RESILIENCE PLANNING FOR TLÁKW AAN (KLUKWAN)

CHILKAT INDIAN VILLAGE
TLÁKW AAN (KLUKWAN), SOUTHEAST ALASKA
ENVIRONMENTAL DEPARTMENT
RESILIENCE PLAN 2023

CHILKAT INDIAN VILLAGE

"Yee gu.aa yax x'wan."

This 2023 Resilience Plan for Tlákw Aan (Klukwan) explores the observed and expected effects of a changing climate and environment on certain plants, animals, and critical infrastructure of Tlákw Aan (Klukwan). The plants and animals are a valuable cultural resource to Tribal Members and the village infrastructure is owned, serviced, maintained, and operated by the Chilkat Indian Village (Klukwan) Tribal Government. This plan and planning process was a project implemented by the Chilkat Indian Village's Environmental Department through the leadership of the Chilkat Indian Village's Tribal Council. The Chilkat Indian Village developed this plan to support actions that build resilience for the Village of Tlákw Aan (Klukwan), and the communities and people that live within the Upper Lynn Canal, with the hopes that current and future generations will continue to flourish here on the banks of the Jilḵáat (Chilkat) River as they have since time immemorial.

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SUMMARY

"Compounding the impacts to our cultural resources are the impacts from climate change. During the past few years, our natural resources within the Chilkat Valley have been diminished due to plants being burned from the sun as well as lack of rain in the valley, which left us fewer gathering options for berries, medicine, and various subsistence plants."
-Tribal Member, Resilience Planning Process, 2019-2022

"Chilkat River flooding and erosion is removing a large section of the riverbank next to the Jilkaat Kwaan Heritage Center campus and threatens the existence of this campus and its buildings."
-Tribal Member, Resilience Planning Process, 2019-2022

"The damage to homes from landslides, flooding, extreme rain and freeze/thaw events, and avalanches have made homes unsafe and unhealthy to live in."
-Tribal Member, Resilience Planning Process, 2019-2022

"There was always snow on the mountain tops during my childhood. Now, there are times when there is no snow on the mountain tops."
-Tribal Member, Resilience Planning Process, 2019-2022

Chilkat Indian Village (CIV) Tribal Council and staff, CIV Tribal Members, and residents of Tlákw Aan (Klukwan) are observing environmental changes and impacts on village infrastructure and the plants and animals. The Chilkat Indian Village is a federally recognized sovereign nation, with the local jurisdictional and governing authority of the Village of Tlákw Aan (Klukwan). Our elected governing body, the Tribal Council, is responsible for upholding our tribal government's constitution and works to provide services to our Tribal Members. The CIV Tribal Council passed a resolution in 2018 that identified Climate Change as a priority issue for the Environmental Department to research, plan for, and respond to, by the end of 2022.

Following the Council's resolution, in 2019, the Environmental Department initiated a multiyear planning process to increase CIV's understanding of how the climate is changing and how the changing environment is impacting plants and animals and community infrastructure. The planning process meant to identify next steps to continue to address rapidly emerging issues and develop an Action Plan to improve CIV's resilience and sustainability in the face of climate change.
The Environmental Department is responsible for providing the following services and coordinating the following programs for CIV and the Village of Tlákw Aan (Klukwan):

1. Water and sewer
2. Landfill
3. Environmental Monitoring
5. Brownfields Program
6. Environmental Planning
7. Government to Government Consultation and Permitting

This plan offers important insight for the Environmental Department but also CIV's Housing, Transportation, Emergency Operations, and Realty departments.

The objectives of the Chilkat Indian Village's resilience planning process were to:

- Work with Tribal Members, CIV staff, and CIV Council to compile knowledge of Tlákw Aan (Klukwan) infrastructure and plants and animals and their historical relationship to weather and climate.
- Work with climate scientists to compile relevant climate information for the Jilḵáat Ḵwáan and Lḵoot Ḵwáan territories (Upper Lynn Canal region)
- Assess the vulnerability of infrastructure and plants and animals based on projected changes in climate.
- Develop an action plan addressing the most vulnerable resources.
- Compile all information into a final plan that can be referenced by CIV, our partners, and others working to respond to a changing environment in the Chilkat Valley.

ACKNOWLEDGEMENTS

Gunalchéesh.

This resilience planning process was a multi-year undertaking. Many people and entities contributed to the planning process and made this final plan possible. The Chilkat Indian Village is grateful for all who provided time, information, and resources. The knowledge, skills, and tools CIV acquired throughout this planning process has equipped our Tribal Government and staff with necessary understandings, capacities, and partnerships to try and address the impacts from Climate Change on Tlákw Aan and the plants and animals that live within the territory of the Jilḵáat Ḵwáan and Lḵoot Ḵwáan. This plan would not have happened without the leadership and guidance of Vice President Jones P. Hotch Jr. and Tribal Council Member and project coordinator Dan Hotch.

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Chilkat Indian Village, Environmental Department
Sustainable Solutions

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Chilkat Indian Village, Klukwan

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- Southeast Alaska Watershed Coalition
- Takshanuk Watershed Council
- Central Council Tlingit and Haida Indian Tribes of Alaska

PART 1

This Resilience Plan is organized into two parts: Part 1 provides an overview of what information was gathered and learned during the Resilience Planning Process. Part 2 is meant to provide an overview of possible next steps to address climate vulnerabilities, and technical reports that informed this plan and planning process.

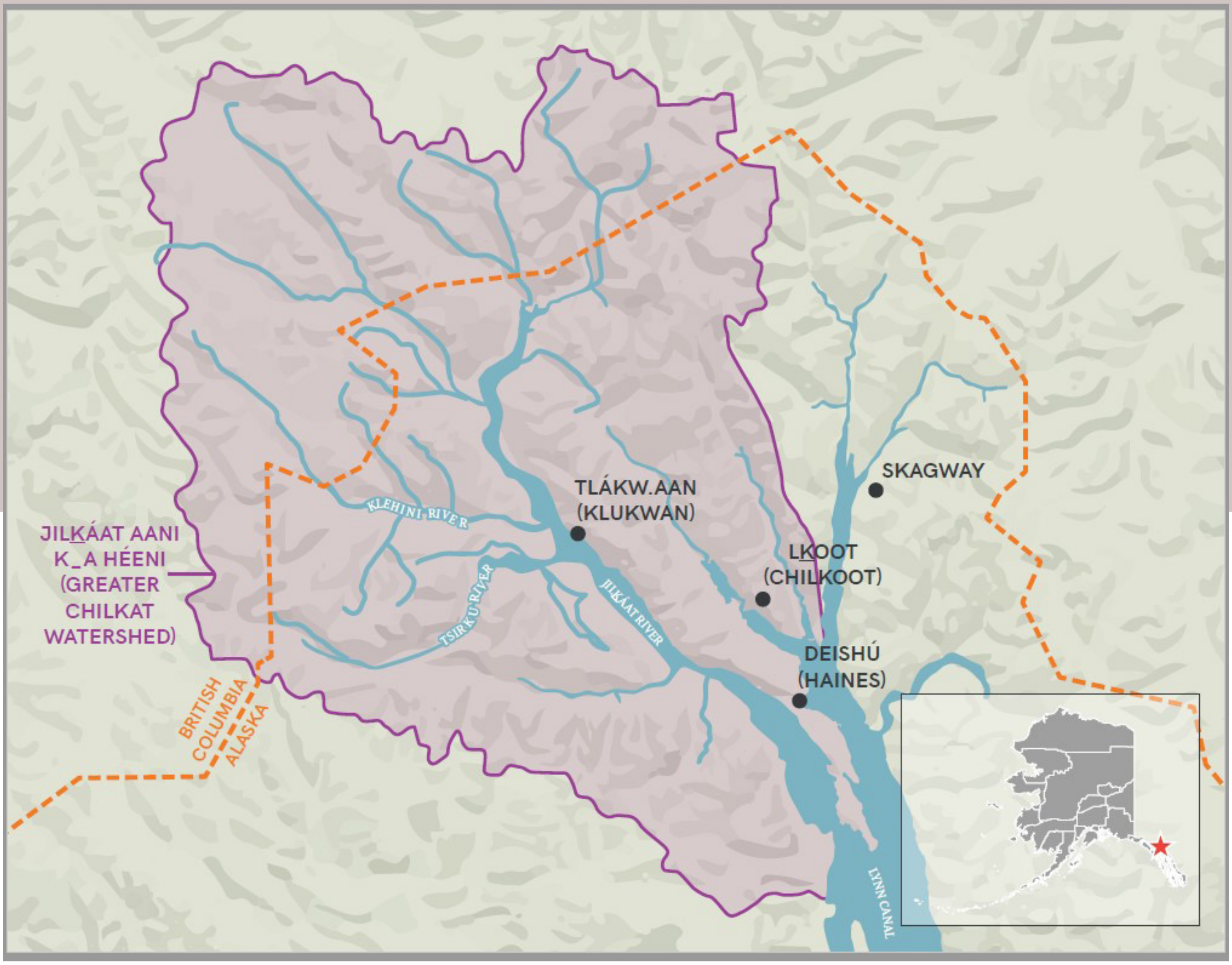
This resilience plan focuses on climate change impacts on critical infrastructure in Tlákw Aan (Klukwan) and to the plants and animals that are important cultural resources to the Chilkat Indian Village and its Tribal Members.

GENERAL OVERVIEW: TLÁKW AAN (klukwan)

Photo: Village of Tlákw Aan along the bank of the Jilḵáat River

Tlákw Aan (Klukwan) is located within the Jilḵáat Aani Ka̱ Héeni (Chilkat River Watershed). Jilkáat Aani Ka̱ Héeni is one of the primary watershed basins within the Jilḵáat Ḵwáan traditional territory that sustains the present-day way of life of the Jilḵáat Ḵwáan[1] and the residents of the Village of Tlákw Aan (Klukwan). The village rests on the banks of the glacially fed Jilkáat (Winter Salmon Container) (Chilkat) River, immediately below its confluence with the L'ehéeni (Klehini) River, and across from its confluence with the Dzixkú (Tsirku) River.

1 Jilḵáat Ḵwáan and Lḵoot Ḵwáan (region name) with communities: Haines, Chilkoot, Skagway, Dyea, Chilkoot Trail, Upper Lynn Canal



Map: Jilḵáat Aani Ḵa Héeni (Chilkat River Watershed) of the Upper Lynn Canal, Southeast Alaska. This map depicts the territories of the Jilḵáat Ḵwáan and the Lḵoot Ḵwáan.

Tlákw Aan is approximately 22 miles upriver from the community of Haines, and within 17 miles of the border of British Columbia, Canada. Tla'kwaan has been a site of human habitation for millennia and is the only inland Lingít (Tlingit) village in Southeast Alaska. Klukwan is an anglicized version of the Lingít name Tla'kwaan, which literally translates to "Eternal Village."

The area around Tlákw Aan is defined by rugged mountains, steep-gradient streams, braided rivers in broad valleys and numerous glaciers[II]. The geography and climate have provided the Jilḵáat Ḵwáan with access to an abundance of plants, animals, fresh water, and clean air. Twenty-two miles southeast of the Village lie the upper reaches of Lynn Canal, where a mild and moist maritime climate supports a western hemlock-Sitka spruce forest ecosystem. Twenty miles to the north are the Canadian border and mountain passes which open to the dry subarctic interior region.

II Bugliosi, E.F., 1988. Hydrologic Reconnaissance of the Chilkat River Basin, Southeast Alaska. U.S. Geological Survey Water Resources Investigation Report 88-4023. Anchorage, AK.

The quantity of water that moves through Jilk̲áat Aani Kag̲ Héeni (Chilkat River Watershed) is significant. The watershed is influenced by melting glaciers, geologic faults, and extreme precipitation events that contribute to avalanches, flooding, and landslide events. Jilk̲áat K̲wáan villages have always been built on the riverbanks and at the confluence of multiple glacially fed rivers. Ground moving events have always been a part of our people's history and, considering climate change projections, will continue to be so. Our ability to adapt is significant and is a key component in our ability to continue to survive and thrive here today.

Photo: Glacier Creek. A tributary to the L'ehéeni (Klehini) River. Derek Poinsette. Takshanuk Watershed Council

Haa Atxg̲ayí Haa Kusteeyíx S̲itee ("Our food is our life"). Our Tribal member's health, nutrition and well-being is directly connected to the health and well-being of the land, water, air, and the wild salmon, other anadromous and terrestrial species, and the medicinal plants that live within the Jilk̲áat K̲wáan territory. The plants and animals are changing, and their behaviors and their physical attributes are changing. These changes are being brought about by changes in the environment we share.

Environmental Setting of Tlákw Aan (Klukwan)

Tlákw Aan is located between two geographic zones, maritime and subarctic interior. Altitudes range from sea level at the mouth of Jilk̲áat Aani Kag̲ Héeni to 7,434 ft at the summit of Mount Henry Clay. The Jilk̲áat Aani Kag̲ Héeni (Chilkat River watershed) is divided into two distinct geologic provinces by the Denali River fault (which roughly parallels the Jilk̲áat River), an extension of the Chatham strait fault system to the south.

Photo: Eagles along the banks of the Jilk̲áat River. Colin Arisman

The geological history of the Jilk̲áat River basin includes periods of mountain building which began as late as 60 million years ago and presently continues. This movement produced the rugged, highly dissected mountains that are characteristic of the area. Glaciation is still dominant in the upper parts of the basin. Most types of glacial features can be found, including ground moraine which covers much of the bedrock at lower altitudes[III]. The ecosystems in the Chilkat Valley could be considered young by most geologic standards because much of the valley was scoured by glacial ice of the last glacial maximum (10,000 years ago) down to 750 feet below present-day sea level[IV].

III Bugliosi, E.F., 1988. Hydrologic Reconnaissance of the Chilkat River Basin, Southeast Alaska. U.S. Geological Survey Water Resources Investigation Report 88-4023. Anchorage, AK.

IV Rennick, P. (ed)., 1984. The Chilkat River Valley. Alaska Geographic, Volume 11 (3). Anchorage, AK.

As the area glaciers have mostly been shrinking since that time, debris from the retreating glaciers and outwash have filled the valley, and vegetative succession using the available moisture from the Gulf of Alaska has actively reclaimed the landscape. This landscape is also "rebounding" upwards as the North American plate is relieved of this previously extensive glacial mass. Glacial Isostatic "rebound" rates in the Upper Lynn Canal have been measured lifting the landscape above sea level at a rate of 17.91mm/year[V].

A defining feature for Tlákw Aan is the Dzixkú (Tsirku) River's "very pronounced, and very active alluvial fan"[VI]. This alluvial fan discharges relatively warm groundwater in seeps and springs year-round to the Jilḵáat River, maintaining ice-free reaches downstream of Tlákw Aan that support spawning habitat for a late run of chum and coho salmon. These late spawning salmon in turn promote one of the world's largest gatherings of eagles on these "council grounds". Tlákw Aan itself sits on the Klukwan alluvial fan at the base of Iron Mountain. This area is prone to ground moving events caused by mudslides, avalanches, flooding and earthquakes.

Jilḵáat Aani Ḵa Héeni (Chilkat River Watershed) is a site of climate[VII] variability, neither truly coastal rainforest nor interior boreal forest. The Chilkat Valley experiences a climate that is directly regulated by its densely mountainous ("orographic") setting in-between the Gulf of Alaska, with its persistent low-pressure systems, and the Yukon Boreal Cordillera, with its more stable high-pressure systems.

Photo: Village of Tlákw Aan. Looking West upstream with the Dzixku (Tsirku) River alluvial fan to the left.

V Skagway-NOAA: https://tidesandcurrents.noaa.gov/sltrends/

VI Natural Resource Conservation Service (NRCS), 2002. Watershed Planning Assistance to the Village of Klukwan. "Klukwan Trip Report-June 2002". NRCS, Anchorage, AK.

VII "Climate" is generally defined as the long-term average of weather events over 30 years or more.

The valley's dynamic weather[VIII] outcomes are therefore the result of these competing dominant climate systems; a complex blending of these climates can bring moderate temperatures and light winds to the region, but often the weather is the result of one climate system prevailing over the other:

the coastal low-pressure systems that bring moderate temps, strong southerly winds, and precipitation in the summer and winter, and the Yukon air mass which brings clear weather and warm diurnal temps in the summer and cold air and northerly outflow winds in the winter.

Within the Chilkat Valley, Tlákw Aan's location is influenced by unique climate characteristics: it is far enough up the valley to be in the lee of many of the strong southerly low-pressure systems travelling up Lynn Canal. It is often said the weather in Tlákw Aan is more "pleasant" with less wind and rain then 22 miles down valley in Haines on the shores of Lynn Canal. Tlákw Aan's protected location also facilitates warmer average temperatures in the summer months and colder average temperatures in the winter months when compared to Haines, often differing by as much as 10°F[1].

Photo: Chilkat Lake draining into the Dzixkú (Tsirku) River. Colin Arisman

VIII "Weather" is defined as the state of the atmosphere at any given time in a certain location.

ONGOING CLIMATE CHANGE

Global average annual temperature has increased about 1.5° Fahrenheit from 1880 to 2012. Over half of this observed warming from 1951-2010 is attributed to human activities[2], such as the burning of fossil fuels for power generation, heating, and transportation, as well as agricultural practices and deforestation[3], all of which release heat-trapping greenhouse gasses (GHGs) into the Earth's atmosphere[4]. This global increase in temperature has driven many observed changes across the earth's ecosystems (Figure 1).

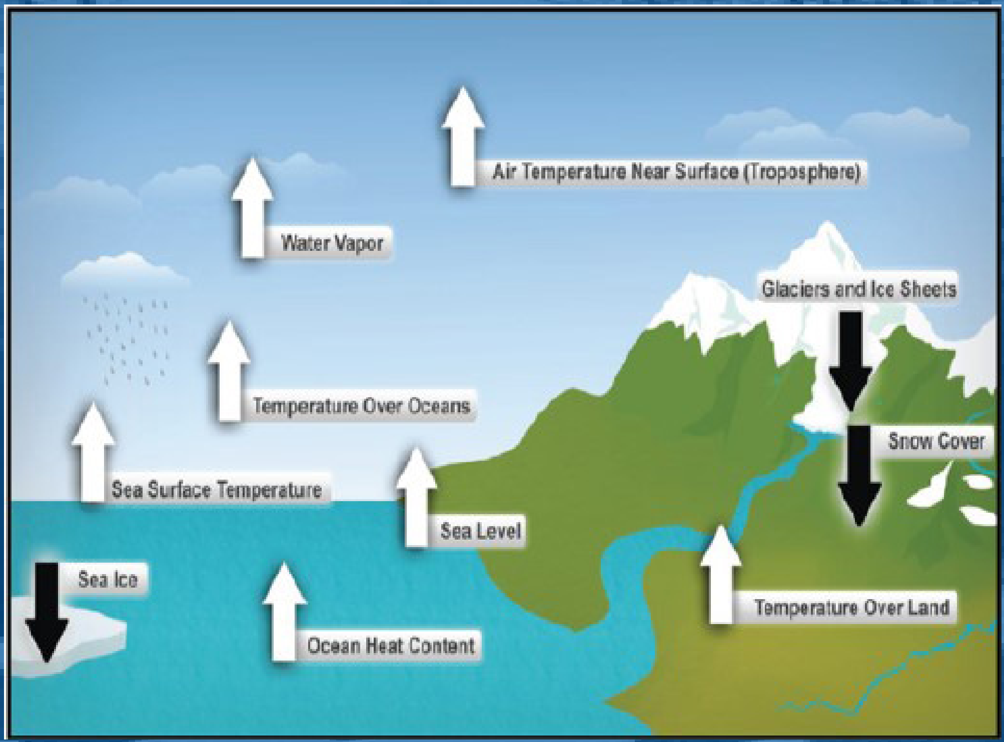


Figure 1. Some of the global indicators showing that the Earth's climate is warming. White arrows indicate increasing trends while black arrows indicate decreasing trends[5].

Without major reduction of human driven GHG emissions and their dominant contribution to global climate change, there is a worldwide scientific consensus[6] that global temperature increases and associated ecosystem trends will continue over the next century. In Alaska, warming has occurred over twice as fast as the global average since the middle of the 20th century. Alaska has experienced an average annual increase of 0.7^{0}F per decade since the 1970s. The warming involves more extremely hot days and fewer extremely cold days[7].

During this planning process, residents of Tlákw Aan noted recent changes from the historical climate of the Chilkat Valley, including warmer temperatures, shorter winters, less snow in the winter, earlier snowmelt in the summer, more flooding events, more extreme precipitation events and more frequent, and lower extremes of river levels.

These categories of observed changes are broadly shared by other tribal and first nation members across Southeast Alaska and Coastal British Columbia[8]. These collective Traditional Ecological Knowledge observations speak to region and ecosystem-wide change, and that generally "animals are not following their usual behaviors.[9]", resulting in increased uncertainty in timing and access to traditionally harvested resources.

CLIMATE EXPOSURE AND PROJECTIONS FOR THE JILḴÁAT AANI ḴA HÉENI (CHILKAT RIVER WATERSHED)

Scientists use the global warming they have already observed over the last century, paired with scientific findings about much longer-term climate changes on the planet, to "project" future temperatures and associated atmospheric effects. These global climate trends and projections are an important starting point, but regional and local understandings of climate change projections are the most useful for assessing the potential impacts to the ecosystems, plants, animals, and infrastructure resources of the Chilkat Valley. To develop the regional climate projections that are presented below, CIV partnered with Alaska Sea Grant, University of Alaska Fairbanks and Alaska Climate Adaptation Science Center, University of Alaska Fairbanks.

The climate projections for the Northern Southeast Alaska region generally describe an environmental future that will be warmer, that receives more precipitation falling as rain that historically fell as snow, and receives increased precipitation during extreme events. These changes hold widespread implications for the regional watersheds, through alterations to snowpacks, glaciers, and riverine and alpine habitats. Across the ecosystem, later freeze dates and earlier thaw events will shift patterns of snow accumulation, glacier volume, soil temperatures, and types of precipitation run-off.

Table 1 below describes different projections of climate variables relevant to the Chilkat Valley. Descriptions of "less severe" or "more severe" climate change refer to RCP 4.5 (less severe) and RCP 8.5 (more severe) emissions scenarios. See Part 2: Technical Reference for more information on these scenarios.

Table 1. Relevant Climate Change Projections for the Chilkat Valley

Climate Variable	Mid-century (2040-2069) with less severe climate change	Mid-century (2040-2069) with more severe climate change	End of century (2070-2099) with more severe climate change
Klukwan area Average Annual Temperature[10] See Footnote[11]	Increase 4.3 °F	Increase 5.5 °F	Increase 8.5 °F
Klukwan area Average Annual Precipitation[12] See Footnote[13]	Increase 9.7%	Increase 8.2%	Increase 17.5%
Klukwan area October-March Snowfall Precipitation (measured in snowfall water equivalent)[14] See Footnote[15]	Decrease ~15%	Decrease ~20%	Decrease ~40%
Southeast AK Annual Maximum One-day Precipitation Amounts AND Annual Maximum Five-day Precipitation Amounts[16]		Increase 10-15%	
Inland areas of Southeast AK: Day of First Freeze[17]		Occurs 5-10 days later	Occurs 10-20 days later

There are many climate change factors that will impact the diversity of resources that are important to CIV. Below we have highlighted several areas that are being and will continue to be altered by a changing climate and in turn will impact our way of life: 1. Watershed Projections- Shifting Watershed Types, 2. Glaciers, 3. Rivers and riverbanks, 4. Riparian Vegetation, 5. Wildfires, 6. Alpine Habitat, 7. Landslides, and 8. Marine Environment.

1. Watershed Projections- Shifting Watershed Types

Jilḵáat Aani Ḵa̱ Héeni (Chilkat River Watershed) holds a diverse array of streams and watershed types; high gradient and low gradient courses, braided channels, wetlands, rain, snow, and glacially fed drainages, all with unique characteristics in type and timing of maximum and minimum discharge. Tribal Members access and utilize almost all these diverse types of systems. Warmer regional temperatures will generally bring more precipitation above freezing to fall as rain that historically fell as snow[18]. This will result in complex watershed "shifts" from glacial →snow→ rain watershed types.

Table 2. General Watershed Response to Climate Change in SE Alaska. Table adapted from[19]

Climate or Climate-Driven Change	Anticipated Watershed Response		Most Vulnerable Areas
	Glacial Streams	Non-Glacial Streams	
Air temperature increases	• Larger and/or earlier glacial melt inputs • Increased stream flow in all seasons • Increased water temperatures unlikely unless glacial source disappears	• Higher winter flows (increased rain runoff) and reduced summer flows (less snowmelt) • Increasing water temperatures, especially in summer • Less dissolved oxygen	• Non-glacial streams that are not connected to stable higher-elevation snowpack or groundwater • Glacial streams that lose all of their glacial ice • Streams with young growth riparian stands • Lower elevation streams • Streams on islands • Lower elevation, shallow and tannic stained lakes

Precipitation Changes	• Shifts from snow to rain:
	  • Increased winter runoff and turbidity
	• Increased precipitation:
	  • Increased flows and turbidity
	  • Higher magnitude rainfall peak flows
	• More extreme precipitation events:
	  • Increased runoff, flood magnitudes, and turbidity
		• Shifts from snow to rain:
		  • Increased winter runoff and turbidity, reduced summer runoff
		• Increased precipitation:
		  • Increased flows and turbidity
		  • Higher magnitude rainfall peak flows
		• More extreme precipitation events:
		  • Increased runoff, flood magnitudes, and turbidity	

Reduced Snowpack and Earlier Melt	• Increased summer stream flows	• Longer periods of lower summer stream flows • Decreased annual peak flows	

For the purpose of informing this planning process and the planning of future actions, the Southeast Alaska Watershed Coalition (SAWC) completed a "Watershed Hydrology Assessment: Current and Future Flow Patterns for Chilkat Indian Village." The assessment examined 30 watersheds across the Upper Lynn Canal and used a "more severe" climate change scenario (RCP 8.5) to project future streamflow patterns for: glacial dominant, snow dominant, transient (rain/snow mix), and rain dominant watersheds at the end of century (2080-2100). The comprehensive findings of this assessment are included in **Part 2: Watershed Hydrology Assessment.**

Thirty watersheds were selected for the purposes of this resilience planning process because of habitat importance for salmon spawning and rearing, use for drinking water or hydropower, and/or availability of relevant ancillary data (e.g. stream temperature). Watersheds were also included to incorporate a broad range of watershed types and sizes. Study watersheds range in size from <1 to 3815 km2, with mean elevation from 80-1355 m. All the study watersheds have streamflow that is currently dominated by glacial or snowmelt runoff. By the end of the century, most or all the glacial streams in the watersheds will have shifted to snowmelt-dominated, and several of the smaller, lower elevation watersheds will likely have streamflow patterns dominated by rainfall or a mix of rain and snowmelt. These shifts have the potential to increase drinking water and hydropower insecurity, especially during summer months. The impact of these watershed shifts on local salmon populations are likely to be largely negative, but these outcomes are complex and difficult to predict, this is considered in more detail below.

Of the 30 study watersheds in the Watershed Hydrology Assessment, six have streamflow patterns currently dominated by glacial melt: The upper and lower Chilkat watersheds, the Lḵoot (Chilkoot) headwaters, upper Glacier Lake Creek, Goat Lake watershed, and the Katzehin watershed. Of these, the Lḵoot (Chilkoot) River headwaters and Goat Lake watershed currently have the least percent glacier cover and are most likely to shift to snowmelt-dominated streamflow as the glaciers recede. Although glacier coverage is currently high in the Katzehin watershed, extensive glacial loss is expected there[20], so it will also likely shift to snowmelt dominated. The upper and lower Chilkat watersheds have glacier coverage projections at the end of century between 10%-20%. These watersheds are also likely to shift toward stream flow patterns that are more snowmelt influenced. The Glacier Creek watershed may see glacial melt continue to dominate streamflow through the end of the 21st century. Because of the lack of watershed-scale projections for glacier coverage (except for the Katzehin watershed), the timing of glacier loss in study watersheds is highly uncertain.

All other watersheds in the assessment have streamflow patterns dominated by snowmelt runoff. Although all watersheds are projected to receive less winter precipitation as snow, the majority will likely continue to receive enough snow to retain snowmelt-runoff dominated streamflow patterns. However, many of the lower-elevation watersheds are projected to lose enough snow to shift to streamflow patterns that are characterized by mixed snowmelt-rainfall or rainfall runoff. By the end of the century, Lily Lake and Mink Creek watersheds are projected to lose approximately two-thirds of their winter snowpack and shift to rain-fed systems.

Other watersheds that are expected to receive declining snowfall to the point where their streamflow patterns will shift toward a snow-rain mix include Little Salmon River, Mule Meadows, Assignation Creek, Mosquito Lake, Herman Creek, Clear Creek, and Chilkat Lake. The climate driven impacts of more severe drought and more severe flooding are likely to be more intense in rainfall- and mixed rain-snow dominated streams. More comprehensive findings of this assessment are included in **Part 2: Watershed Hydrology Assessment.**

- **Shifting Watersheds and Salmon**

The Jilḵáat Aani Ḵa̱ Héeni (Chilkat River Watershed) is home to all five species of wild pacific salmon. It has been noted that "The entire Chilkat Valley is fish habitat, with virtually every stream and river either a salmon spawning stream or tributary to a spawning stream[21]".

This Resilience Plan considers 6 distinct salmon stocks:

- Sockeye Salmon from Chilkoot Lake
- Sockeye Salmon from Chilkat Lake and Chilkat River mainstem
- Chinook Salmon from Chilkat River Sub-drainages
- Chum Salmon from Chilkat River Sub-drainages
- Coho Salmon from Chilkat River Sub-drainages
- Pink salmon from the entire Upper Lynn Canal

There are much more extensive details and references for each salmon species climate vulnerability in the Part 2: Technical Reference

These different salmon stocks will endure shifting watersheds in different ways based on their unique biological tolerances, spawning behaviors, and habitat use. All salmon transition through a range of life history stages: egg, alevin, smolt, fry, ocean phase, spawning phase. This life history involves two freshwater phases and one ocean phase which means salmon are subjected to wide range of environmental conditions during their lives.

All salmonids are poikilotherms *"...meaning their temperature and metabolism is determined by the ambient temperature of water. Temperature therefore influences growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food.[22]"*

Somewhat surprisingly, salmonid species do not vary much in their life history water temperature needs, regardless of their geographic location[23]. It is theorized that temperature tolerance is a core characteristic of salmon physiology and therefore has not seen large scale evolutionary changes between stocks (eg. Coho salmon will share water temperature thresholds across different locations).

This direct relationship between salmonids and water temperature means that certain temperatures can hold detrimental impacts across life stages:

Temperature changes can also cause stress and lethality. Temperatures at sublethal levels can effectively block migration, lead to reduced growth, stress fish, affect reproduction, inhibit smoltification, create disease problems, and alter competitive dominance. Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival[24].

EPA Region 10 recommends that the 7 day average of maximum water temperatures (7-DADM) should not exceed 55.4°F (13°C) for salmonid spawning, egg incubation, and fry emergence[25]. This could be thought of as an upper thermal threshold for salmonids with detrimental consequences when it is exceeded. The EPA also states that "optimum" temperatures for salmonid egg survival ranges from 42.8-50°F (6-10°C)[26]. These optimum temperatures can be thought of as the "...temperatures at which growth rates, expressed as weight gain per unit of time, are maximal for the life stage[27].". The EPA has also determined that water temperatures of approximately 71.6-75.2°F (22-24°C) can totally eliminate salmonids from a water body, and that changes in competitive interactions can lead to other species outcompeting salmonids at temperatures starting at 64.4°F (18°C)[28].

The potential increase of freshwater temperatures in critical salmon streams in the watershed is a concern for the Chilkat Indian Village. CIV supports the efforts of the Takshanuk Watershed Council, the Chilkoot Indian Association, and the Southeast Alaska Watershed Coalition to better understand stream temperatures in the Jilḵáat Aani Ḵa Héeni.

Climate change may increase the temperature of important salmon rearing areas in the Jilḵáat Aani Ḵa Héeni, potentially making them less hospitable. For example, local fish biologists have observed that sockeye from the Chilkat river mainstem do not overwinter in the Chilkat River after they emerge from eggs in the spring. Though little is known about the distribution of the young sockeye after they emerge from eggs it is unlikely that they rear in the cold side channels of the river. Instead they move into the shallow flooded marsh habitat of the valley, areas like the Little Salmon swamp, or Mule Meadows. These large, shallow areas have a very high biological productivity and they warm to temperatures far higher than the adjacent rivers.

The high temperatures and abundant food allow the young sockeye to grow very rapidly and attain a sufficient size to smolt and leave for saltwater later in the summer. Climate change may increase the temperature of these important rearing areas, potentially making them less hospitable to the young sockeye[29]. Conversely, warming water temperatures could increase salmon productivity in some habitats that are currently temperature limited.

Water temperatures also impact the timing of the salmon runs. The shift in timing of local and regional fish runs has been noted often in the past several years. Climate driven increases in winter fresh water temperatures in the watershed will likely result in fry emerging earlier from eggs. This earlier emergence may mean the salmon migrate to the ocean before there is sufficient sunlight to trigger the phytoplankton blooms they depend on for growth. Smolt survival in the nearshore habitat will be greatly diminished if there is not adequate food in that environment.

Under climate change, salmon habitat resilience can be bolstered by protecting and enhancing hydrologic connectivity between streams and their floodplains and riparian areas, identifying and protecting salmon refugia from floods (e.g. lower gradient streams) and thermal stress (e.g. snowmelt and groundwater-influenced streams, shaded streams), and maintaining robust habitat heterogeneity.

2. Glaciers

Most glaciers along the Gulf of Alaska have been slowly retreating since achieving a recent[30] maximum in the Little Ice Age (approx. 1750-1900AD), but the increased air temperatures in Alaska over the past 50 years, and particularly increased summer temperatures, have been identified as the main cause of the acceleration in widespread glacier mass loss and retreat in Alaska and northwestern Canada[31] [32]

Over the recent historical period glacial retreat in the Upper Lynn Canal has been visible on commonly observed glaciers like the Davidson and Rainbow and observed more indirectly in earlier and prolonged summer glacial meltwater present in the watersheds.

Future glacier coverage projections were not currently available at the watershed scale for the Upper Lynn Canal, so some relevant projections used in the SAWC hydrology assessment include:

Glacial Area	Projected Glacial loss from 2010 to 2100
All Alaska Glaciers[33]	Glacial loss of 25%
Juneau Icefield (including Katzehin watershed)[34]	Glacial loss of 57-63%

There are only a few locations in Southeast Alaska that have the potential to remain cold enough for increasing glacial mass through the end of the century, notably the highest elevation areas of the Fairweather Range[35]. Melting glaciers contribute significant sediment and hydrologic factors that alter the landscape and the habitats and food web of plants and animals. The Watershed Hydrology Assessment concluded that, "it is reasonable to expect that many glaciers in the study watershed will have retreated significantly, if not completely disappeared, by the end of the century."

- **Changing Glaciers and Salmon**

The impact of continued glacier retreat on diverse types of salmon habitat (lakes, river, and streams) is complex and benefits from assessment at the watershed level. Mark Sogge, a retired Alaska Department of Fish and Game fish biologist (Haines Area Management/Stock Assessment Biologist) has identified some possible threats from local glacier retreat:

Increased glacial melt will potentially cause Chilkoot Lake to become less productive over time as more glacial silt is exposed and washed into the lake. This may result in a reduction in the depth of the euphotic zone, and thus a reduction in the number of phytoplankton produced. Zooplankton, which feed on the phytoplankton, may thus become less numerous, and since these are the prey of rearing sockeye salmon, the lake may produce fewer salmon. Conversely, in the very long term the lake may tend to clear as the glacial influence is lost and the finer glacial flour has all been mobilized, resulting (in) increased lake productivity

Chilkat Lake may be threatened by more frequent flooding from the Tsirku River as higher flows occur and more sediment is deposited. As the headwater glaciers retreat there may be greater quantities of glacial debris exposed, and this material is subject to movement by storm caused flood events. As the bed of the Tsirku River aggrades, the potential for flood flows into Chilkat Lake increases. This could dramatically impact the productivity of the lake, and potentially result in large swings in the number of smolt produced by the lake. The influx of silty Tsirku River water will cloud the lake, reducing the euphotic zone and suppressing zooplankton populations. It is also possible that the silt could directly impact sockeye spawning areas, causing a reduction in egg to fry survival.

Additionally, glacier retreat will increase the rate of river aggradation by the Klehini, Tsirku and Chilkat Rivers. This could threaten Tlákw Aan. The riverbed elevations could rise substantially relative to the elevation of the village. The natural bank armoring provided by the composition of the Tlákw Aan alluvial fan will continue to slow bank erosion, but the likelihood that the bank will be overtopped will increase[36].

3. Rivers and riverbanks

The Jilḵáat River upstream of Tlákw Aan is a wandering, multi-channel river that transports mostly fine sediments and is about 300 to 400 feet wide. Once the L'ehéeni (Klehini) and Dzixkú (Tsirku) join the Jilḵáat River immediately upstream and alongside Tlákw Aan, their much coarser sediments help transition the Jilḵáat into a very broad, braided gravel-bed river where it is 2,000 to 3,000 feet wide[37]. At Tlákw Aan, streamflow is typically lowest in winter, when higher elevations in the watershed are frozen snow and ice, and greatest in summer, when the melting snow and glacial ice contribute to the flow past the village. There are also continuous year-round groundwater inputs to these river systems from seeps and alluvial fans[38].

Near Tlákw Aan the confluences of the Chilkat tributaries are quite active, as a report by the Natural Resource Conservation Service noted in 2002:

In 1948 the Klehini entered the Chilkat just downstream of the Wells Bridge. Prior to 1978 the Klehini changed course so the confluence with the Chilkat was about 1 mile further down valley (to the south). During a similar time- period more distributary side channels of the river formed even further to the south…The proportion of the (Tsirku) river that occupies any part of the fan changes as deposits block the flow, and that flow changes location. There is some evidence between the 1948 photos and the 1998 photos that currently a larger portion of the river is exiting on the north part of the fan above Klukwan than in 1948. This is very difficult to know for sure due to seasonal variations in flow…Given this high variability, we would expect the Tsirku to be less predictable with regards to location[39]..

Photo: Spawning sockeye. Colin Arisman

Since the above report was written in 2002, the main channel of the Dzixkú (Tsirku) has again shifted on its alluvial fan and now has an outlet south of the village, which has contributed to decreasing river channel depth and diminished success in subsistence salmon fishing in front of the Village.

The riverbanks around Tlákw Aan are generally composed of glacial silts with lenses of river gravel, but also have deposits from the Tlákw Aan alluvial fan, which are more resistant to erosion. There is ongoing active riverbank erosion[40] around Tlákw Aan (again, from the 2002 NRCS report):

Streambank erosion is evident in many places along the Chilkat River. Exposed tree and brush roots, slumped blocks of soil, and vegetation leaning towards the stream channel were all observed...Much of this erosion may be recent...bank erosion rates have increased around Klukwan in the last 20 years. This time period is coincident with increased recreation and tourist traffic on the river, but also with a period of increased glacial retreat[41].

The Jilk̲áat River main channel has moved away from the Tlákw Aan riverbank over the past decade, potentially related to the Dzixkú (Tsirku's) tributary shift southwards across the Dzixkú (Tsirku) fan. This change has shallowed the river along most of the village's riverbank, making subsistence access to boats and good fishing more challenging. Photo: Feb 2020

The Jilk̲áat main channel runs back along the riverbank immediately downstream of Tlákw Aan, in front of the Jilkaat Kwaan Cultural Heritage Center. Engineered log jams are visibly installed along the riverbank. Photo: Feb 2020.

The riverbank at the south end of the village shows the layering of the Iron Mountain "mudslides" that occur periodically during heavy rain events. This grey layer can be seen as more resistant to erosion than the riverbank deposits below it. Some structures in the village are built directly on top of this slide layer and therefore remain in the historical slide path. Photo: Feb 2020.

As described in SAWC's hydrologic assessment, glacial retreat and melt is projected to continue in the Upper Lynn Canal. The recent riverbank erosion around Tlákw Aan has been partly correlated with increased glacial melting, so it is expected that erosion will continue under climate change, although as has been described, the outcomes of these erosional processes are highly dynamic[42].

There are some specific erosion scenarios that would bring higher magnitude flooding impact to Tlákw Aan: *The most worrisome scenario for the Village would be if two different events would happen at the same time. If the Klehini River would avulse into its southernmost channel…in combination with a majority of the Tsirku water flowing off the northwest corner of the fan, the increased flow past Klukwan would be significant. The Chilkat River channel would then change shape and location to deal with these added flows of water and sediment[43].*

Erosion occurs much more rapidly during flooding events. Historically the different watershed types and shapes of the Jilḵáat, L'ehéeni, and Dzixkú Rivers has meant peak flows are not directly synchronized past Tlákw Aan. It has been estimated that if the Jilḵáat, L'ehéeni, and Dzixkú Rivers had synchronized maximum flooding events, the flow below Tlákw Aan could reach 41,000 cfs[44]. Flooding events can increase erosion, channel scour, channel adjustment (width and depth), wood transport, and downstream sediment deposition[45].

Higher flows may increase in both frequency and magnitude in Southeast Alaska due to warming temperatures, increased annual precipitation and/or extreme precipitation events, and potential shifts from snow to rain. Warming temperatures could increase glacial stream flow in summer. Higher annual precipitation and shifts from snow to rain may increase the likelihood, frequency, and magnitude of high flows and runoff in both glacial and non-glacial streams, particularly in winter or fall when large frontal storms hit the Southeast Alaskan coast[46].

As has been noted, climate models suggest that future precipitation will arrive more often as extreme precipitation events: annual maximum one-day precipitation amounts AND annual maximum five-day precipitation amounts are projected to increase by 10-15% in Southeast Alaska by the end of the century under "more severe" climate change scenarios[47].

Over the time frame of this planning process, there have been several extreme precipitation events that have caused flooding in the winter, fall, summer and spring seasons in Tlákw Aan and the Jilḵáat Aani Ḵa̱ Héeni. Floods can occur at any time of the year and frequently landslides and/or avalanches occur alongside the flooding.

The following images are just a few of the many examples of culvert blowouts and other infrastructure damage due to extreme precipitation events in the Jilḵáat Aani Ḵa̱ Héeni. Extreme precipitation events move unstable soils, and are a catalyst for flooding, landslides, ground movement and riverbank erosion.

Starting in 2018, the Alaska Department of Transportation & Public Facilities (ADOT&PF), in partnership with the Federal Highway Administration, started construction on a Haines Highway improvement project that aimed to, among other things, develop and implement "long-term solutions to debris flow problems near Mileposts 17, 19 and 23."[48]. At Milepost 19, the State raised the roadway about 40 feet and constructed four “giant culverts” in an effort to “tame a mountainside that’s been sliding into the Chilkat River for more than a century.”[49]. Although the structure was only completed one year ago, in 2021, the culvert foundations are already failing, with the concrete cracking, disintegrating, collapsing, and exposing the underlying rebar frame.

In December 2020, severe rains caused destructive avalanches, landslides, and flooding in Tlákw Aan, Haines and surrounding areas, resulting in extensive damage to many roads and homes[50]. 2022 was a year with multiple floods occurring in various watersheds in the Jilḵáat Aani Ḵa̱ Héeni and in Tlákw Aan.

Many roads have been heavily damaged in Haines after heavy rain and flooding. Dec 2, 2020. (Photo provided by Darwin Feakes)

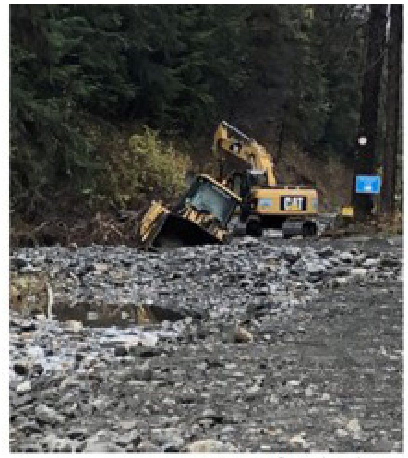
Photo: Jilkaat Kwaan Heritage Center Campus, Traditional Knowledge camp. Flooding October 2022

Photo: Tlákw Aan looking south. Flood Event July, 2022

Particularly heavy rains in September 2022 caused flooding in Porcupine Creek, the L'ehéeni River (Klehini River), and the Jilḵáat River (Chilkat River), as well as a landslide near Mile 23 of the Haines Highway[51]. High waters in Porcupine Creek flooded Constantine's Big Nugget mining camp, which lies on flat land and serves as the base camp for the Palmer Project[52].

A sudden surge of Nugget Creek, a tributary of the Tsirku River, flooded a separate mining camp as well[53].

Across the border in British Columbia, Canada, rainstorms and flooding in the summers of 2020 and 2022 similarly caused overflowing creeks, culvert blockage, and road damage on the Alaska Highway, Stewart-Cassiar Highway, and North Klondike Highway[54].



Courtesy of Mark Sebens.

A loader leans over in the aftermath of flooding near the entrance of Constantine's Big Nugget camp along Porcupine Road.

Extreme precipitation events, seasonal flooding, landslides, are natural characteristics of the Jilḵáat Aani Ḵa̱ Héeni, and their frequency and severity are being exacerbated by climate change.

4. Riparian Vegetation

Much of the riverbank in the Chilkat Valley is composed of unconsolidated silts and gravels, so vegetation appears to play a key role in providing strength to these streambanks[55]. Vegetation is also the biotic link between terrestrial animals and the aquatic environment, providing food and shelter.

Riparian vegetation will be affected by the increasing air temperatures, changing water temperatures, shifting water availability, decreasing snowpack, and later freeze and earlier thaw dates projected under climate change. A useful summary of riparian vegetation responses to climate change is provided in Table 3 below:

Table 3. Anticipated Riparian Vegetation Response to Climate Change in Southeast Alaska. Adapted from[56]

Climate and climate-driven changes	Anticipated riparian vegetation response in Southeast Alaska
Warmer year-round temperatures	• Prolonged growing season, reduced dormancy length • Increased growth rates • Increased transpiration • Summer: Increased flows in glacial streams, affecting water availability and disturbance • Higher risk of erosion from larger glacial melt floods
Shifts from snow to rain, increased annual precipitation, reduced snowpack, and earlier snowmelt leading to altered hydrology	• Winter: Shifts in avalanche activity, higher and more frequent flooding events, higher likelihood of landslides will all increase vegetation disturbance with increased sediment/wood deposition downstream • Summer: Decreased water availability and prolonged low flow periods in non-glacial streams • Altered soil stability • Reduced snow insulation and increased root frost damage (especially at low elevations)

5. Wildfires

The relatively consistent and dynamic precipitation of Southeast Alaska makes future projection of wildfire risk a difficult endeavor. With the projected increase in annual precipitation under climate change, models suggest drought in Southeast Alaska in both summer and winter will become about half as likely to occur by 2050 (compared to 1925-2020)[57]. Despite this trend, other environmental factors also contribute to drought conditions and wildfire risk; the projected increase in annual temperatures in Southeast will increase evaporation in the summer, potentially leading to summertime drying of forests and soils that would periodically put coastal forests at high intensity wildfire risk[58]. Warming temperatures, extended growing seasons, and more frost-free days will also increase coastal forest productivity, especially at low- and mid-elevations, and therefore likely increase available wildfire fuels[59,60]. Alongside more typical southeast tree species, the Chilkat valley holds substantial stands of shore/lodgepole pine in the mid and upper valley, a species that is projected to see increased wildfire risk under a warming climate[61]. Some climate change projections suggest that the southeastern coast of Alaska and northern coast of British Columbia will transition from a low to high probability of wildfire by 2040[62]. Other projections for Northern Southeast Alaska suggest that under both "less severe" and "more severe" climate change scenarios, there is expected to be no change in the number of future fire events compared to a historical average. However, the neighboring Yukon/B.C. area of Canada with its drier air mass will likely see increased wildfire risk under climate change. The Yukon/B.C. region northwest of the Chilkat Valley shows a potential increase in one more fire per century under both "less severe" and "more severe" climate change scenarios[63].

6. Alpine Habitat

Climate change is occurring more rapidly in high-elevation alpine and mountain ecosystems than elsewhere, a process termed "alpine amplification"[64,65]. The described changes of higher temperatures and more future precipitation falling as rain that historically fell as snow, holds wide-scale implications for the alpine ecosystems that have evolved to depend on a seasonal presence of snowpack. The alpine snowpack insulates the ground, provides year-round water storage and slow-release water dispersal, and provides shelter to many alpine species, including dens for wolverines and brown bear[66,67]. In addition, the unique slow melt of the snowpack in alpine areas helps support summer long "spring flushes" of high-quality vegetation critical to support the growth and winter survival of alpine herbivores[68]. For mountain goats the extended alpine snow melt and green-up periods increase growth rates of kids[69], and cool summer temperatures lead to increased annual survival[70].

The mountain goat is considered a "sentinel" species of alpine environments and is one specific animal that is projected to experience significant negative impact under climate projections[71]. The net impact of such changes on mountain goats is expected to be negative, as the beneficial effects of reduced snowfall in winter are outweighed by the deleterious effects of warming temperatures during the summer growing season (Figure 2)[72]. Warming temperatures will induce both long-term shrinkage of alpine habitat and shorter-term changes in weather. Shorter-term changes include increased frequency of extreme events (i.e. heat waves, rain-on-snow) which are particularly impactful to mountain goats[73].

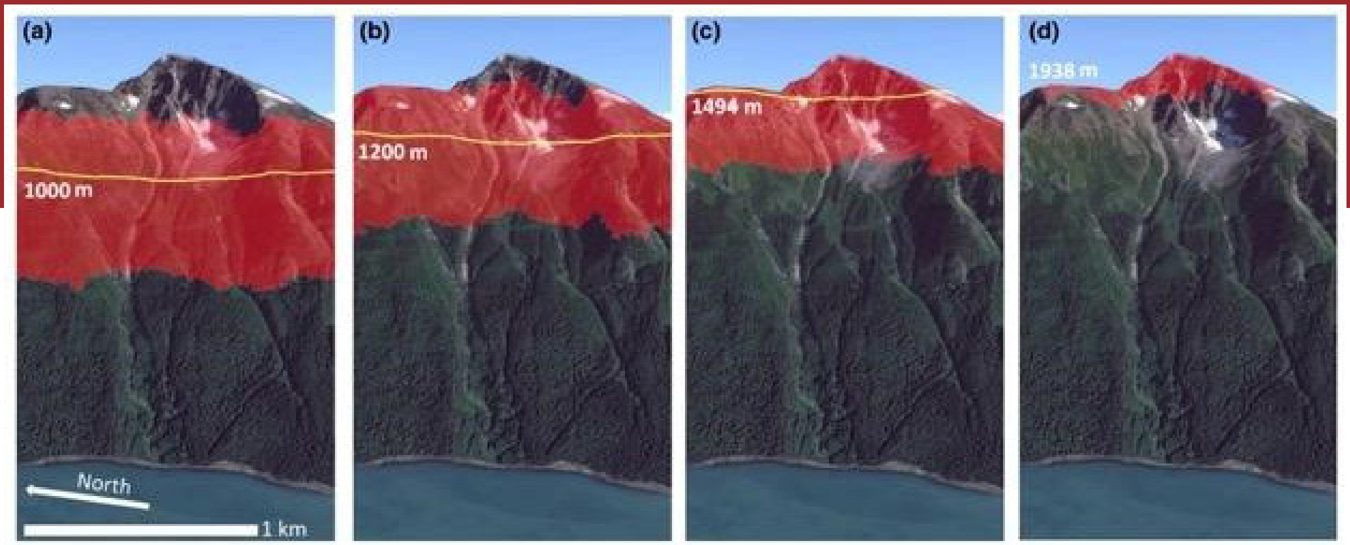


Figure 2. Maps[74] illustrating how mountain goat summer habitat is expected to shift upslope in response projected to warming in summer temperature due to climate change. Four scenarios are illustrated: (a) current distribution: 2005–2015, (b) year 2085: "best case scenario", (c) year 2085: "intermediate scenario, and (d) year 2085: "worst case scenario". The example area mapped is located in upper Lynn Canal, near Sinclair Mountain.

It has been estimated that by the end of the century, southern Alaska coastal forests ecosystems could see a 2000 to 3000 foot upward shift in vegetation distribution due to the temperature and precipitation changes under climate change[75]. This shift would come at the expense of the alpine vegetation no longer enjoying favorable growing conditions, and affecting the range of animals that depend on the alpine ecosystems[76,77]. Under a "more severe" climate change scenario, projections suggest that by the 2080s average annual temperatures in the alpine of mainland Southeast AK will be warmer than the present day average annual temperatures of the subalpine habitat[78]. Overall, this suggests that across the Upper Lynn Canal, alpine species such as mountain goats, other mountain specialists (i.e. marmots, ptarmigan), and species that use the alpine for critical life events (i.e. brown bears, wolverines), will be stressed and at a great competitive disadvantage to subalpine and forest species by the end of the century.

Alpine characteristics also determine avalanche potential, which is a driver of disturbance and ecosystem structure in certain parts of the alpine[79] and a major cause of mountain goat mortality[80]. A shifting snowpack will certainly change avalanche patterns[81], though possibly in too complex a manner to draw simple conclusions. Rain-on-snow events are known to produce large-scale avalanches with stand-replacing potential for forests[82]. During the extreme rainfall event of December 1-8, 2020, in the Chilkat Valley, snow and rainfall on the loading zone of an avalanche chute just south of Tlákw Aan (Milepost 21) gave way to a large destructive (D3) avalanche that almost crossed the highway (Figure 3). This same path was loaded with snow and rain a month later and slid again and this time crossed the highway on January 15, 2021[83]. These types of avalanches could be expected to correlate with future extreme rain-on-snow events. In areas that are projected to lose a snowpack completely, former avalanche chutes could be expected to see a change in vegetation communities[84] from subalpine to forest species[85]. This potential landscape change could have ecosystem-wide impact, since the frequent disturbances in avalanche paths promote biodiversity[86] and provide a unique habitat readily used by a variety species including: bears, wolverine, moose, and mountain goats[87,88].

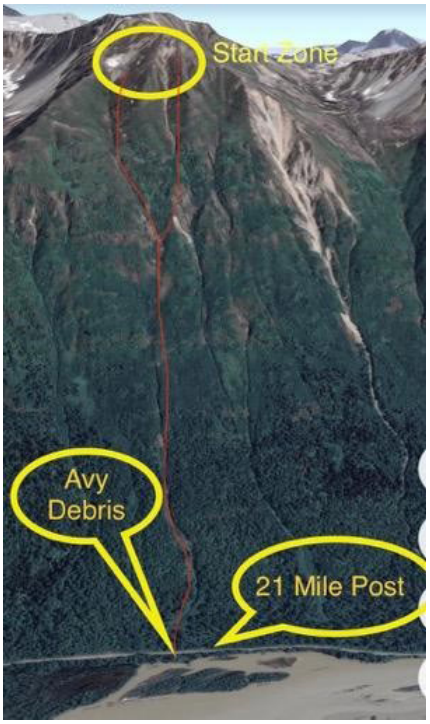


Figure 3. Avalanche path near milepost 21, described in slide events December 2020/January 2021[89]

Photo: Milepost 21 avalanche shortly after it crossed the road January 15th, 2021[90]

7. Landslides

As described in the Riverbank section, the stream channel on the Tlákw Aan alluvial fan has periodically flooded during extreme precipitation events and sent debris flows from Iron Mountain into the southeast corner of the village into and under buildings. Over recent decades, AKDOT modifications to the drainage channel upstream on the fan may have helped decrease occurrence of these types of landslides in the Village.

Photo: Milepost 21 avalanche path (snow bottom center) viewed from Tlákw Aan

Southeast Alaska and the Chilkat Valley have a history of landslide events, as stated in a recent newspaper article:

Southeast is an area with a history of flooding and landslides due to its steep peaks and rainforest climate. In 2015, a landslide killed three people in Sitka. In Haines, storms have caused flooding and landslides with records dating back to the late 1800s. The historic Tlingit village of Kattx_'awultu' (often referred to as "Kluktoo"), located at what is now 19-mile Haines Highway, was taken out by a slide in the 1890s. In recent years (in Haines), heavy rains have caused damage to public and private property in 1998, 2005, 2012, and 2014[91]*.*

Over December 1st-8th, 2020, following a period of record rainfall onto an existing deep snowpack, saturated soils in the Jilḵáat Ḵwáan (Upper Lynn Canal) let loose a torrent of flooding, wide-ranging and destructive landslides, avalanches, a geologic mass-wasting event, and a localized tsunami. These extreme events caused the destructions of eight homes, severe damage to 24 other homes, and the death of two Haines residents, along with long-term neighborhood evacuations and instances of residents displaced because of the event[92].

This Haines landslide event of 2020 was initiated by precipitation events with deep sub-tropical connection, transporting anomalously high precipitable water values. The persistent precipitation throughout the week of December 1-8, 2020 in Haines broke records for precipitation amounts and frequencies; over these multi-day time periods the precipitation reflected 50-200 year return interval amounts (i.e. rainfall only expected to occur every 50-200 years)[93].The largest of the Haines landslides along Beach Road was "*...likely triggered by a combination of bedrock failure and oversaturated soils that allowed the entire soil mass to become liquified and move downhill. The failed material was primarily bedrock in the upper portion of the slide, which then incorporated saturated soils and other surface materials as it traveled downslope in a debris flow.*[94]"

Widespread landslide events along the West Coast of the US are often caused by prolonged intense rainfall associated with atmospheric rivers[95]. Under climate change, these extra-tropical storm tracks are projected to move northward[96,97]. The more rain that falls over a shorter time period, the higher likelihood that landslides will occur. However, measures of rainfall alone have limitations in landslide forecasting, as they do not consider the longer-term subsurface moisture levels and water pressures from extended rainfall or snowmelt[98]. Other complex interacting climate change effects like warmer overall temperatures, more rain-on-snow events, and more precipitation falling as rain that historically fell as snow, will also generally lead to increased landslide risk for the Chilkat Valley. The loss of glacial ice and permafrost from previously glaciated and frozen terrain also holds a general increasing landslide hazard risk. Unfortunately, predicting specific landslide hazards out of this general hazard trend is a highly complex and difficult task[99].

Landslides are common occurrences in Tlákw Aan. These geohazards would move through the community on a yearly basis until the mid 2000's when divergent mechanisms were built and put in place higher up in the alluvial fan. As elder and community leader Jones Hotch Jr. explains- landslides are very culturally balanced. They have hit both the Whale House and Bear House. The Eagle and the Raven moieties have therefore both been impacted.

8. Marine Projections

The traditional territory of the Jilḵáat Ḵwáan (Upper Lynn Canal) marine environment presents a unique setting for assessing climate change vulnerabilities. The Canal is a deep fjord, with large amounts of freshwater inputs from the surrounding steep mountainous drainages and glaciers. It is functionally connected to the North Pacific Ocean, yet nearshore waters are the initial marine mixing zone for terrestrial freshwater inputs. Under climate change, watersheds shifting from glacial → snow → rain types, are expected to alter the productivity of nearshore waters through its effect on quantity and timing of nutrient inputs from riverine sources[100]. A long term transition towards more rain dominant watershed types could mean a short term increase in glacial discharge before a longer term reduction in glacial inputs to the nearshore environment.

The ocean is in constant interaction with the atmosphere, biosphere, and land and functionally regulates atmospheric gases and the distribution of heat and water across the planet[101]. The average sea surface temperature (SST) of the Pacific Ocean has increased 0.31°C over the period 1950-2009, which is consistent with expectations of climate change effects over the past century[102].

Although this sea surface temperature trend is certain and projected to continue, the resulting outcomes to ocean mechanics are highly complex. As the IPCC states:

Regional changes observed in winds, surface salinity, stratification, ocean currents, nutrient availability, and oxygen depth profile in many regions may be a result of anthropogenic GHG emissions (low to medium confidence). Marine organisms and ecosystems are likely to change in response to these regional changes, although evidence is limited and responses uncertain[103].

Higher winter temperatures under climate change with more precipitation falling as rain that historically fell as snow, will have important implications for the timing and amount of freshwater flowing to the Gulf of Alaska from coastal mountains, and have resulting effect on the phytoplankton and zooplankton at the bottom of the food chain. The resulting SST alterations will also impact many aspects of plankton physiology such as adult mortality, reproduction, respiration, embryonic and development[104].

- **Ocean Acidification**

As part of the ocean's constant interaction with the atmosphere, the ocean has absorbed about one quarter of human-produced CO2 emissions in the last two centuries[105]. The result of this uptake of CO2 is a direct correlation between increasing atmospheric CO2 since 1958 and decreasing pH (increasing acidity) of ocean waters[106]. More acidic waters influence a range of physiological processes in marine organisms: skeleton formation, gas exchange, reproduction, growth, and neural function[107]. Any impact to shell-building organisms quite obviously holds implications across the entire food chain. The tiny planktonic snail known as a pteropod is a key food source for salmon and herring (over half the diet of juvenile pink salmon). Both in laboratory studies and in observed populations in the Southern Ocean, pteropods show rapid and significant shell dissolution in water of the same carbonate chemistry as is currently being measured at some locations off Alaska[108].

The current rate of ocean acidification is unprecedented within the last 65 million years and possibly longer[109]. Global oceans will continue to warm and acidify under climate change, though the rates will vary regionally[110].

In a 2015 statewide risk assessment for Ocean Acidification (OA), the Haines Borough ended up 17th out of 29 Alaska wide census areas/boroughs. Areas of Southern and Western Alaska had the highest overall risk. Features of higher risk for Haines included a large economic and subsistence dependence on commercial marine species that will be negatively affected by OA[111].

- **Marine Conditions and Salmon**

All salmon species leave the freshwater stream of their birth to spend a range of years in saltwater feeding and growing, before returning to their home (natal) stream to spawn. In fact, the majority of the life cycle of salmon is spent in this "ocean rearing phase". In this phase salmon smolt, subadults, and adults seek waters with temperatures less than 59ºF (15ºC)[112]". For salmon species of the Jilk̲áat Aani K̲a Héeni (Chilkat River Watershed) this ocean rearing environment includes the inside waters of southeast Alaska (including those saltwaters surrounding Haines) all the way out to the North Pacific's Gulf of Alaska. Salmon migrate to saltwater to feed and mature adequately for successful spawning, therefore the central impact of ocean warming is through: changes to their food supply, changes to their metabolism from the actual temperature of the water, and changes to relevant predator populations. Temperature driven alteration of migration timing to the ocean also holds potential to create "trophic mismatches" between salmon and their prey (like plankton). The success of migrating juvenile salmon depends on synchronized pulses of plankton production in the Pacific Ocean to provide adequate nutrients during this vulnerable stage of their life cycle[113].

- **Sea Level Rise**

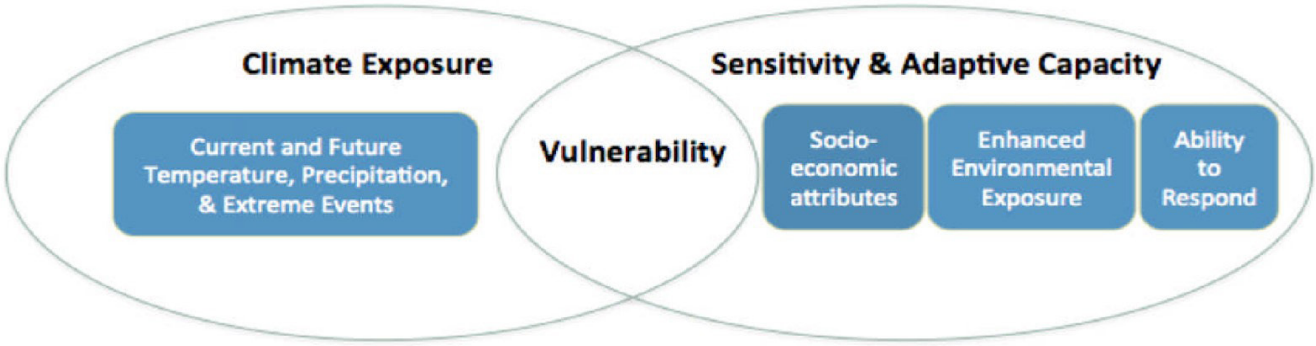
Global sea level rise has occurred at least since the beginning of the 20th century and has continued to accelerate. Since the 1970s melting glaciers and thermal expansion from a warming ocean explain about 75% of the global sea level rise[114]. Rapid warming has been recorded in the deep ocean (down to 2300 feet) starting in the 1970s[115]. In recent times (1992-2014), NOAA has measured North Pacific sea level rise at 2.8 to 2.4 mm/yr +/-0.4. By the end of this century (2081-2100) under "more severe" climate change scenarios, global Sea Level Rise could be occurring at a rate of 8-16mm/yr. It is "virtually certain" global mean sea level rise will continue to occur beyond 2100[116].

Southeast AK has its own geomorphic influence on mean relative sea level as its land mass is experiencing "isostatic rebound", where the landmass lifts rapidly in response to the loss of the glaciation of the last ice age and more recent glacial maximums. This rapid rise of the land in the region around Haines has led to the mean relative sea level decreasing with the sea level measured by NOAA as decreasing at a rate of -17.91mm/ year from 1944-2019 at a station in Skagway (20 miles Northeast of Haines)[117]. By simply comparing the rate of current relative sea level drop in Skagway (-17.91mm/yr) with the long term projection of global sea level rise rate at the end of the century (8-16mm/yr), it is probable that mean relative sea level could continue to drop in the Haines area through at least the end of this century, barring some large scale geologic process.

VULNERABILITIES

With a better understanding of climate projections for the Jilḵáat Aani Ḵa Héeni (Chilkat River Watershed) and the broader region, the CIV Environmental Department was able to work with consultants to carry out vulnerability assessments for Infrastructure and Plant and Animal species. As described by the US Department of Agriculture Climate Hub, a vulnerability assessment determines the susceptibility of a natural or human system to sustaining damage (or benefiting) from climate change. The following vulnerability assessments considered a wide range of climate change vulnerabilities in the areas of infrastructure and traditional plants and animals. The specific infrastructure and plants and animals that were considered in this vulnerability assessment process represent only a SUBSET of the entire range of infrastructure and plants and animals important to and in-use by the Tribal Members of the Chilkat Indian Village. The exclusion of any infrastructure or plant or animal from this assessment does not reflect lack of use by the Tribal members of the Chilkat Indian Village. For instance, some species NOT included in this assessment, but extremely important to Tribal Members include: Duck, Geese, Swans, Beaver, River Otter, Lynx, Snowshoe Hare, Marten, Wolf, Wolverine, Coyote, Fox, Porcupine, Sitka Blacktail Deer, Elderberries, Labrador Tea, Devils Club, Chocolate Lily, Wild Celery, Nettles, Mushrooms, Sea Lion, Tanner Crab, and Herring.

CIV followed the widely used climate change vulnerability assessment process outlined by the Central Council of Tlingit & Haida in their "Climate Change Adaptation Plan" template. This process establishes climate change vulnerability of a given resource through consideration of both its "sensitivity" and "adaptive capacity" to climate change. The descriptions and images below are adapted from the CCT&H Template.



This image shows how Climate Vulnerability depends on the interaction of exposure, sensitivity, and adaptive capacity.

- **Climate exposure** is the extent and magnitude of a climate or weather event.
- **Sensitivity** is the degree to which a resource is susceptible to a climate impact.
- **Adaptive capacity** is the ability of the resource to adjust to or respond to the changing conditions.

As has been described thus far in this document, important Climate Change "Exposures" for Klukwan include:

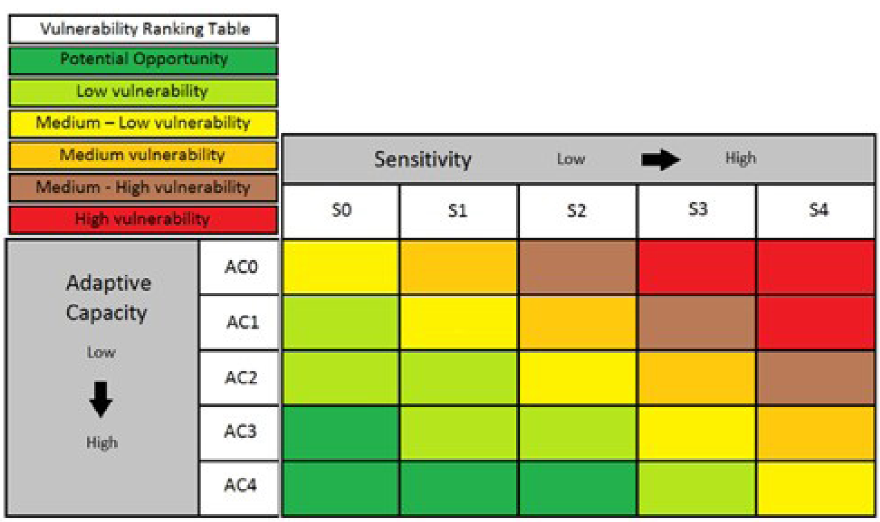
- less snowfall,
- warmer winter temperatures,
- warmer waters,
- more extreme precipitation events,
- more extreme drought,
- deeper ground freeze (due to lack of snow),
- increased wildfire risk in Yukon/B.C.,
- poor air quality (wildfire and dust),
- shifting watershed types (glacier → snow → rain).
- marine impacts

Each resource considered in this assessment was assigned sensitivity and adaptive capacity rankings based on available research and consultation with CIV staff, Council, and community members. The sensitivity and adaptive capacity rankings are defined as:

Sensitivity Levels	
S0	System will not be affected by the climate impact
S1	System will be minimally affected by the climate impact
S2	System will be somewhat affected by the climate impact
S3	System will be largely affected by the climate impact
S4	System will be greatly affected by the climate impact

Adaptive Capacity Levels	
AC0	System is not able to accommodate or adjust to the impact
AC1	System is minimally able to accommodate or adjust to the impact
AC2	System is somewhat able to accommodate or adjust to the impact
AC3	System is mostly able to accommodate or adjust to impact
AC4	System is able to accommodate or adjust to impact in beneficial way

Those resources that are the most vulnerable have the highest sensitivity and the lowest adaptive capacity. Those that were the least vulnerable have lower sensitivity and higher adaptive capacity.



Infrastructure Vulnerabilities

CIV identified the following infrastructure issues to assess during this planning process. Observed impacts to the following list was informed by community-based interviews hosted by the Chilkat Indian Village Environmental Department, that included staff and village members who have a specific knowledge of the infrastructure. Vulnerability assessments were developed using the information from local experts in combination with local observations and relevant climate change projections.

- **Drinking Water System**
  - Distribution System
  - Treatment System
- **Sewer**
  - Transfer System
  - Treatment System (lagoon)
- **Housing**
  - Mold
  - Wildfire & Extreme Heat
  - Extreme Rain
  - Energy Efficiency
- **Effective Utilities: Heating/Cooling**
- **Solid Waste Management (landfill)**
- **Roads**
  - Church Road flooding
  - Landfill roads mud/holes
- **Riverbank erosion**
- **Wildfire and Air Quality**

The vulnerability table below provides an overview of the infrastructure considered most and least vulnerable to climate change. The vulnerability assessments were very helpful in informing the Action Plan found in Part 2.

CIV Vulnerability Overview for Infrastructure Resources

		Sensitivity: Low → High				
		S0	S1	S2	S3	S4
Adaptive Capacity: Low ↓ High	AC0					
	AC1		*Solid waste management (landfill)	* Drinking water Distribution System *Drinking Water Treatment System	*Effective utilities: Heating/Cooling *Wildfire and Air quality	*Housing: Mold *Housing: Wildfire and Extreme heat *Housing: Extreme rain *Housing: energy efficiency
	AC2			* Sewer Treatment System (lagoon)	* Sewer Transfer System *Riverbank erosion	
	AC3				*Landfill roads mud/holes	*Church Road Flooding
	AC4					

Plant and Animal Vulnerabilities

The following plants and animals were identified by CIV staff and Tribal Members and Chilkoot Indian Association staff and Tribal members during this planning process. This is not a full list of all animal and plants used by Tribal Members. This vulnerability assessment intended to carry out focus group meetings for some of the foods listed below over the period of the initial planning phase with the Chilkat Indian Village staff, Tlákw Aan residents, Chilkoot Indian Association staff and Tribal Members, and other individuals with locally relevant expertise. Unfortunately, the wider community outreach actions of this project for gathering Traditional Ecological Knowledge and local information on plants and animals, were hindered by the health risks of the global COVID-19 pandemic and necessary health response measures. CIV hopes this information will still be collected. See Part 2. Action Plan.

Chilkoot Lake Sockeye	Hooligan	Moose	Other birds; Duck, Geese, Swans
Chilkat Lake and River Sockeye	Harbor Seal	Mountain Goat	Beaver
Chilkat Watershed Chinook	Shrimp	Brown Bear	Furbearers (river otter, lynx, snow-shoe hare, marten, wolf, wolverine, coyote, fox)
Chikat Watershed Chum	Dungeness Crab	Black Bear	Porcupine
Chilkat Watershed Coho	Sea otter	Ptarmigan	Sitka Blacktail Deer
Trout: Cutthroat and Steelhead	Halibut	Grouse	Herring
Dolly varden	Red-ribbon seaweed	Wild berries	Cultivated Species
Other Plants (elderberries, Labrador tea, devils club, chocolate lily, wild celery, nettles, mushrooms)	Sea Lion	Tanner Crab	

Photo: Smoking fish in Tlákw Aan

Below is a vulnerability table with an overview of the adaptive capacity and sensitivity of some of the plants and animals that were assessed during the planning process.

CIV Vulnerability Overview for Plants and Animals

		Sensitivity: Low → High				
		S0	S1	S2	S3	S4
Adaptive Capacity: Low ↓ High	AC0					
	AC1				*Chilkat Chum *Chilkat Chinook *Cutthroat & Steelhead *Shrimp *Moose *Brown Bear *Ptarmigan	*Chilkat River Sockeye *Mountain Goat *Lynn Canal Pinks *Chilkat Coho
	AC2			*Hooligan *Dolly Varden *Seal *Halibut *Black Bear *Bald Eagles *Grouse *Wildberries *Red-ribbon sea-weed	*Chilkoot Lake Sockeye *Chilkat Lake Sockeye *Dungeness Crab	
	AC3					
	AC4					

Throughout this assessment process it became clear that there is a lot we do not know about the plants and animals and how they are and will be impacted by the changing climate. However, we know that changes are occurring and will continue to occur. Tribal Members are uniquely qualified to help human communities understand and grapple with changes in plants and animals because of their knowledge base that stems from thousands of years of observing and living in reciprocity with plants and animals. Someone living in the Chilkat Valley for only one or two generations will find it difficult to pinpoint subtle changes in plants and animals. CIV hopes that western scientists will continue to come to the Valley to carry out research. Research led by Tribal Members can ensure studies and findings are grounded in local observations and a Lingít(Tlingit) way of knowing.

There are also more extensive details and references for each species vulnerability in the Part 2: Technical Reference

Photo: Colin Arisman

PART 2

This Resilience Plan is organized into two parts: Part 1 provides an overview of what information was gathered and learned during the Resilience Planning Process. Part 2 is meant to provide an overview of possible next steps to address climate vulnerabilities, and technical reports that informed this plan and planning process.

This resilience plan focuses on climate change impacts on critical infrastructure in Tlákw Aan and to the plants and animals that are important cultural resources to the Chilkat Indian Village and its Tribal Members.

ACTION PLAN

Part of the planning process was dedicated to identifying technical experts, mitigation measures, monitoring methods, planning methods, adaption tools, partners, and funding to address the most vulnerable infrastructure and plants and animals. These actions and next steps are associated with on-going efforts that were happening prior to this planning process and new efforts that resulted from the planning process. Actions are meant to address the most vulnerable infrastructure and some of the plants and animals, as they are understood in December of 2022. These actions will change overtime and, in some instances, rather quickly, as additional information is gathered. CIV's Environmental Department will be mainly responsible for tracking the actions and next steps.

Six general areas were identified that will help CIV respond to the changing climate. Carrying out any of the actions listed below will require dedicated staff and resources. Many are not small undertakings. The Tribal Council, CIV staff, community, and climate events will continue to help prioritize what actions are addressed.

1. **Support food security and** sovereignty projects, programs and partnerships:

- **CIV can support the ongoing projects in Tlákw Aan promoting food security and sovereignty.**

  » The Jilkaat Kwaan Heritage Center (JKHC) has supported the Tlákw Aan Community Garden since it was first started in 2005. It is now a large vegetable garden, greenhouse, and root cellar. It is used as a demonstration garden to teach gardening skills and provide participants with locally grown vegetables. In addition, CIV is currently building a dry/cold storage unit that will keep produce grown in the village fresh longer and thus extend its availability to the community. The Klukwan School has submitted a grant proposal that will fund a collaborative project to grow and teach student gardeners about the Tlingit Potato---a heirloom variety. In addition, the JKHC hosts a moose harvest camp every fall (via Alaska Department of Fish and Game Cultural Education Harvest Permit) which, like the salmon camp, teaches participants how to butcher, sort and process meat cut from large game animals. Foods are distributed to all participants of the camp and some is given to the Klukwan School for their school lunch program. Participants also share a portion of their meat with elders in their respective families or with elders who do not have any family members participating in the camp.

- **Convene Traditional and Subsistence User Groups to Discuss Past, Present, and Future Changes**

  » As this vulnerability assessment process began, it was recognized that tribal traditional plant and animal gatherers and hunters would bring a wealth of knowledge to this process. It was identified early on that getting an up-to-date understanding of Tlákw Aan households' actual and desired use of traditional plants and animals would assist in understanding the magnitude of impact to the community as these traditional foods were affected by climate change. A traditional foods survey was administered in the spring of 2020. The survey asked each household what traditional foods they used or desired to use and what barriers existed to them acquiring and using these foods. It was realized that the knowledge of traditional harvesters around past, present, and future changes to the most vulnerable species should be gathered. This knowledge base would provide important context to these issues and help identify appropriate actions to build resilience. This planning effort intended to include the gathering of some of this information. Unfortunately, the wider community outreach actions of this project were hindered by the health risks of the global COVID-19 pandemic and necessary health response measures. It is hoped that this plan and the vulnerability assessments will be a foundation for continued information gathering and recording regarding the changes being observed.

- **Develop and/or Support an Improved Region-wide Native Led Traditional Food Sharing and Exchange Network**

  » Early in this vulnerability assessment process, when it was realized that all traditional foods in this assessment held potential vulnerability to climate change, the idea was put forward that more efficient sharing of traditional foods among Alaska Native tribes and First Nations across the region could help buffer individual tribes from the negative effects of climate change. For instance, the impacts of a smaller moose population in the Chilkat Valley might be moderated by the opportunity to share or trade locally caught salmon for deer from another regional tribe. This sort of traditional food sharing has existed and continued for millennia across the region. It was discussed again in this context to see if the network could be re-designed, potentially improving and developing new components and infrastructure, like interface with the internet, community cold storage, and bulk shipping. The Jilk̲áat K̲wáan has always traded with other Alaska Native and First Nations people. The culture is built on established trade routes and trading customs. The trading of different foods and medicinal plants within this greater region is important to the adaptability of our people who have lived here since time immemorial. By bolstering back our traditional trade of plants and animals, we will build food sovereignty and food security in a changing climate.

2. Monitor watershed characteristics and the health of the plants and animals and their habitats:

There are many plants and animals that show various changes in behaviors and appearance from one season to the next. We commonly observe that the fish are getting smaller, are returning at different times, and/or are not coming back to their historic habitats. Some years it seems as if there are very few pollinators, in which case the berries are not as prolific, and the bears are thin. It is difficult to know if these observed changes are due to a changing climate. This is an important time to partner with various entities to build tribally led monitoring programs and projects that will contribute information to better understand how plants and animals are adapting to the changing climate

» CIV and the Environmental Department should continue to put resources toward its own water quality monitoring program and the monitoring and research efforts of the Chilkoot Indian Association's Eulachon Project, Takshanuk Watershed Council's Stream Temperature Monitoring, Central Council Tlingit and Haida Tribes of Alaska's water quality monitoring and Alaska Department of Fish and Game fish and wildlife monitoring.

» The Environmental Department can continue outreach to various entities to bring additional monitoring and research to the region. CIV has reached out to the University of Alaska, United States Fish and Wildlife Service, Alaska Department of Fish and Game and others to initiate and express support for plant and animal monitoring in the Jilk̲áat Aani Ka̲ Héeni.

» The following broad recommendations were provided in the watershed hydrology assessment for protecting aquatic resources in the future:

- Maintain and restore hydrologic connectivity between streams and their floodplains. This connectivity provides resilience to flooding and a connection to groundwater, which helps moderate water temperatures year-round. Avoid activities like roadbuilding and paving in the floodplain and modifying streams and riparian areas in ways that cause bank erosion and downcutting.
- Maintain riparian vegetation. Vegetation provides shade and temperature moderation, and habitat and food resources for fish and other aquatic life.
- Identify and protect groundwater sources and groundwater-influenced stream reaches. Groundwater streams provide important cool water refugia during the summer and warmer open water areas in the winter. Groundwater sources (the water itself and infiltration zones) should be identified and protected from development and pollution, and the groundwater-fed streams should be protected from development and loss of hydrologic connectivity to the surrounding landscape.

- Protect salmon habitat in lower-gradient streams as a refuge from powerful scouring floods, particularly in watersheds transitioning away from snowmelt-dominated to rain-dominated.
- Expand hydrologic monitoring (e.g., precipitation, snowpack, stream flow) and modeling (e.g., spatially explicit glacial melt projections) to inform risk assessments and future decisions about drinking water systems and hydropower facility management and development. Direct implications of hydrologic changes, such as water quality, should also be explored in more detail.
- Focus research on high value/low information resources (such as eulachon, which spawn in large glacial river systems that are changing) to expand understanding of climate impacts on aquatic resources.

3. Address climate impacts to the most vulnerable infrastructure

A. HOUSING: Housing issues quickly rose to the top of infrastructure issues in Tlákw Aan that are most vulnerable to climate exposure. All the current and projected climate exposures for Tlákw Aan will impact housing conditions. Less snow fall and extreme freeze events will continue to freeze pipes and cause ground shifting. Increased wildfires in Yukon/BC and other areas will cause poor air quality. Extreme precipitation events will cause flooding of homes and landslides that cause ground movement, destroying existing foundations. The damage done to homes from environmental events causes human health issues, as well as economic hardship and unlivable conditions.

- **Housing Response:** Over the past two years CIV has invested resources and staff time to gather information to better understand housing conditions and housing needs in Tlákw Aan. A Housing Committee was formed that was made up of CIV staff: the housing coordinator, resilience coordinator, IGAP coordinator, emergency operations coordinator and the Tribal Administrator. The Housing Committee collected information to support CIV to better address housing issues. Fixing the housing issues in Tlákw Aan will require an investment in capacity, resources, and continued planning.
- **Repairing Homes**
  - In 2021, CIV partnered with Cold Climate Housing Research Center (CCHRC) to develop a housing survey specific to Tlákw Aan. The purpose of the survey was to collect information from households that will help CIV address housing conditions and needs. The survey was completed by over 75% of households in Tlákw Aan.
  - In 2022, CIV worked with the DOE's- Office of Indian Energy, Technical Program to bring CCHRC to Tlákw Aan to do assessments of homes in Klukwan. CCHRC identified energy efficiency issues, moisture and mold issues, electrical issues, plumbing issues and significant structural issues.
  - Based on the work of the housing committee, the community housing survey and the information provided by CCHRC's assessments, CIV will have the information necessary to apply for funding to address the most significant issues.
- **Building New Homes**
  - It has been expressed through the housing survey that there is a need for new housing in Tlákw Aan. The Housing Committee is researching the optimal type of building considering the climate exposures.

- The Environmental Department is partnering with Sitka Sound Science Center and the Khutí project to better understand risks from flooding, landslides, avalanches, and bank erosion. This mapping of geo-hazards will generate important information to ensure new homes are not put in areas with a high likelihood of future geo-hazard events.
- The Housing Committee continues to identify areas to build capacity to qualify for large housing grants

RIVERBANK: As discussed above, the homes and buildings in Tlákw Aan reside on the bank of the Jilḵáat River. The bank of the river is vital infrastructure. Better understanding of the risk to bank erosion and flooding is a top priority. Already, flooding and erosion are removing a large section of the riverbank next to the Jilkaat Kwaan Heritage Center campus and threatens the existence of this campus and its buildings. The Jilkaat Kwaan Heritage Center campus serves many needs in the village of Tlákw Aan. The Heritage Center Campus consists of the Jilkaat Kwaan Cultural Heritage and Bald Eagle Preserve Visitor Center, the Hospitality House Likoodzi Kaayuwateen Hídí (more accurately interpreted as Generous Reception House), and the five buildings at the Traditional Knowledge Camp.

The flooding and bank erosion is also causing a loss of salmon spawning and rearing habitat. The Jilḵáat River watershed produces the third to fourth largest run of Chinook salmon and is the second largest Coho salmon stock in Southeast Alaska. It also has an important, late fall Chum salmon run. All five species of salmon within the Jilḵáat Aani Ka̱ Héeni (Chilkat River Watershed) provide essential food and connection to our cultural heritage and traditional foods and ceremonial practices necessary for our tribal members' health and well-being. Haa Atx_aayí Haa K_usteeyíx_ Sitee (Our food is our life). These salmon are part of a larger intact ecosystem that supports small forage fish such as hooligan, and other anadromous species, mammals such as brown bear, black bear, moose and mountain goats, birds, and medicinal plants, all of which provide essential food and economic value to the communities in the Chilkat Valley, and particularly to tribal members. The salmon fishery plays an important role in our region's economy because the seafood industry is the second largest economy after tourism.

Over the last several years, CIV leaders, partners and contractors researched different types of bank stabilization strategies that have been used to create natural solutions to riverbank stabilization in other parts of Washington and Alaska with similar floodplain ecology. We chose Engineered Long Jams and Bank Roughening Structures (ELJ) because they provide the most environmentally friendly method for bank stabilization for the protection of water quality and fish habitat.

Current bank stabilization:

Photo: Derek Poinsette, Heritage Center and Culture Camp.

This year CIV received funding from the BIA Tribal Resilience Program and the National Fish and Wildlife Foundation to carryout phase 3 of a large network of Engineered Log Jams along the Chilkat River in front of the Jilkaat Kwaan Heritage Center Campus. Phases

1 and 2 are complete, with monitoring results indicating successful Chinook salmon rearing, Chum salmon spawning, and bank stabilization for village structures. Phase 3 will protect the important cultural buildings and ceremonial grounds within Klukwan.

Planning for future bank stabilization: The Environmental Department is working to better understand risks from flooding, landslides, avalanches, and bank erosion. All these geohazards impact the riverbank. The mapping of geo-hazards will generate important information to plan for potential relocation of smoke houses and other structures and inform building of new structures in the near and distant future. CIV can work with Tlákw Aan residents to ensure that building on the riverbank and or altering the riverbank does not exacerbate riverbank erosion for homes downstream.

WATER PLANT: Tlákw Aan has one water treatment plant and water storage tank. CIV operates the water plant and services drinking water and water for emergency fire use to the residents of Tlákw Aan. The Environmental Department is partnering with Sitka Sound Science Center and the Kutí Project to better understand risks from flooding and landslides at the location of the treatment plant and water storage tank. If the treatment plant and storage tank are at risk of geohazards, a backup tank should be built. The drinking water source is largely ground water that is fed by surface runoff in higher elevations. CIV has not reported a shortage of water. Unfortunately, when the treatment plant was built, a metering device was not built into the system. A device to meter water use should be added to the system.

Photo: Water Tank

4. Improve understanding of geohazards and the risk they pose

The Environmental Department should continue to partner with outside entities to better understand the risks that geological hazards (geohazards) pose to the community. We hope that information will be gathered from the Kutí Project and new partnerships will continue to bolster CIV's understanding of the timing of geohazards and the risks posed. The following is a list of opportunities that would support geohazard understanding in the Chilkat Valley. This list of actions is an initial list that was identified by CIV staff and the Kutí Project technical experts. Carrying out the below actions could help geohazards planning and response for Tlákw Aan.

The Kutí Project is a 5-year, NSF-funded project (Award # 2052972) to develop natural hazard monitoring tools in collaboration with six communities in Southeast Alaska, following an effort to investigate landslides and develop a warning system in Sitka (see SitkaLandslide.org). The professional research team consists of atmospheric scientists, landslide geomorphology specialists, hydrologists, social scientists, developers for environmental sensing technology, graduate students, educators, tribal environmental staff, and others. In 2023, the project is entering its second year.

Use existing hazard planning information and the information that is being generated and compiled from the December 2020 storm event in future planning

- University Alaska Fairbanks/Alaska Division of Geological and Geophysical Surveys Geologic compilation of December 2020 impacts to structures and infrastructure
  - Summer 2023: bedrock mapping, landslide inventory
- Analysis of DOT database of impacts
- Sensor installation considerations: Takshanuk Weather Station (above 19-mile fan), soil moisture, snowpack, wells
- Utilize information in the Haines Borough Multi-Hazard Mitigation Plan 2015 in continued planning

Support a landslide early warning system in Chilkat Valley

- Utilize examples like the Sitka Landslide webpage (sitkalandslide.org) and other community warning systems, like radio or phone alerts, to help inform the development of an early warning system.
- Deploy possible technologies:
  - Rainfall forecasts and observations
  - Hydrologic monitoring (soil moisture, groundwater well pore pressure)
- Landslide alerts (e.g., in the event of active hazard, possible road closure) at Mile 19 or other site ("nowcasts" not forecasts")
- Possible technologies:
  - Seismic/geophones
  - Game cameras

Avalanche Hazard

- Map return intervals for avalanche paths of interest to CIV
- Examine role of climate change on avalanches and impacts to infrastructure, operations, and resources
- Study the role of avalanches in the population dynamics of critical mountain species such as mountain goats

Hazards mapping to inform decisions about evacuation, future development

- Landslide hazard maps (Possible technologies: LiDAR, Susceptibility mapping using LiDAR data combined with LAHARZ initiation and runout models)
- Avalanche hazard maps
- Flood inundation maps

Characterize hazards on Tlákw Aan debris fan: channel avulsion (change) dynamics (possibly include protective infrastructure to water tower and village)

» Possible technologies:
  - Modeling
  - Historical analysis
  - Geologic mapping to complement existing maps

Flooding and river hydrology

» How does flooding and hydrology impact bank erosion and important aquatic species habitat?
  - Develop processes and tools that support the exchange of information in Tlákw Aan among residents that alerts people to possible landslides, flooding and avalanches.
  - Compile a more complete record of extreme precipitation events and impacts.

5. Seek Funding for Energy Efficiencies and Continue to Assess Renewable Energy Options

Energy costs are significant in Tlákw Aan. The retail power rate is about $0.66/kW-hr. Even, with the power cost equalization the rate is high by Alaska standards. At one point, the village had their own utility and diesel generating system. Later, the village worked an agreement with an area utility to supply power. Over time, the cost has become prohibitive[118]. During this planning process CIV partnered with the DOE, Office of Indian Energy, and CCHRC to assess energy issues in homes and buildings in the village. CCHRC provided CIV with several housing assessments that highlight ways in which home repairs can support energy efficiencies. The Environmental Department and the Housing Department can use these assessments to seek funding and partners to address energy issues in homes.

CIV has applied multiple times for funding to put solar panels on the JKHC. However, even though feasibility assessments were conducted, funding has been denied due to the DOE's concerns about the use of and design placements of solar panels. CIV and the JKHC could seek grants to investigate the feasibility of geothermal, solar panel placements, and run-of the river hydroelectric generating plant.

Though there may be several possible options in the future, it will be necessary to understand potential legal issues with the electrical utility agreement and permitting considerations for in-river hydro systems.

6. Update Emergency Preparedness and Response to address Climate Vulnerabilities

Both the COVID 19 pandemic and recent flooding and landslide events have emphasized the need to ensure CIV's emergency planning, preparedness and response is up to date and operating. It is likely that landslides over the Haines Highway could cut Tlákw Aan off from Haines, which is the source of Village medical care, fuel, food, and other essential items that are brought into Haines by barge. During a community meeting discussing geohazards, CIV tribal council members, staff, and Tribal Members discussed current gaps in preparedness, for instance; ensuring elders with specific medical needs have energy backup systems in their homes for the power outages, and satellite phones for CIV vehicles that can be used on the highway where cell service does not work. Having a plan if a landslide does impact the village was identified as a real need. Educating Tlákw Aan residents of the risks and the emergency response plans will be central to the process of updating emergency response.

Looking Forward

This planning process allowed us to assesses critical aspects of our community and culture and established for us a process by which we can take time to plan for and create innovative solutions to adapt to a changing world. This Resilience Plan and the issues it addresses are a small subset of many factors that are being exacerbated by a changing environment. This plan does not address specifically; impacts of Climate Change to human health, cultural and sacred sites, cultural identity and practices, and the economy in Tlákw Aan (Klukwan) and the communities that live within Jilḵáat Ḵwáan and Lḵoot Ḵwáan territory. Since we are living in a time of rapid climate change and weather extremes it seems that all forms of community capital should be assessed for vulnerability. Our young children and their children will grow up in a different Jilḵáat Aani Ḵa̱ Héeni. We can help them prepare so they too will thrive.

Please contact the Chilkat Indian Village Environmental Department for these additional information resources related to this Plan and/or follow the link below.

WATERSHED HYDROLOGY ASSESSMENT

TECHNICAL REFERENCE

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