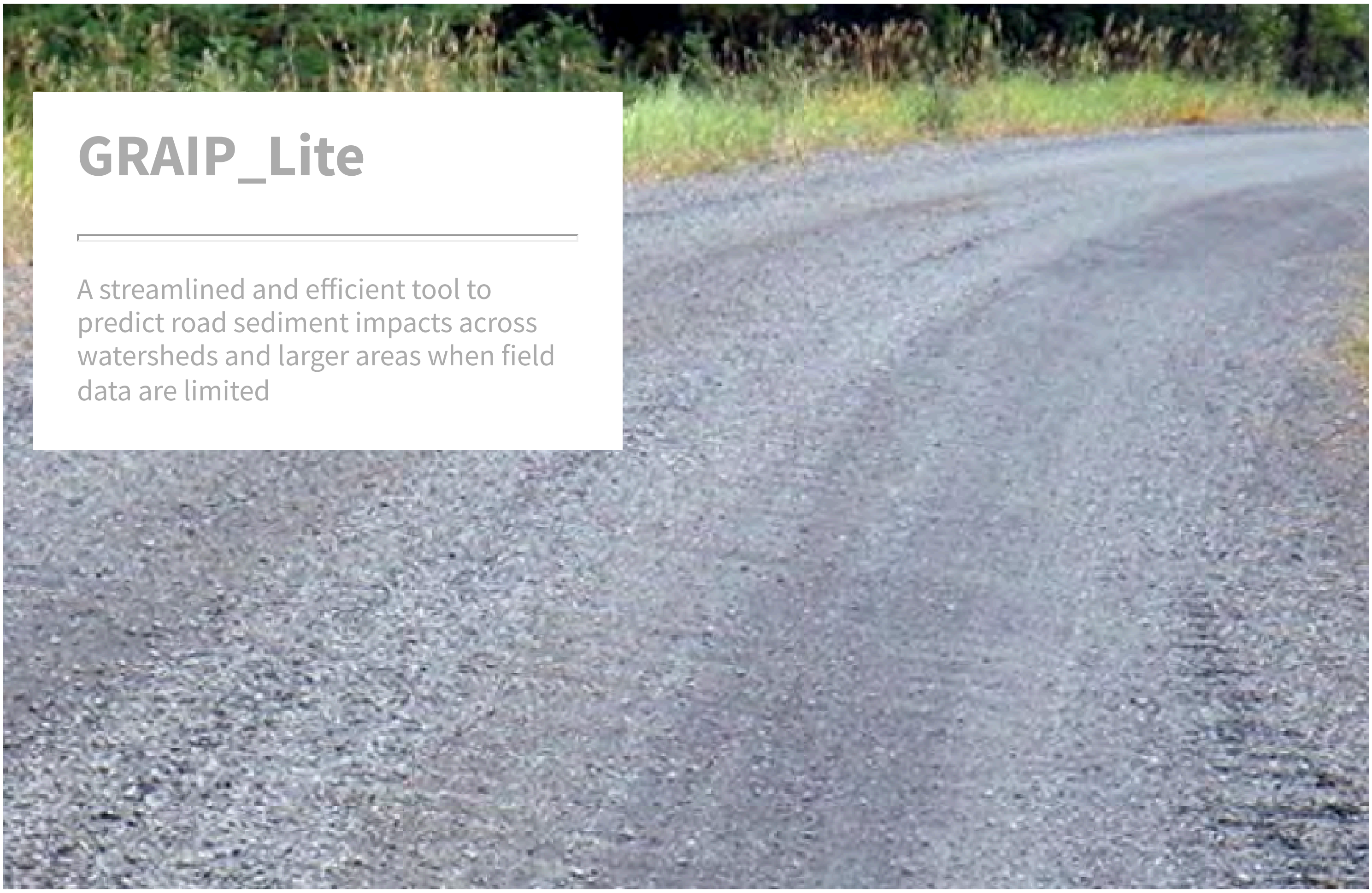


GRAIP_Lite

A streamlined and efficient tool to predict road sediment impacts across watersheds and larger areas when field data are limited

GRAIP_Lite

Status: Ongoing

GRAIP_Lite is a streamlined and efficient way to predict road sediment impacts across watersheds and larger areas when field data are limited. If you need to model site specific road impacts on smaller project areas where field data can be applied, then the GRAIP tool set may be more appropriate.

Overview

GRAIP_Lite uses DEMs, already existing road GIS layers with surfacing type information, and a small field calibration dataset to determine 6th code subwatershed scale road sediment production and delivery.

Road layers are broken into GRAIP-style segments. Production is calculated in the usual GRAIP way, and delivery is based on the flow distance from the road to the stream and the calibrated probability of delivery at that distance. GRAIP_Lite is good at narrowing a large potential project area to the smaller watersheds with the most sediment problems.

Though GRAIP and GRAIP_Lite share some elements, the two models are not equivalent. GRAIP is used to inventory and analyze forest roads at a fine road-segment scale, and utilizes an intensive field inventory to accomplish this. GRAIP results are spatially explicit within a few meters and can be used to locate, prioritize, analyze, and monitor specific road treatments. Because GRAIP is so comprehensive, the time investment often prohibits its application it on a scale wider than a 5th code watershed at a time.

GRAIP_Lite uses the same principles as GRAIP to determine broad-scale road surface sediment risks over a much wider area very quickly, and is used as a tool to determine where the largest problems likely occur on a 6th code subwatershed scale. Further work such as a full GRAIP inventory can then be applied in order to find the specific locations within the subwatershed that have problems that should be addressed. There is a minimal field component (to gather a calibration dataset), but most of the modeling uses existing datasets and can be completed in the office.

We suggest that you start in your areas of critical concern. In Oregon, Washington, and Idaho we are focused on roads impacting aquatic habitat for endangered fish species. We have worked on watersheds that are on the 303(d) list due to elevated fine sediment input. Other regions have concerns about road related landslides and gullies, post-fire effects and restoration, or decommissioning un-needed roads. GRAIP_Lite can help determine which watersheds in a larger area are likely to be most impacted by road surface fine sediment.

Deliverables

GRAIP_Lite Download

- Arc Hydro Downloads for ArcMap and ArcGIS Pro

Nation-wide Model Runs for Watershed Condition Classification Assessments

GeoDatabase Documents and Information

- Information on the road layers for WCC - About these Data
- General Methods and Processing Steps

Other documents

- Watershed Condition Classification (WCC) Technical Guide
- Watershed Condition Framework (WCF)

Downloads

Road Density, Proximity and Erosion Data (both unit sets1) and Stability Index Information by Forest Service Region available here.

National Geodatabases

Road Density, Proximity, and Erosion Data for the entire U.S.

- National SI GeoDatabase (contact team to request files)
- National USC GeoDatabase

Stability Index Information for the entire U.S.

- National Slope Stability GeoDatabase
  GRAIP_Lite uses the Standard International Units (SI) unit system commonly used in scientific and academic work. Since most users of this data are more likely to be using the U.S. Customary units (USC), and the thresholds for condition classes also use those units, we have done the appropriate unit conversions to provide a dataset using the USC units. It is important to note that, since we are using a unit baserate, that any sediment production and delivery values are index values and are not representative of actual sediment masses. If a baserate is known, however, they can be multiplied by that baserate in order to estimate actual sediment masses, but this baserate data is not widespread. Likewise, all slope stability values are index values and local knowledge is needed for interpretation.

Past Case Studies

Watershed	Project	Group	Contact	Reference	Version	Year
Battle Creek, CA	Battle Creek Sediment Assesment	TerraAqua for Battle Creek Watershed Conservancy	Steven Fortney	http://www.battle-creek.net/docs/watershe	ArcHydro GRAIP_Lite	2017
Upper Big Wood River, ID	Upper Big Wood River Project	USFS Sawtooth NF	Scott Vuono		ArcHydro GRAIP_Lite	2017
Middle Fork Weiser River, ID	Middle Fork Weiser River Landscape Restoration Project	USFS Payette NF	Melanie Vining	https://www.fs.usda.gov/nfs/11558/www/nepa/95	ArcHydro GRAIP_Lite	2017
Pacific NorthWest	Northwest Forest Plan Monitoring	USFS Pacific Northwest Regional Office, Portland, OR, AREMP	Peter Eldred		ArcHydro GRAIP_Lite	2016-2017
Southwest Crown of the Continent, MT	BSLRP (Blackfoot Swan Landscape Restoration Project)	USFS Northern Region Office, Missoulla, MT	Wade Davis		Netmap GRAIP-Lite	2016
North Fork of the Boise River, ID	Becker Integrated Management and Restoration Project	USFS Boise NF	Brian Anderson		GRAIP_Lite Beta version	2015

Training and Manuals

GRAIP_Lite Manuals

- GRAIP_Lite: A System for Road Impact Assessment
- GRAIP_Lite: A System for Road Impact Assessment (Poster)
- GRAIP Lite Quick Start

Trainings Videos

- GRAIP Lite: A Tool for Large Scale Assessment of Road Erosion
- GRAIP Lite: System setup tutorial
- GRAIP Lite: Basic Run Tutorial
- GRAIP Lite: Calibrated run tutorial
- GRAIP Lite: Basic Run Workshop
- GRAIP Lite: Calibrated Run Workshop
- GRAIP Lite: Alternatives Run Workshop

Tutorial Files

Tutorial files are available here.

Frequently Asked Questions

What does GRAIP_Lite do?

GRAIP_Lite uses DEMs, already existing road GIS layers with surfacing type information, and a small field calibration dataset to determine 6th code subwatershed scale road sediment production and delivery. Road layers are broken into GRAIP-style segments. Production is calculated in the usual GRAIP way, and delivery is based on the flow distance from the road to the stream and the calibrated probability of delivery at that distance. GRAIP_Lite is good at narrowing a large potential project area to the smaller watersheds with the most sediment problems.

How do I download GRAIP_Lite?

GRAIP_Lite is a GIS tool for predicting the sediment delivery from forest roads to streams using minimal field data. The required inputs are a road line and a DEM. The model is a component of ArcHydro and runs in ArcGIS 10.3 and higher.

People

Jump to: Key Personnel GRAIP_Lite Technical Team

Key Personnel

GRAIP_Lite Technical Team

Thomas A. Black
Hydrologist

Charles H. Luce
Research Hydrologist

Nathan Nelson
Hydrologist

Resources

Jump to: Data and Tools Documents Projects Publications Understory Publications

Data and Tools

Dataset

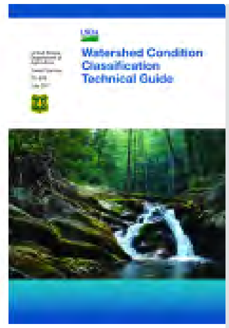
Road Density, Proximity, and Erosion Data and Stability Index Information

Tool

GRAIP_Lite Tutorial Files

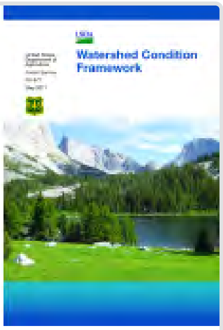
Documents

[GRAIP Lite Model Runs Processing Documentation](#)
File Type: pdf
File Size: 516KB



[GRAIP Lite Watershed Classification Guide](#)
File Type: pdf
File Size: 1816KB

[GRAIP Lite Slop Stability Nation Wide Model Runs for Watershed Condition Classification Assessments](#)
File Type: pdf
File Size: 284KB



[Watershed Condition Frameworks 2011](#)
File Type: pdf
File Size: 4477KB

[GRAIP_Lite Quite Start Guide](#)
File Type: pdf
File Size: 7789KB

[GRAIP_Lite Poster](#)
File Type: pdf
File Size: 13188KB

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Projects

Project

[Geomorphic Road Analysis and Inventory Package (GRAIP)](#)

Publications

- Thomas A. Black, Charles H. Luce. 2013. Measuring water and sediment discharge from a road plot with a settling basin and tipping bucket

Understory Publications

General

Evaluating Large-Scale Long-Term Forest Road Restoration Effects on Public Lands in the Northwestern United States Poster

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