National Park Service
U.S. Department of the Interior

Water Resources Division
Natural Resource Program Center

Technical Report NPS/NRWRD/NRTR-2006/349

ASSESSMENT OF COASTAL WATER RESOURCES AND WATERSHED CONDITIONS AT KLONDIKE GOLD RUSH NATIONAL HISTORICAL PARK, ALASKA

Eran Hood, Ginny Eckert, Sonia Nagorski, and Carrie Talus

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Assessment of Coastal Water Resources and Watershed Conditions at Klondike Gold Rush National Historical Park, Alaska

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Technical Report NPS/NRWRD/NRTR-2006/349

March 2006

This report was prepared under Task Order J9W88 04 0016
of the Pacific Northwest Cooperative Ecosystem Studies Unit (agreement CA90880008)

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

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Acknowledgements

We would like to thank numerous people for their help in the preparation of this report. Amber Bethe at the Taiya Inlet Watershed Council and Meg Hahr at KLGO provided a wealth of information about the park. Mark Flora, Meg Hahr, and Kristen Keteles at the National Park Service provided extensive comments on the draft report, which greatly improved the final product. Ewin Knuth at UAS provided the original maps for the report.

Commonly used abbreviations

ADEC – Alaska Department of Environmental Conservation
ADFG – Alaska Department of Fish and Game
ADNR – Alaska Department of Natural Resources
ANILCA – Alaska National Interest Land Conservation Act
AP&T – Alaska Power and Telephone
EMAP – Environmental Monitoring and Assessment Program (of the EPA)
EPA – US Environmental Protection Agency
HAB – Harmful Algal Bloom
KLGO – Klondike Gold Rush National Historical Park (National Park Service Designation)
NADP – National Atmospheric Deposition Program
NOAA – National Oceanic and Atmospheric Administration (US Department of Commerce)
NPS – National Park Service (US Department of Interior)
NRCS – National Resources Conservation Service
NWI – National Wetlands Inventory (of the US Fish and Wildlife Service)
PMIS – Project Management Information System
POPs – Persistent Organic Pollutants
PSP – Paralytic shellfish poisoning
UAS – University of Alaska Southeast
USFWS - US Fish and Wildlife Service (US Department of Interior)
USGS – US Geological Survey (US Department of Interior)

Executive Summary

Klondike Gold Rush National Historical Park (KLGO) is located at the head of Lynn Canal in Southeast Alaska. The park consists of distinct three units that encompass 5,338 ha (13,191 ac). The Chilkoot Trail Unit includes the old gold rush townsite of Dyea and the Chilkoot Trail corridor in the Taiya River valley. The White Pass Unit in the upper Skagway River basin is the least developed unit in the park. There are no visitor services in this unit, however it receives visitors via the White Pass and Yukon Railway and the Klondike Highway, both of which pass through the unit. The Skagway Town Unit receives the most visitors within the park, primarily from cruise ship passengers, and consists of a group of historic buildings within downtown Skagway. The park has a relatively short coastline that spans 3.2 km (2 mi) of shoreline along the Taiya Estuary in the Chilkoot Unit. The mission of KLGO is to preserve in public ownership historic structures and trails associated with the Klondike Gold Rush of 1898. Within this context, park lands are managed by the National Park Service (NPS) for historic preservation, maintenance and interpretation of the historic scene, protection of natural resources, and public use.

Historically, both the Chilkoot and White Pass corridors have served as important trade and commerce routes in Southeast Alaska because they provide direct, glacier-free access to the interior through the coast mountains. These valleys also provide an interface between the maritime ecosystems along the Lynn Canal and the continental ecosystems of Northwest Canada. As a result, the Chilkoot and White Pass Units of KLGO are biologically diverse areas that encompass strong elevational and ecological gradients that include coastal rainforest, sub-alpine boreal forest, and alpine tundra.

Water resources within KLGO are diverse, ranging from glaciers and snowfields in the coast mountains to rivers, streams, lakes, and wetlands that extend down to the coast. The purpose of this report is to assess the existing conditions and to identify possible impairments of water resources in KLGO, based on a review of currently available data and information. Additionally, this report will identify existing data and information gaps that need to be addressed in order to best manage water resources within the park.

The City of Skagway has a population of about 850 year-round residents which approximately triples during the tourist season in the summer. The present-day economy in Skagway is dominated by tourism, and tourist visits exceeded 850,000 in 2004. Outside of visitation to the historic buildings in the Skagway Unit, recreation is the primary use of park lands in KLGO. Approximately three thousand visitors each year retrace the footsteps of the goldrush stampeders along the Chilkoot trail. Additionally, the road-accessible area along the lower Taiya River is used for camping and sport fishing.

The climate in KLGO is temperate maritime, with a mean annual temperature of 41.0˚F. Skagway is located in the rain shadow of the coastal mountain ranges to the west, thus the area is dry relative to most of southeast Alaska. Annual average precipitation is 25.5 inches, the majority of which comes in the fall, while annual snowfall is nearly 40 inches per year. Snowcover at sea level is intermittent to an elevation of 200-300 meters.

The primary watersheds in KLGO are the Taiya and Skagway Rivers, although the Skagway Town Unit is largely within the Pullen Creek watershed. Data on streamflow are available for three watersheds within the KLGO: the Skagway and Taiya Rivers and West Creek, however only the Taiya River is currently gaged. The Skagway and Taiya watersheds range in elevation from sea level to over 6,000 ft elevation in the coast mountains, and both of these watersheds have strongly seasonal hydrographs with peak flows in summer when inputs of glacial meltwater are at a maximum. The Pullen Creek watershed, which runs through the Skagway Unit into Skagway Harbor, is contained entirely within the City of Skagway. This stream has been heavily impacted by urbanization and development and is currently listed on the Environmental Protection Agency (EPA) Clean Water Act Section 303(d) list of Impaired Water Bodies.

Other important water resources within the Skagway and Taiya watersheds include glaciers and snowfields, wetlands, and groundwater. As of the mid-1990s, 33% of the Taiya watershed and 17% of the Skagway watershed was glaciated. Within KLGO, both of these watersheds contain abundant riverine wetlands as well as estuarine wetlands at the outflow of the Taiya River. In 2004 a small tidal wetland ("Nelson Slough") in the Chilkoot Unit underwent restoration in order to restore natural bank structure and native aquatic vegetation for the benefit of anadromous fish. The alluvial deposits around Skagway extend to a depth of at least six hundred feet and provide municipal water, although relatively little information is available regarding groundwater resources within KLGO.

In terms of biological resources, the marine environment in Taiya Inlet is less productive than other areas of Lynn Canal to the south because of large amounts of freshwater and sediment input. However, there is a subsistence fishery for both fish (salmon and non-salmon) and invertebrates (crab and shrimp) in Skagway. The shoreline of Lynn Canal around KLGO has been mapped by the ShoreZone project, a multi-agency collaboration which has produced an online database consisting of interactive GIS layers, digital maps, aerial images, and video. Vegetation in the Taiya estuary along the KLGO coastline consists mainly of graminoids and forbs, silverweed, beach pea, and sedges.

In upland areas, the park units in KLGO are located at the northern end of a maritime hemlock-spruce-cedar temperate rainforest. As a result, flora in KLGO are a mixture of old growth coniferous forest, peatlands, alpine vegetation, and successional communities. These communities support more than 30 species of mammals, at least one species of amphibian and more than 130 species of birds.

The three primary freshwater watersheds in the park (Taiya and Skagway Rivers and Pullen Creek) support three of the five species of Pacific Salmon: chum salmon (*Oncorhynchus keta*), pink salmon (*Oncorhynchus gorbushca*), and coho salmon (*Oncorhynchus kisutch*), as well as anadromous and resident Dolly Varden char (*Salvelinus malma*). Chinook salmon (*Oncorhynchus tshawytsch)* have also been introduced in Pullen Creek through a hatchery program run by the Douglas Island Pink and Chum (DIPAC) hatchery and the City of Skagway. A commercial-scale Chinook salmon hatchery in the upper Taiya Inlet is currently being proposed, although little is known about its possible ecological repercussions. The maintenance of healthy salmon stocks is important because spawning salmonids can have significant impacts on biological resources in both terrestrial and freshwater aquatic ecosystems. Macroinvertebrate sampling in the Taiya River suggests that water quality is relatively good in areas that are not substantially affected by glacial sediment or tidal inundation with saline water from Taiya Inlet.

There has not been a consistent or long-term effort to monitor water quality in KLGO. The Chilkoot Unit of the park contains two monitoring stations with long-term water quality records from the 1960s and 1970s: West Creek and the Taiya River. There are no stations with long term records for the Skagway River in the White Pass Unit, however there is a monitoring station on the Skagway River approximately 8 miles downstream from the KLGO boundary that has more than 30 years of data extending to the mid-1980's. There are no historic water quality data available for Pullen Creek, however the Skagway Traditional Council conducted a watershed assessment in 2003-2004 that included the collection of baseline water quality data including: field parameters, heavy metals, and hydrocarbons.

In the Taiya and Skagway watersheds, the limited, and somewhat outdated, water quality data available suggest that the watersheds are relatively unimpacted. Levels of turbidity were generally below the EPA standard of 50 formazin turbidity units, however both of these rivers are prone to episodic increases in turbidity associated with rainfall events and increased inputs of silt-laden glacial meltwater. The few measurements of fecal coliforms suggest that this form of bacterial contamination is not an issue of concern. Metal contamination similarly does not appear to be an issue of concern in the Taiya and Skagway Rivers, with less that 5% of samples exceeding EPA criteria for copper, silver, zinc, cadmium, and mercury. Levels of inorganic nitrogen and phosphorus, which are of concern for eutrophication, were also low in both watersheds.

Water quality data for precipitation and the marine environment along KLGO are limited. A National Atmospheric Deposition Program (NADP) site near Juneau is located 50 km south of KLGO and is likely representative of precipitation received in KLGO. Precipitation chemistry data from this site are available online through the NADP website and database. Marine waters in Skagway Harbor were shown to have elevated levels of fecal coliforms in the late 1970's, although more recent data are not available so it is not possible to assess the extent of any ongoing water quality impairments in Skagway Harbor.

The primary subject of water quality impairment within KLGO is Pullen Creek. Heavy metal and hydrocarbon pollutants within the Pullen Creek watershed are thought to be associated with an ore transfer facility as well as runoff from hydrocarbon-contaminated sites and urban surfaces in Skagway. Sampling of surface waters, bank soils, and stream sediments collected along Pullen Creek in 2003-2004 showed that despite contaminated soils, levels of metals and hydrocarbons in the stream and groundwater are generally below State of Alaska standards for remediated sites. A series of synoptic surveys of basic water quality measurements during the same period showed that parameters such as temperature, pH, and dissolved oxygen were typically within state standards for aquatic life. Other impairments within Pullen Creek include fish passage obstacles and debris accumulation. The Taiya Inlet Watershed Council (TIWC), an interagency/community partnership formed by the City of Skagway, the Skagway Traditional Council, and KLGO, is currently working to assess, remediate and restore Pullen Creek. Other potential sources of water quality impairments to KLGO watersheds include a series of ADEC contaminated sites both within the City of Skagway and along the railroad in White Pass.

Petroleum spills are the primary point source pollution threat to coastal water resources in KLGO, and several small spills have occurred. In 1993 an underground storage tank in Skagway leaked petroleum into surrounding soils, and although contaminated soils were later excavated, subsequent sampling revealed lingering petroleum contamination in the local area. Another case of hydrocarbon pollution in Skagway was identified on a vacant lot from which 100 gallons of free product were recovered. A railway site along the East Fork of the Skagway River was also contaminated with hydrocarbons when a diesel fuel pipeline broke, although the incident likely poses insignificant risk to the Skagway River.

On a more regional level, the heavily used port of Skagway, located in close proximity to the KLGO coastline in Taiya Inlet, receives more than 80,000 tons of petroleum products as freight annually. Taiya Inlet has been identified as one of five sensitive areas in the upper Lynn Canal within the regional oil spill response plan coordinated by ADEC, meaning that this area has a site specific response strategy. Skagway harbor is also identified as a sensitive area and has a site specific protection plan in place.

Another potential point source of pollution is backcountry pit toilets along the Chilkoot Trail. All five of the Dyea and Chilkoot trail campgrounds are located next to the Taiya River, thus leaching from current and historic pit toilet sites pose a contamination threat to shallow groundwater and nearby surface water resources. Recently, two composting toilets were installed at Sheep camp, the most heavily used KLGO camp on the Chilkoot Trail. These toilets contain human waste in above-ground containers which allow for the removal and incineration of human waste and may be an appropriate substitute for other pit toilets within the park.

The primary non-point pollution threats to coastal water resources in KLGO are runoff from impervious surfaces and air pollution. Presently, the majority of surface water that drains from paved surfaces and buildings in Skagway is transmitted into city storm drains that empty into Pullen Creek or the Skagway River. This urban runoff contributes to water quality impairments documented in Pullen Creek, however recent water quality data are not available to assess potential problems associated with runoff from impervious surfaces in the Skagway and Taiya Rivers.

The air pollution that affects aquatic resources in KLGO is derived both from local/regional sources and long-range/global sources. Pollution sources affecting the airshed around Skagway include: air and motor vehicle emissions, waste burning and incineration, emissions from cruise ships and diesel tourist trains, and dust from historic ore transport operations. A recent air quality assessment that sampled concentrations of chemicals in lichen tissues at 4 locations in and around KLGO indicates that the Klondike-Skagway airshed has relatively high levels of heavy metals and sulfur compared to unpolluted areas of Southeast Alaska.

In addition to local pollution sources, evidence is mounting that Alaskan ecosystems are being contaminated by long-range atmospheric transport of chemicals such as mercury and persistent organic pollutants (POPs). Although these contaminants have not been studied in KLGO, two recent studies in Southeast Alaska indicate the region as a whole is being impacted by these contaminants. Seabird eggs in Sitka Sound had high levels of POPs and polychlorinated biphenyls (PCBs) relative to other Alaskan bird colonies. In addition, a series of dated sediment cores collected in Glacier Bay lakes indicate that rates of mercury accumulation in lake sediments have approximately doubled since pre-industrial times.

At the present time, coastal development in the Skagway area is not a primary concern for water resources in KLGO. The population of Skagway has remained relatively stable for the last two decades and is expected to grow at a modest rate of 1-2% over the next several decades. The City of Skagway Dyea Flats Land Management Plan prohibits camping outside of designated areas and residential, commercial, and industrial development in the flats, however Skagway's future growth plan does designate large areas for low density residential development along the Dyea Road on the east side of the Taiya River. The Alaska Department of Transportation and Public Facilities also plans to build a road from Juneau to Skagway. The present preferred alternative for this road is to terminate the road at the Katzehin River about 30 km south of Skagway and run a ferry to Skagway and Haines from that location.

Several land use issues in KLGO and its surroundings have possible implications for local water resources. Riprap has been installed along the Dyea road in an effort to minimize erosion caused by the Taiya River that is threatening cultural resources at the Dyea townsite. Additionally, a scour control structure on the Skagway River near the Skagway airport may interfere with fish movement. New culverts and a rebuilt lower section of Pullen Creek appear to have improved fish passage, although one culvert was identified as potentially problematic during high flow conditions. The Skagway River Flood Control Master Plan has the potential to cause a small increase in stream velocity due to channel constriction, but overall should help protect the Skagway KLGO unit from large floods.

Marine vessel impacts are a concern along the coastal portion of the Chilkoot Unit. In 2004 the port of Skagway was visited by 850 vessels, of which the majority were cruise ships and Alaska State Ferries, and the Upper Lynn Canal sees traffic from charter and recreational boats. Direct impacts from marine vessels include water quality degradation through petroleum or waste discharges and noise pollution from vessel engines. KLGO does not have jurisdiction over the marine waters around the Taiya Inlet or Skagway Harbor, and marine vessel traffic does not pose a direct threat to park resources outside of a large petroleum or hazardous waste spill that could adversely affect intertidal ecosystems. However, discharge from marine vessels does have the potential to generate water quality impairments in near-shore waters in the upper Taiya Inlet.

Very little is known about harmful algal blooms, which are caused by a few dozen marine phytoplankton that produce toxins. Harmful algal blooms have been documented for centuries in Southeast Alaska. The earliest recorded event in Alaska was in 1799 when a party of Aleut hunters under the command of a Russian fur trading company ingested mussels. Within minutes, half the party experienced nausea and dry mouth, and two hours later, 100 hunters had died. Alaska has figured prominently in the discovery of HABs and associated toxins, as the family of toxins responsible for PSP were named saxitoxins because they were extracted from the butter clam *Saxidomus giganteus* from Peril Strait, just northeast of Sitka. NPS should advise against non-commercial harvests of shellfish because of the risks associated with PSP.

KLGO has a well-established exotic plant management program. In 2005, 23 exotic plant species were identified in KLGO, and park staff and others spent over 300 hours manually removing exotic plants within park boundaries. In general, aquatic ecosystems in Alaska are more likely to be invaded by non-indigenous species relative to upland environments because the temperature ranges of these systems vary less than temperature ranges in terrestrial systems, however there has not been a survey of aquatic invasive species in KLGO. Fish species that have the greatest potential to invade aquatic systems in KLGO include Northern Pike (*Esox lucius* (Linnaeus)) and Atlantic salmon (*Salmo salar*). The first recorded recovery of an Atlantic salmon in Southeast Alaska occurred in 1991 and since then ADFG has documented over 700 recoveries. In addition a variety of invertebrate invasive species pose a threat to near-shore and freshwater aquatic environments in KLGO.

The physical environment around KLGO is extremely dynamic and as a result park resources face threats from a variety of geomorphic hazards including: landslides and tsunamis in Skagway Harbor, outburst flooding on the Taiya and potentially the Skagway River, and changes in hydrology coastal environments associated with land surface uplift. In both 1966 and 1994, landslide-generated tsunami events occurred in Skagway Harbor. The findings of investigations into these events suggest that coastal construction activities that cause loading to slope material in the intertidal zone pose an ongoing tsunami risk for the region around Skagway harbor.

The Taiya River is extremely dynamic and is subject to channel migrations and catastrophic flooding from glacial outburst events. For example, in 2002 the collapse of a lateral moraine along the West Creek Glacier triggered an outburst flood that was estimated to be 150% of the predicted 500-year flood for West Creek. Since that event, outburst flood potential in both the Nourse River and West Creek has been investigated by hydrologists from the Bureau of Land Management. Moraines in these drainages appear stable; however if the Nourse Glacier moraine were to fail, the resulting flood would have a magnitude of more than five times the estimated 500-year flood event on the Taiya.

Active tectonics in Southeast Alaska as well as the increased thinning of glaciers are both contributing to the extremely high rates of land surface uplift in the KLGO region. Over the past 250 years, shorelines in the upper Lynn Canal south of KLGO have been raised between 3 and 5.7 meters primarily as a result of land surface uplift. Measurements using global positioning systems (GPS) have shown that the land surface in the Skagway area is being uplifted at a rate of approximately 10-14 mm yr^{-1}. This uplift has the potential to alter the physical landscape and cause dramatic changes in fisheries and wildlife habitat as well as the hydrology of small coastal streams.

Climate change is an important natural resource issue for national parks in Alaska, and recent research suggests that changes in climate may dramatically impact water resources in these parks. The most obvious effects of climate change on hydrologic resources in Alaska are changes in the extent of permafrost, snow cover, glaciers, and sea and lake ice cover. Climate stations in the region around KLGO show an increase in average summer air temperature since about 1940 when the meteorological record began. Glaciers in the Taiya and Skagway watershed are generally thinning at rates ranging from 0-2 meters per year. One important effect of increased glacier melt is a surge in runoff from glaciers, which can alter the sediment, streamflow, and temperature regimes of downstream waterbodies and can lead to the creation of new streams. Climate change also has the potential to affect water quality in KLGO by inducing ecosystem-scale changes in the distribution and composition of soil microbial and plant communities.

Finally, specific recommendations for management and monitoring of both freshwater and marine water resources in KLGO are provided (Table i).

Table i. Potential for impairment of coastal KLGO water resources.

Indicator	Freshwater Taiya R.	Freshwater Skagway R.	Freshwater Pullen Cr.	Estuary	Marine/ Intertidal
Water Quality					
Eutrophication	OK	OK	OK	OK	OK
Contaminants	OK	OK	EP	OK	OK
Metals	OK	OK	PP	OK	OK
Turbidity	OK	OK	PP	OK	OK
Pathogens	OK	OK	OK	PP	OK
Hypoxia	OK	OK	PP	OK	OK
Habitat Disruption					
Physical benthic impacts	OK	OK	PP	PP	OK
Recreation/Tourism usage	PP	OK	PP	OK	OK
Altered flow	OK	OK	PP	NA	NA
Erosion/Sedimentation	EP	PP	PP	OK	OK
Other Indicators					
Harmful algal blooms	NA	NA	NA	PP	PP
Aquatic invasive species	PP	PP	PP	OK	OK
Impacts from fish/shellfish harvesting	OK	OK	OK	OK	PP
Terrestrial invasive species	EP	EP	EP	NA	NA
Climate change	PP	PP	PP	PP	PP
Glacial outburst flooding	PP	PP	OK	NA	NA
Fuel/Petroleum spills	OK	PP	PP	PP	PP
Atmospheric contaminants/Air pollution	PP	PP	PP	PP	PP

Definitions: EP= existing problem, PP = potential problem, OK= no detectable problem, shaded =limited data, NA= not applicable.

A. Park Description

A1. Background

A1a. Setting

Klondike Gold Rush National Historical Park (KLGO) is located in northern Southeast Alaska, approximately 140 km (86.99 mi) north of Juneau (Figure 1). The park boundaries encompass 5,338 hectares (13,191 acres) within three distinct park units: the Skagway historic district (Skagway Unit), the Chilkoot Trail and Dyea townsite (Chilkoot Unit), and the White Pass Trail and city area (White Pass Unit) (Figure 2). The town of Skagway is a popular destination for cruise ship tourism and as a result, KLGO is the most visited national park in Alaska (NPS 2005a).

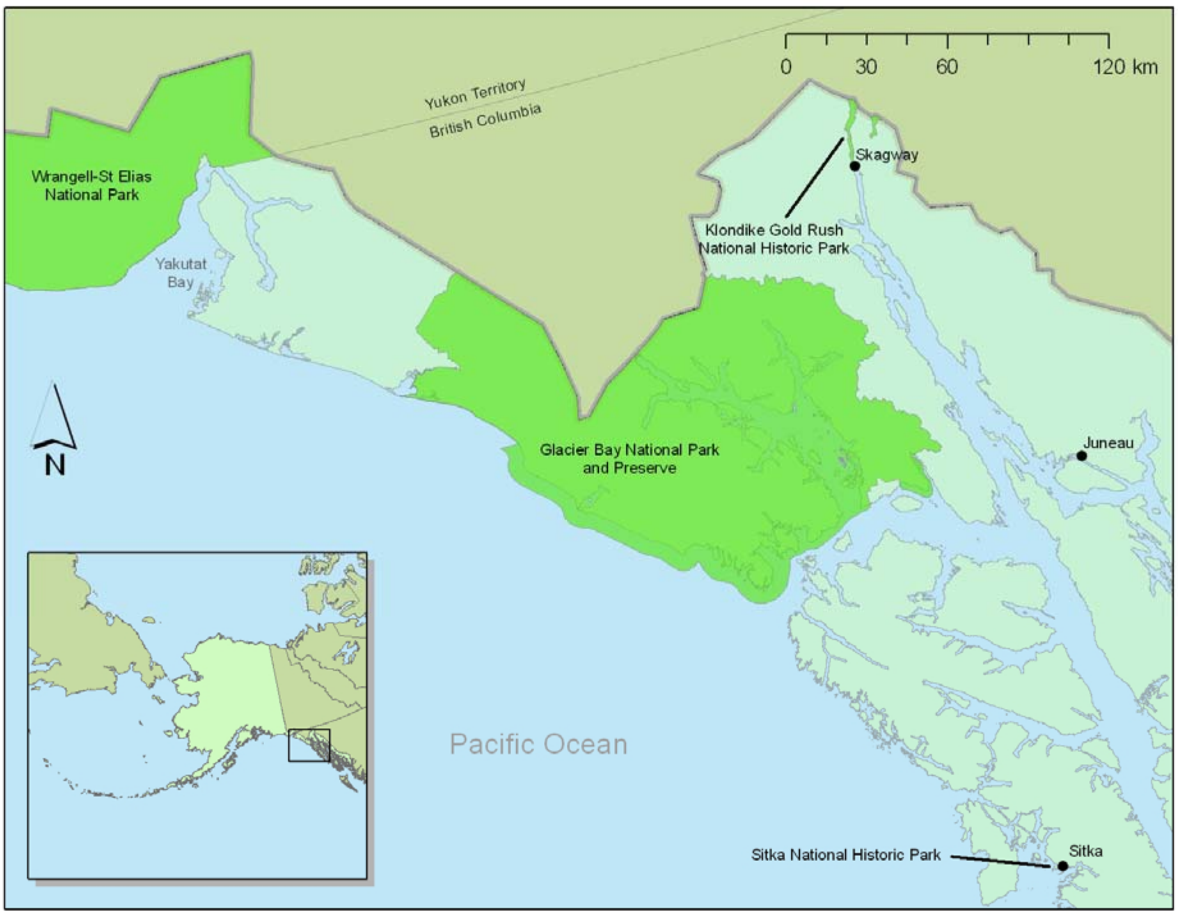

Figure 1. Location of Southeastern Alaska Coastal Cluster National Parks. The coastal cluser includes two National Parks: Glacier Bay and the coastal portion of Wrangell-St. Elias and two National Historic Parks: Klondike Goldrush, and Sitka.

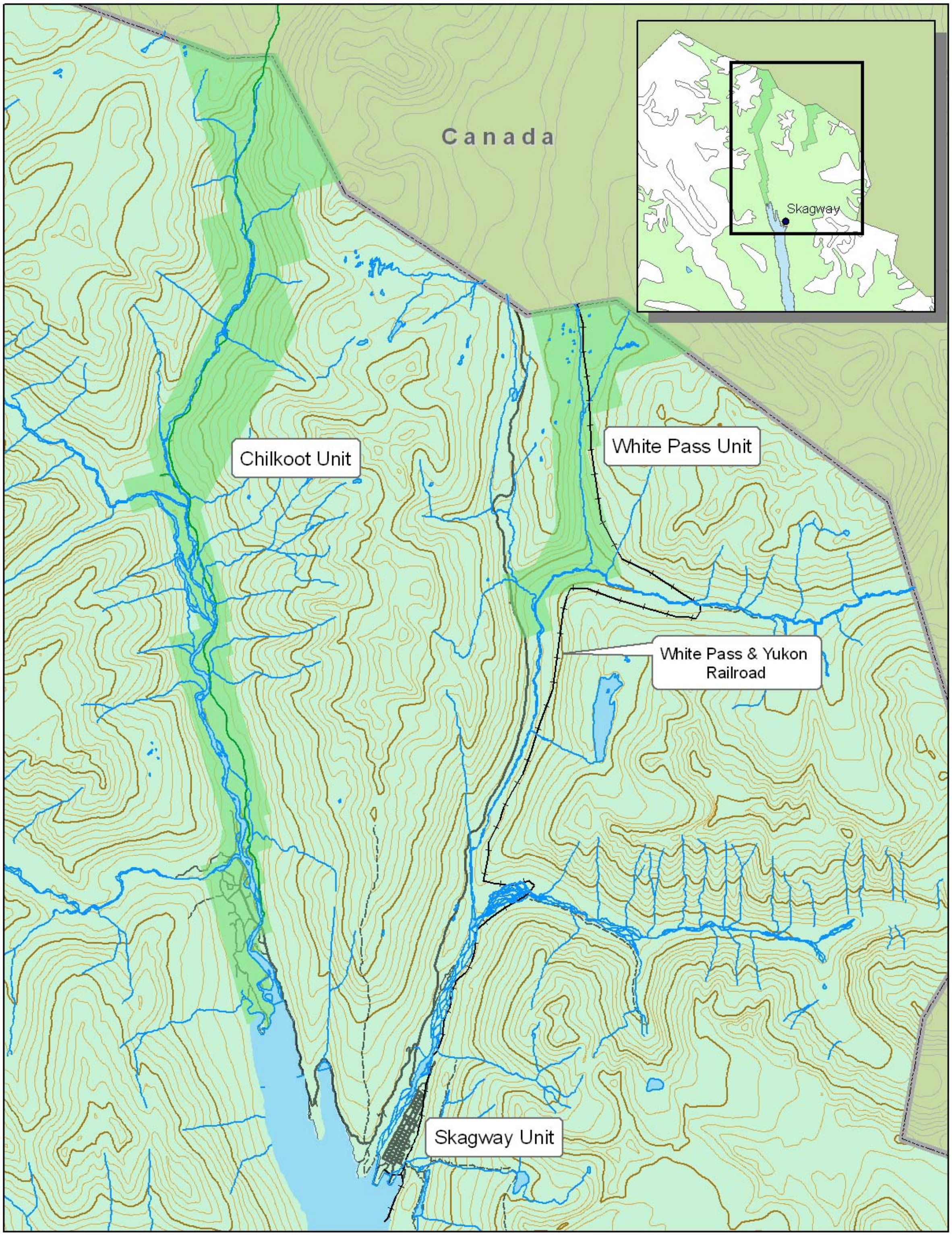

Figure 2. Location of the three KLGO park units in southeastern Alaska. The White Pass and Yukon Railway runs along and through two of the three park units.

The three units within the park have different management strategies. The Skagway unit, located in the heart of downtown Skagway, experiences the most visitor traffic, and in 2004 it received over 850,000 visitors. The Skagway unit contains 20 restored or rehabilitated historic buildings from the Gold Rush Era that are owned by the National Park Service (Figure 3). The Dyea and Chilkoot Trail unit encompasses the Dyea gold rush town site and Chilkoot Trail corridor (Figure 4), where approximately 3,000 visitors annually come to hike (NPS 2005b). Because the Chilkoot trail crosses the US/Canada border, KLGO and Parks Canada work cooperatively to manage a permit system for hikers on the Chilkoot Trail, and each maintains trail operations on their own side of the border. KLGO operates a campground in Dyea and provides ranger services in Dyea and on the Chilkoot Trail. The White Pass unit is the least developed of the KLGO units, with no established trail system and no developed visitor services. KLGO provides interpretive wayside exhibits along the Klondike Highway which passes through the southeast corner of the unit. Additionally, the White Pass and Yukon Route Railroad, a Canadian company, operates a regularly scheduled sightseeing service that brings over 400,000 visitors through the White Pass unit each year.

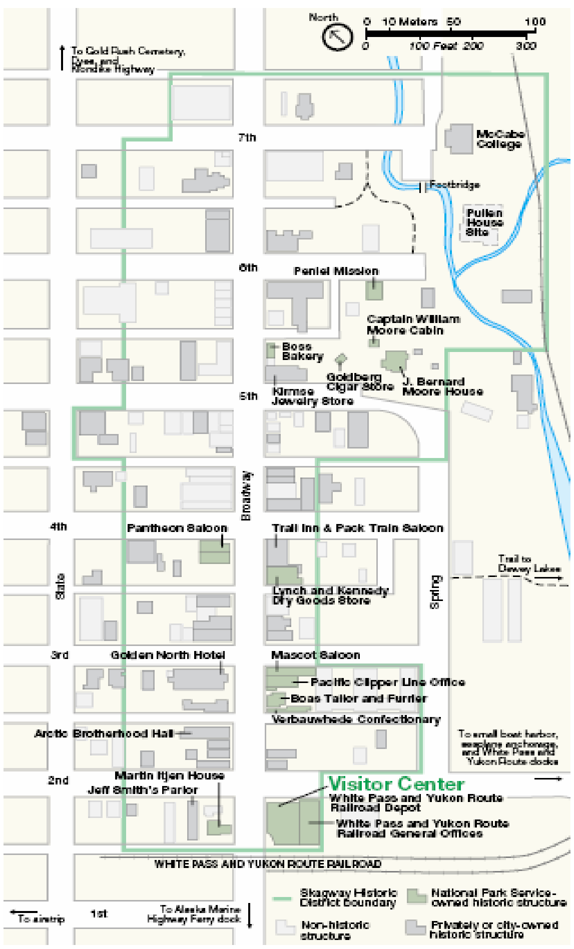

Figure 3. Area (outlined in green) of the Skagway Unit of KLGO within downtown Skagway. Pullen Creek is located in the upper right hand corner. From NPS 2005b.

KLGO is unique in that most of the property within its boundaries is not owned by the NPS, and as a result, multiple jurisdictions manage and influence watersheds within the park. The State of Alaska owns over 4,046 hectares (10,000 acres) in the Dyea/Chilkoot and White Pass units (NPS 2005a). The City of Skagway has recently received large sections of land within the Dyea and Chilkoot unit of KLGO through the Municipal Entitlement Act (NPS 2005a). A Memorandum of Understanding between KLGO and the State of Alaska allows KLGO management authority over State lands that contain the Dyea campground, the Chilkoot Trail corridor, and Canyon City and Sheep Campgrounds. In the Dyea and Chilkoot unit, a small portion of land is privately owned, while nearly all of the property within the Skagway unit is privately owned.

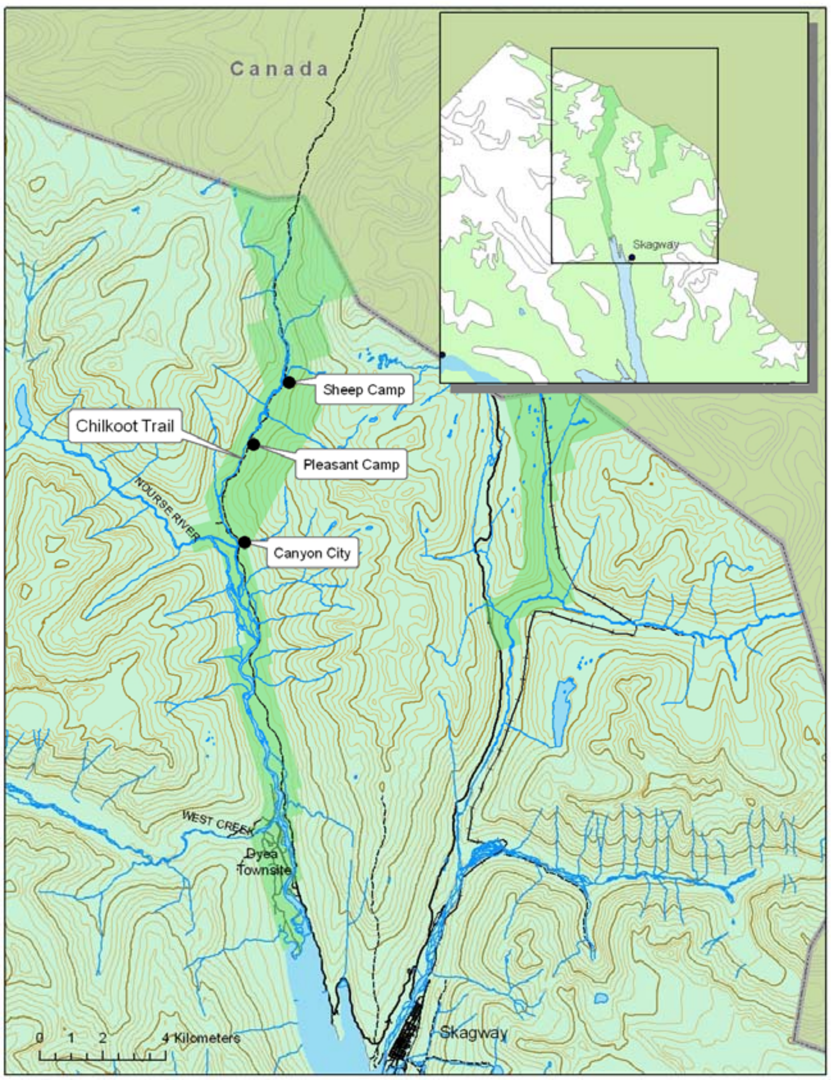

Figure 4. Location of the Chilkoot Trail and Dyea townsite along the Taiya River on the Canadian border. The location of several popular camps along the Chilkoot Trail are also shown.

The primary watersheds in KLGO, the Skagway River and the Taiya River including the upper Taiya Inlet, extend from tidewater to nearly 1,828 m (6000 ft) elevation and contain two mountain passes that are passable from the coast to the interior —White Pass (883 m/2,900 ft) and Chilkoot Pass (1,074 m/3,525 ft). Because these mountain passes are short and glacier-free, they were attractive to both Tlingit traders and gold rush stampeders. The Skagway town unit of KLGO also contains a portion of the Pullen Creek watershed.

A1b. Human Utilization

The region encompassing KLGO was populated by coastal and inland Tlingit and Tagish peoples for hundreds, if not thousands of years, before the 1890s gold rush (Thornton 2004). The area was settled by the Chilkoot-Chilkat Tlingit with villages at Dyea and Skagway. The Tlingit village at Dyea probably consisted of a small fishing and hunting camp near the mouth of the Taiya River, and the Taiya and Nourse River valleys were used by Tlingit people to hunt game such as goats and bear (Norris 1996). In the Skagway area, a smaller Tlingit settlement was used less often than the Dyea area (Norris 1996). These Tlingit peoples controlled access into the interior along what has become known as the Chilkoot Trail, which follows the Taiya River over Chilkoot Pass. It was a major route for trading with interior Tlingit and Athabaskans; the coastal Tlingits trading eulachon oil and other marine products from the coast in exchange for caribou and moose hides, fur, and other inland items (Norris 1996). Throughout the long pre-contact period, the Chilkoot Trail remained the lifeline of the trading network between Tlingit and inland tribes.

In the late 1700s, Tlingit in the KLGO area came into contact with European explorers. Russians settled in Sitka, approximately 270 km (168 mi) from Skagway, around 1800, and Russians and other explorers traded with and then settled in Tlingit lands (Norris 1996). Although control of the major passes into the interior of was maintained by the Tlingit for quite some time, Europeans established settlements in Skagway in 1887. Once the Klondike Gold Rush began in the late 1890's, there was a sudden influx more than 50,000 people into the Skagway area. During the gold rush the Chilkoot Trail gained status as the major route into the interior, and Skagway and Dyea became well established towns and served as staging areas for hopeful prospectors (Thornton 2004). Skagway continued to grow, became Alaska's first incorporated city in 1900, and continued to be the port city for the Yukon Territories.

Before World War I, Skagway saw an increase in tourists and ship traffic, and then World War II brought a second rush to the area with road development, pipeline construction and presence of military personnel (Norris 1996). During the post-war period, logging in the Taiya River valley took place, as well as development such as airport improvements, the Dyea road, and the highway over White Pass (Norris 1996). In the late 1960's, the Cyprus Anvil mine opened over the coast range in Faro, Canada. Shipments of lead and zinc from this mine increased the volume of freight shipped through Skagway via the White Pass and Yukon Railway Route to 800,000 tons by the mid 1970s. A decrease in ore prices in the late 1970s led to the closure of this mine and associated railway in 1982. The railroad was reopened in 1988 and is currently one of the leading tourist attractions in Skagway.

The present-day economy in Skagway is dominated by tourism with 41% of jobs in the leisure/hospitality and retail trade sectors. (City of Skagway 2005). Tourist visits to Skagway have increased approximately 4-fold in the last 20 years to more than 850,000, with the majority of the increase occurring in cruise ship visitors (Table 1).

Table 1 Annual tourist visits to Skagway by mode of arrival. Modified from City of Skagway (2005).

Mode of Arrival	1985	1990	1995	2000	2004
Cruise ships	77,623	136,512	256,788	565,639	722,095
Alaska Marine Hwy	31,522	33,234	33,961	30,732	23,171
Klondike Highway	89,542	63,237	87,977	94,925	77,837
WP&YR	NA	16,072	15,521	19,231	13,187
Small cruise vessels	15,000	17,767	13,000	NA	NA
Air	4,000	4,799	17,000	15,626	6,046
Other	NA	NA	4,100	8,362	15,069
Total visitors	217,687	271,621	428,347	734,515	857,405

Fishery resources in upper Taiya Inlet near Skagway do not support a significant commercial fishery, and only four residents of Skagway currently hold commercial fishing permits (City of Skagway 2005). In 2004, commercial fisheries in the Chilkoot Inlet (ADFG statistical area 115-34) included Tanner crab, Dungeness crab, king crab and coho, sockeye, pink, chum, and king salmon and were valued at more than $200,000 (Catherine Tide, ADFG, Commercial Fisheries Entry Commission, Juneau, Alaska, personal communication 2005). Local residents and visitors sport fish for fish and shellfish in the upper Lynn Canal and Taiya Inlet, with a small sport charter fleet in Skagway. In addition to fishing in marine waters, recreational fishing occurs in and near KLGO from the banks of the Taiya and Skagway Rivers and Pullen Creek.

Klondike Gold Rush National Historical Park was authorized by Congress in 1976 with the passage of Public Law 94-323. The mandate of the park was to preserve in public ownership for the benefit and inspiration of the people of the United States, historic structures and trails associated with the Klondike Gold Rush of 1898. Park lands are managed by the NPS for historic preservation, maintenance and interpretation of the historic scene, protection of natural resources and public use.

A2. Hydrologic Information

A2a.Climatic Setting

KLGO has a temperate maritime climate, although the Skagway region is substantially drier than most of Southeast Alaska. Skagway has a mean annual temperature of 5 ˚C (41.0˚F). Monthly mean temperatures vary annually by greater than thirty degrees, ranging from -5.3 ˚C (22.5˚F) in January to 14.6 ˚C (58.2˚F) in July (Figure 5).

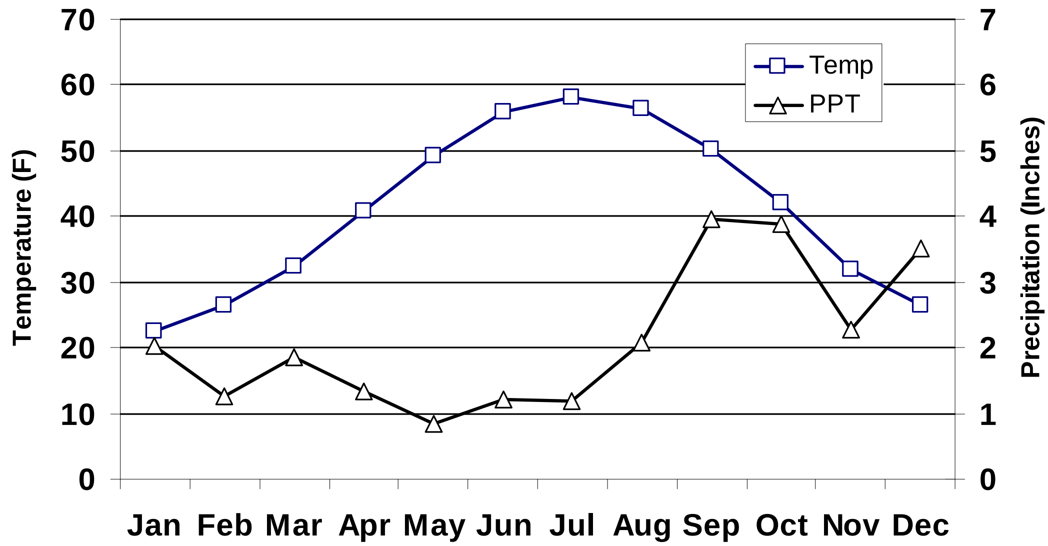

Figure 5. Monthly mean precipitation and temperature in Skagway, Alaska for the period 1898-2004 (record is not continuous). Data from NOAA climate database (http://pajk.arh.noaa.gov/cgi-bin/searchClimData?station=Skagway_Airport).

The upper Lynn Canal is in the rain shadow of coastal mountain ranges to the west, and consequently Skagway receives only 20-60% of the precipitation that falls in neighboring Southeast Alaska communities such as Juneau, Yakutat, and Haines. In Skagway, mean monthly precipitation ranges from less than 2.5 cm (1 in) in May to nearly 10 cm (4 in) in September and October, with an annual average of 64.8 cm (25.5 in) of precipitation (Figure 5). Snowfall averages 99.1 cm (39 in) per year at sea level and falls mainly between November and March. Snowfall in mountain passes such as Chilkoot and White Pass can exceed 1,270 cm (500 in) per year. At sea level, snow cover is intermittent, while elevations above 200-300 m (656-984 ft) often experience a continuous snow cover during winter and early spring.

A2b. Park Hydrology and Water Resources

A2b1. Surface Waters

The three KLGO park units are contained within the watersheds of the Taiya and Skagway Rivers, which are the primary drainages in the upper Taiya Inlet. The hydrologic regime of these watersheds is dominated by runoff from seasonal snow cover and glaciers. Both watersheds have their headwaters in the snowfields and glaciers of the Coast Mountains and range in elevation from sea level to 1,829-2,134 m (6,000-7,000 ft). The Skagway town unit of KLGO also contains a portion of the Pullen Creek watershed. The US Geological Survey (USGS), which delineates the country's hydrologic resources, defines one hydrologic unit in KLGO: Chilkat-Skagway Rivers (19010303) (Figure 6). Streamflow data from the USGS are available for nine streams within this hydrologic unit, however only three are within KLGO (Skagway and Taiya Rivers and West Creek; Figure 7) and only one of the nine gages is currently active (Taiya River).

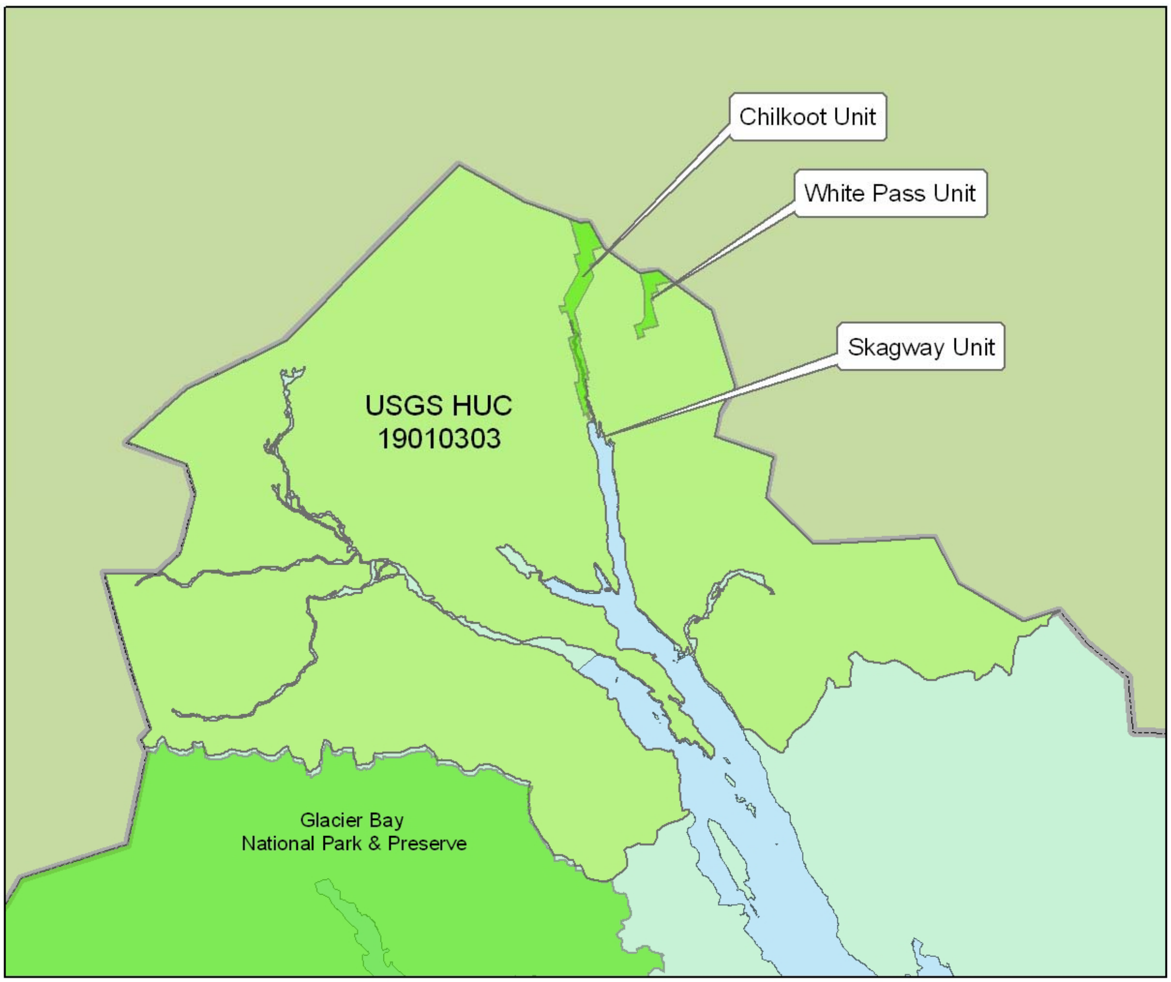

Figure 6. Location of USGS Hydrologic Unit (#19010303) that contains the three KLGO park units.

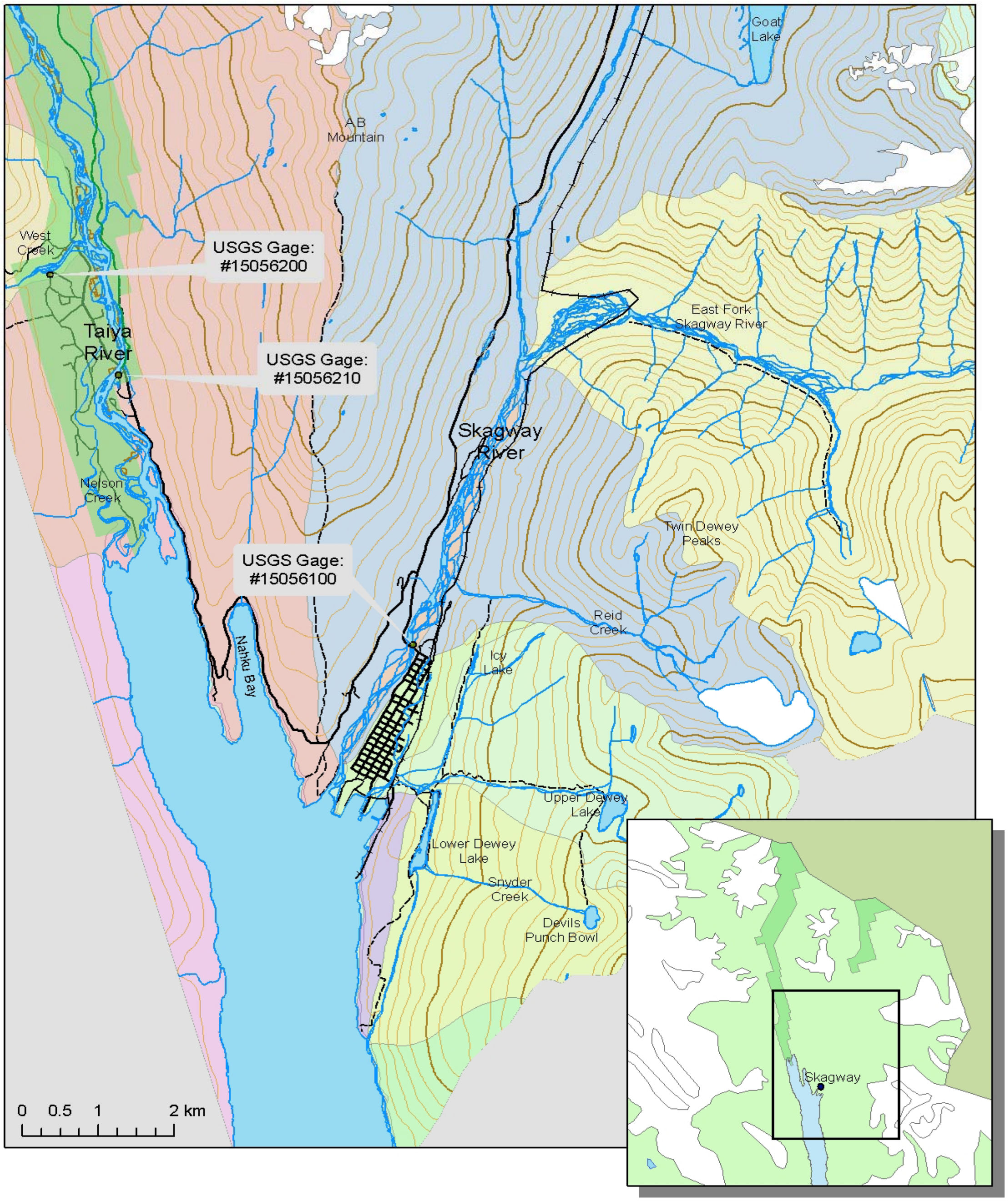

Figure 7. Location of USGS streamflow gages on West Creek, the Taiya River, and the Skagway River. The three watersheds and their sub-basins are shown in different colors.

The Skagway River originates in the Coast Range and its drainage is approximately 30.6 km (19 mi) long and covers a total area of 375.6 km^2 (145 mi^2) (City of Skagway 2005). Major tributaries of the Skagway River include the East Fork and the White Pass Fork, and major glaciers feeding the river include the Laughton, Denver, and South glaciers. The Skagway

River enters Taiya Inlet at the Skagway townsite. Discharge on the Skagway River was measured by the US Geological Survey from 1964-1986 and mean streamflow for this period was 560 cfs (Montgomery Watson 1997). Mean monthly discharge in the Skagway River ranges from <50 cfs in winter to 1500-2000 cfs in summer when discharge is dominated by melt from snowfields and glaciers (Figure 8). The estimated 20 year flood for the Skagway River is 15,300 cfs, while the 100-year flood event is estimated at 38,000 cfs. (TIWC 2005). Peak flows of greater than 30,000 cfs have been recorded three times in the last century (City of Skagway 2005), with a high of approximately 35,000 cfs in October 1901 and October 1943. KLGO staff maintains a National Resources Conservation Service snow survey station at Moore Creek in the Skagway watershed. This site provides a relatively long-term (1989-present) dataset on snow accumulation in the Skagway watershed. Snow depth and snow water equivalent (SWE) at the site typically peak in March and April (Figure 9).

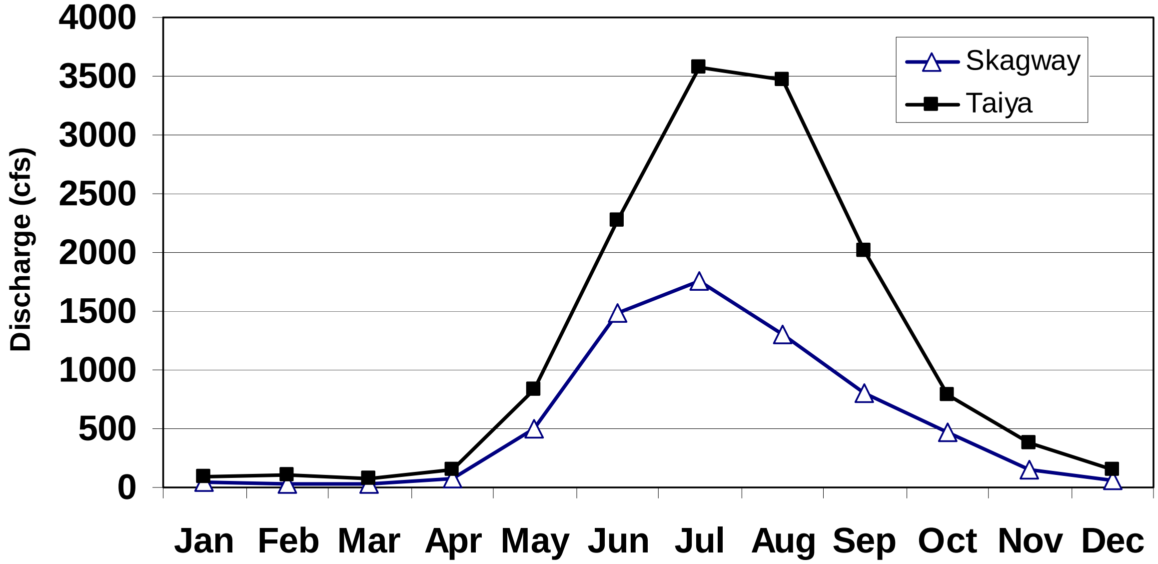

Figure 8. Monthly mean streamflow for the Skagway and Taiya Rivers near Skagway, Alaska. Data for the Skagway River cover the period 1964-1986, while data for the Taiya River cover the period for the period 1969-1977 and 2004. Data from USGS streamflow database for Alaska (http://waterdata.usgs.gov/ak/nwis/sw).

The Taiya River watershed is located west of Skagway and enters the Taiya Inlet at the Dyea historic town site. The Taiya River drainage is approximately 25.7 km (16 mi) long and drains approximately 466.2 km^2 (180 mi^2) (City of Skagway 2005). The Taiya River consists of four subsidiary watersheds: the Nourse River 205 km^2 (79 mi^2); West Creek 115 km^2 (44 mi^2); the upper Taiya River 59 km^2 (22.8 mi^2); and the lower Taiya River 111 km^2 (42.9 mi^2). Hydrologically, the upper Taiya is a tributary and the Nourse is the mainstem, but the name Taiya was applied to the smaller drainage for historical reasons (Curran and Hahr 2005). The Chilkoot Trail unit of KLGO lies entirely within the Taiya River watershed. USGS gaging data for the Taiya River show that the river has a mean annual discharge of 1,130 cfs that changes by as much as 400% between low flows in the winter and high flows in the summer

(Figure 8). Maximum discharge on the Taiya occurred in September, 1967 when a flood caused the river to reach a peak of over 25,000 cfs. More recently, in 2002 a landslide of 10 million cubic yards of moraine material filled a glacial lake in a tributary drainage of the Taiya River, triggering a large flood that swept through park lands (Curran and Hahr

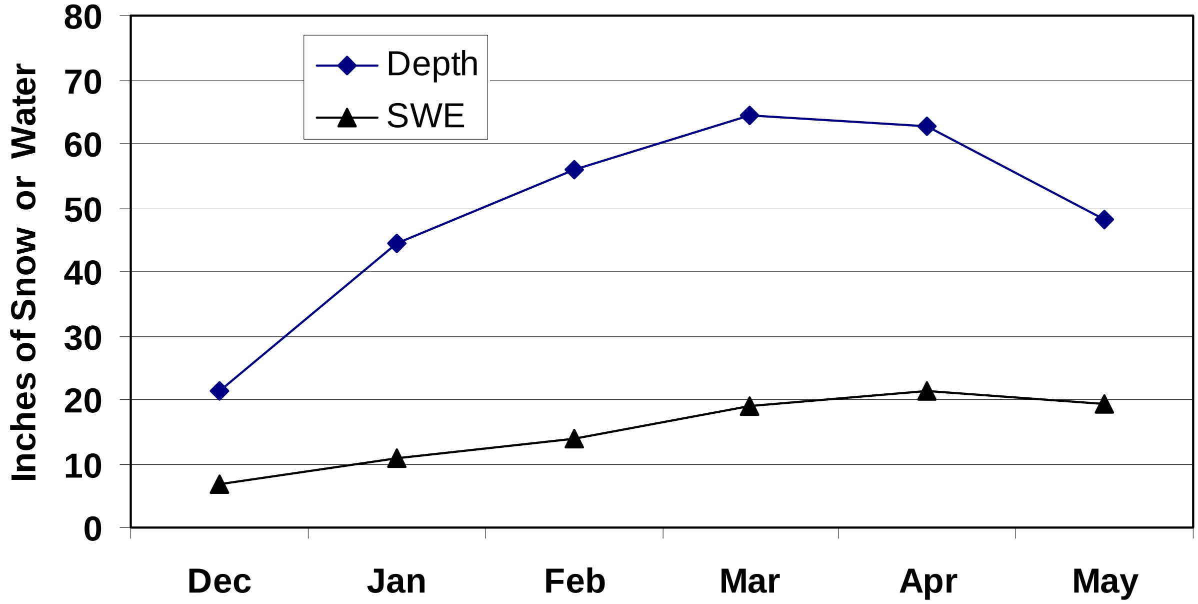

Figure 9. Beginning of month snow depth (inches of snow) and snow water equivalent (SWE; inches of water) at the NRCS Moore Creek snow survey site in the Skagway River watershed. Data are averages for the period 1989-2005 and are available in the NRCS snow course database for Alaska (http://ambcs.org/pub/sc_sum_ak/MOORECREEKBRIDGE.HTM).

2005). The streamflow gage on the Taiya River was reoccupied by the USGS in 2003, and streamflow data for the river are presently available online in real–time (http://waterdata.usgs.gov/ak/nwis/uv/?site_no=15056210&PARAmeter_cd=00065,00060). The USGS gage is currently being funded by the Alaska Department of Natural Resources (ADNR) under an agreement that lasts until 2007 (Edward Neal, Hydrologist, USGS, Juneau, Alaska, personal communication 2005).

Pullen Creek is a small, urbanized watershed that is contained entirely within the City of Skagway and drains into Skagway Harbor. The creek is located within the USGS Hydrologic Unit Code of 19010303. The creek has two tributaries which are spring-fed from three separate headwater locations and the main stem is approximately 1.5 miles long (Figure 10, Skagway Traditional Council 2004). Discharge in the lower reach of the stream is augmented by flow from the tailrace of the Dewey Lakes Hydropower project run by Alaska Power and Telephone (Figure 10). Above the tailrace, average discharge on the creek varies from a

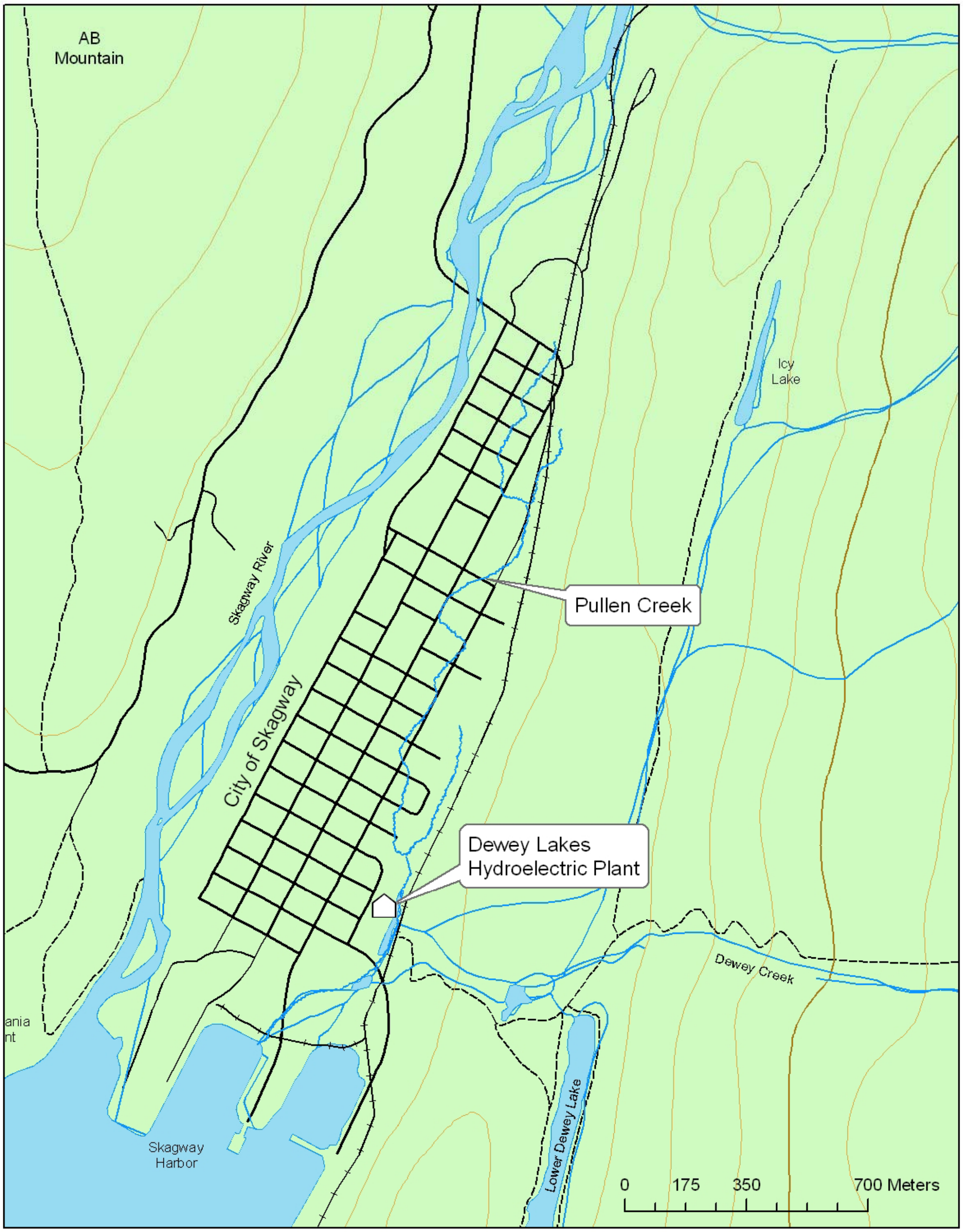

Figure 10. Location of Pullen Creek in downtown Skagway, Alaska. The tailrace from the AP&T Dewey Lakes Hydroelectric Plant discharges water into Pullen Creek.

range of 0.5 – 2.0 cfs above the tailrace to a range of <2.0 – 40.0 cfs below the tailrace (Skagway Traditional Council 2004). Above the tailrace, stream sediments are dominated by silt and sand while below the tailrace the higher stream power removes fine material and the streambed is dominated by larger gravels and cobbles. In 1986, Pullen Creek was placed on the Clean Water Act Section 303(d) list of Impaired Water Bodies (see *B1. Water Quality* below). The City of Skagway in cooperation with the Skagway School system has operated a small hatchery, the Jerry Meyers Fish Hatchery, on Pullen Creek since 1979. The hatchery is used by the school system to teach Skagway students the science of aquaculture.

A2b2. Groundwater

The Skagway area is underlain by relatively impermeable igneous intrusive and metamorphic rock. However, vast deposits of sand and gravel alluvium now cover local river valley bottoms. For example, alluvial deposits within the Skagway town site extend to a depth of six hundred feet. These alluvial deposits contain a substantial volume of groundwater and Skagway's municipal water supply is currently derived from wells that tap into a groundwater aquifer within this alluvium (City of Skagway, 2005). The valley bottom aquifers contained in all three of the KLGO park units are recharged by both runoff from Skagway and Taiya Rivers and their tributary streams and the direct infiltration of precipitation.

A2b3. Wetlands

The Skagway and Taiya River watersheds contain substantial wetlands (Figure 11a&b). The majority of wetlands within KLGO are riverine wetlands located along valley floors. The largest of these wetland complexes occurs on the Taiya River below West Creek. The outlet of the Taiya River is a mixture of estuarine intertidal and riverine wetland types. According to the wetland categories used in the National Wetlands Inventory, the riverine wetlands in KLGO are primarily forest/shrub wetlands. In addition, upland areas of the two main park units contain small areas of both lacustrine and forest/shrub wetlands associated with ponds and saturated soils located on topographic benches.

Wetlands are less abundant in the Skagway area compared to southern and central southeast Alaska. For example, according to the National Wetland Inventory Database, 29% of the landcover in the Tongass National Forest south of KLGO is classified as wetlands. In contrast to KLGO, the Tongass has an abundance of emergent freshwater and forested wetlands in upland areas where compacted glacial tills and glacio-marine deposits act as a hydrologic barrier and produce perched water tables. These upland wetlands are less common in KLGO because of lower rates of precipitation and steeper topography associated with the fjord landscape of the upper Lynn Canal and the Coast mountain ranges.

Wetland areas are important because they serve as an interface between terrestrial habitats and aquatic environments such as streams, lakes and near-shore marine zones. It is possible that the area of intertidal and riverine wetlands at the outlet of the Taiya River will increase as new land becomes exposed as a result of glacial recession and land surface uplift. The ADEC recently developed a guidebook and methodology for functional assessment of streamside wetlands in southeastern and southcentral Alaska (Powell et al 2003). The Hydrogeomorphic

Approach Methodology (HGM) provides a basis for assessing the hydrologic, biogeochemical, community (plant and faunal) support, and habitat functions of wetlands.

A2b4. Glaciers and Snowfields

The Skagway and Taiya River watersheds both contain substantial area above treeline, portions of which are covered by glaciers and snowfields. As of 1994, 33% of the Taiya River watershed and 17% of the Skagway River watershed were estimated to be covered by glaciers (Jones and Fahl 1994). The amount of glacierized area in these watersheds has undoubtedly decreased in the last decade with the thinning and retreat of glaciers in Alaska and the Canadian Yukon (Arendt et al. 2002), however glaciers remain an important source of streamflow in both watersheds. Permanent and semi-permanent snowfields are also common in high-elevation north and northeast facing drainages in the coastal mountains around Skagway. These snowfields are likely an important source of streamflow in the mid to late summer in both the Skagway and Taiya watersheds.

A2b5. Marine Waters

KLGO is located at the head of Lynn Canal in Taiya Inlet (Figure 10). Lynn Canal extends 145 km (90 mi) from the intersection of Icy Strait. Lynn Canal combined with Chatham Strait is the longest (378 km [235 mi]) and straightest fjord-like inlet in North America. Lynn Canal is a classic fjord, a steep-sided and deep estuary, however little is known about its water circulation. Large inputs of freshwater from precipitation, glaciers, rivers, and streams produce a freshwater lens at the surface that is likely most pronounced during the fall when freshwater output is maximal (Figure 12). The peak in freshwater discharge from KLGO watersheds peaks slightly earlier as a result of the strong influence of glacial meltwater (e.g. Figure 7), however non-glacial streams in the upper Lynn Canal show a discharge peak in fall coincident with the fall precipitation peak in Southeast Alaska. Exchange and renewal of marine waters in Lynn Canal with the Gulf of Alaska have not been studied.

The marine habitat of KLGO is a relatively small area, with the park having a total shoreline of 3.2 km (2 mi) at the intersection of the Taiya River and Taiya Inlet (Arimitsu et al. 2003). This intersection includes intertidal estuary and riverine habitat, a mixture of silt and sand flats and gravel and cobble with scattered mussel beds (Armitsu et al. 2003). The intertidal zone in the Skagway area is made up of deltaic deposits, which is composed of sandy gravel, gravelly sand, cobbles, small boulders, shell fragments, sand and silt (City of Skagway 2005). These deltaic deposits are ten to fifty feet thick and are covered with alluvial deposits which come from rivers or by man-made fill (City of Skagway 2005).

The Taiya estuary at the mouth of the Taiya River is composed of a wide, tidal river delta that has been created by sediments deposited by the river and is an uplifted estuary with both poorly drained and well drained soils (Paustian et al. 1994). The estuary unit is bisected along the southeast portion by a broad, braided river channel, which provides important spawning habitat and upstream migration routes for some species of anadromous salmon (Paustian et al. 1994). Nelson Creek, an estuary slough, flows along the western boundary of the Taiya estuary and has little sediment movement and low discharge, making it a slow water aquatic habitat (Paustian et al. 1994).

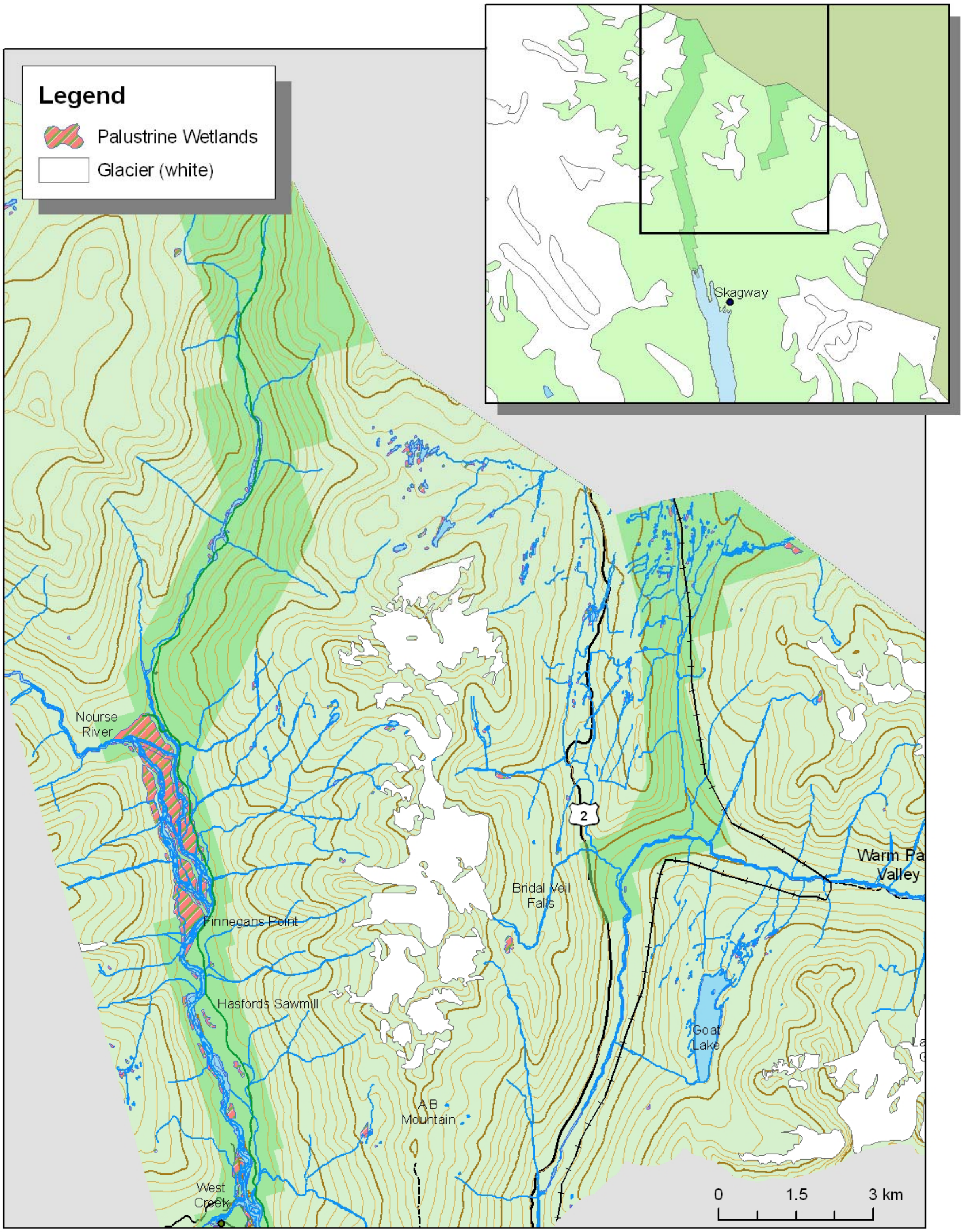

Figure 11a. Location of wetlands in the northern portion of the Taiya and Skagway watersheds. Wetlands coverages are from National Wetlands Inventory surveys. The majority of wetlands in KLGO are located along the floor of the Taiya River valley and at Taiya estuary.

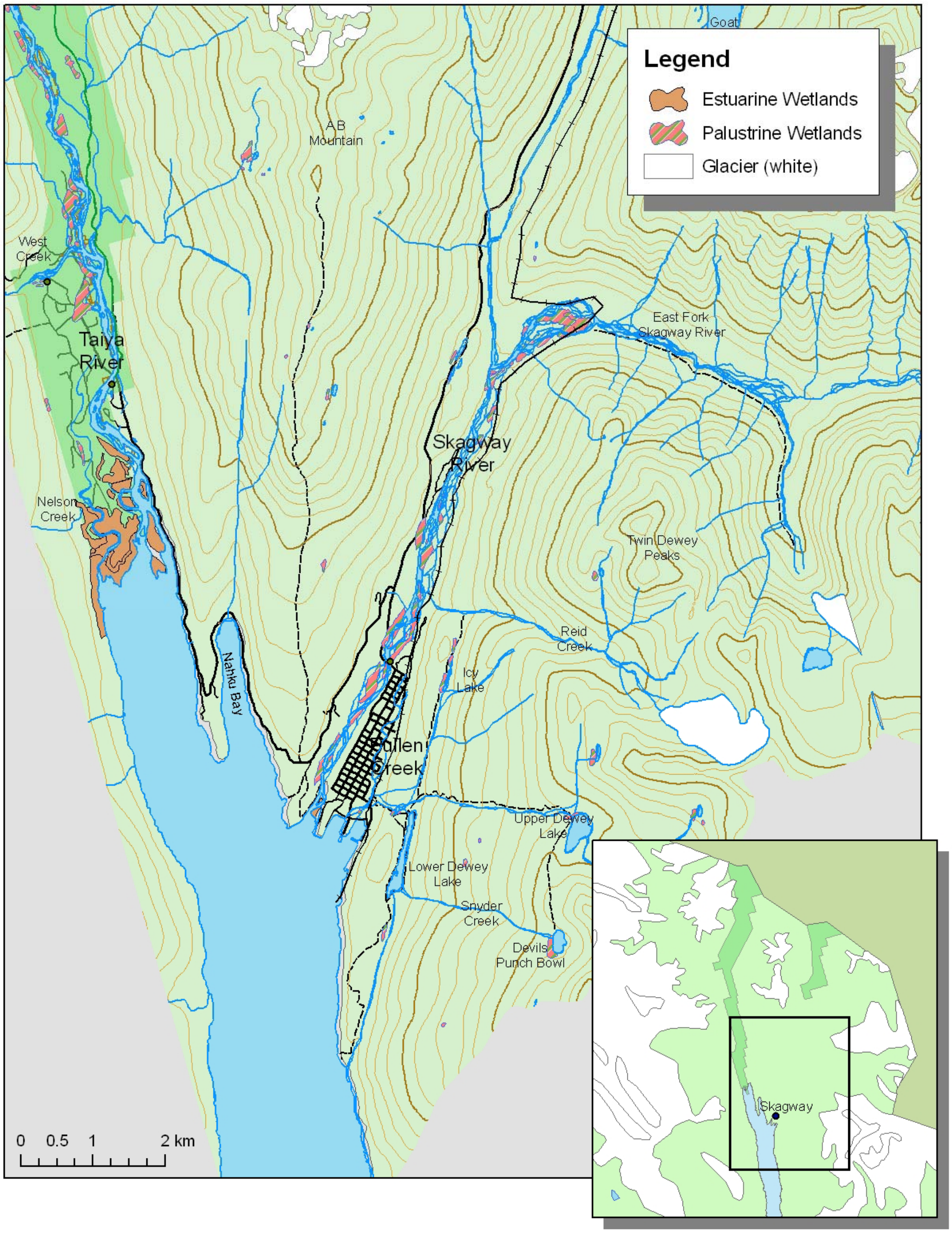

Figure 11b. Location of wetlands in the southern portion of the Taiya and Skagway watersheds. Wetlands coverages are from National Wetlands Inventory surveys. The majority of wetlands in KLGO are located along the floor of the Taiya River valley and at Taiya estuary.

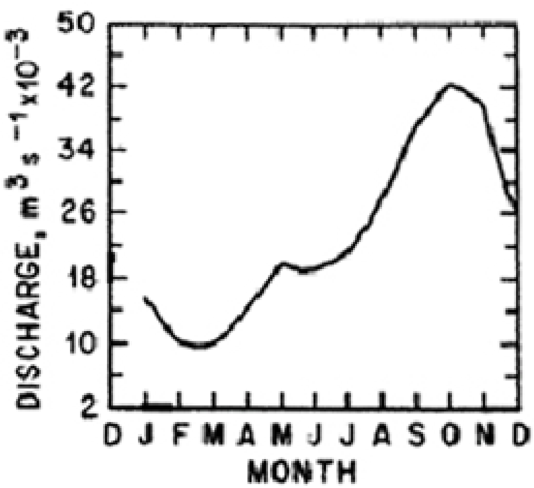

Figure 12. Model-generated values of freshwater discharge in Southeast Alaska based on precipitation, air temperature, and the drainage area of the region, from Royer (1982).

A3. Biological Resources

A3a. Marine and Intertidal

ShoreZone is a project sponsored by multiple agencies and organizations that conducted aerial surveys of intertidal regions of KLGO in 2004. This project aerially surveyed intertidal and shallow subtidal areas to identify shoreline morphology, substrate, wave exposure, and biota of intertidal and nearshore habitats. This coastal habitat mapping effort produced an online database with interactive GIS layers, digital maps, aerial images and video of Lynn Canal with plans to map other areas of Southeast Alaska (http://mapping.fakr.noaa.gov/Website/ShoreZone/). In the uppermost areas of the upper Taiya Inlet, the substrate is soft sediment and the biological cover is continuous marsh grasses, herbs, sedges and continuous or patchy dune grass; wave exposure is very protected; and the oil residency index is months to years (Figure 13). In rocky areas in the upper Taiya Inlet (predominantly along the sides of the inlet), cover is continuous barnacles, mussels and Fucus; wave exposure is semi-protected; and the oil residency index is weeks to months or months to years (Figure 14).

The National Park Service implemented a predecessor to ShoreZone, called the Coastal Resources Inventory and Mapping Program, which was developed to gather baseline data on the coastal resources of Alaska, using an accurate, repeatable, and affordable inventory protocol. This protocol and its resulting GIS (Geographic Information System) layers are used to collect, analyze, and display biological and physical shoreline data. The program uses georeferenced aerial photos along with ground-based observations and ground-based photos to categorize and describe surface substrate, inventory key intertidal flora and fauna, describe vertical zonation patterns in vegetation, identify major stream characteristics, and indicate presence/absence of a variety of special-interest resource attributes such as archeological sites, offshore reefs, kelp beds, clam habitat, urchin recruitment areas, tidepools, seabird colonies, and pinniped haulouts. All of this information is available in a database which can be queried to view graphical summaries of transect data, ground photos, and locator maps.

Figure 13. Taiya estuary area. (ShoreZone 2004 (http://mapping.fakr.noaa.gov/Website/ShoreZone/)

Figure 14. Representative rocky shoreline in Taiya Inlet. Rocky areas are interspersed with cobble areas. (ShoreZone 2004 (http://mapping.fakr.noaa.gov/Website/ShoreZone/).

The database was developed so that those with limited GIS skills can quickly access data collected using the Coastal Resources Inventory and Mapping Protocol. The Coastal Resources Inventory and Mapping Program has currently completed the field work and mapping of the entire Klondike Gold Rush National Historical Park, however data processing and production of the coastal database from this mapping effort have not yet been completed (Lewis Sharman, NPS-GLBA, personal communication 2005). More information about this program can be found at http://www.nps.gov/glba/InDepth/learn/preserve/projects/coastal/

The Taiya Inlet is considered less productive than other parts of Lynn Canal in Northern Southeast Alaska because of large amounts of freshwater and sediment input (City of Skagway 2005), and in fact, an inventory of marine and estuarine fishes in the Taiya River Estuary conducted in summer 2001 documented low fish diversity (Table 2). Armitsu et al. (2003) documented 1,461 specimens, from 11 species, representing seven families (Table 2), estimated to be 85% of the species present in the park. Sampling consisted of beach seining, commercial minnow traps, and intertidal searches (turning over rocks at low tide).

Table 2. Nearshore fish species sampled in KLGO (from Arimitsu et al. 2003).

Family	Scientific Name	Common Name
Osmeridae	*Mallotus villosus*	Capelin
Salmonidae	*Oncorhynchus gorbuscha*	Pink salmon
Salmonidae	*Oncorhynchus tshawytscha*	Chinook salmon
Salmonidae	*Oncorhynchus keta*	Chum salmon
Salmonidae	*Oncorhynchus sp*	Unidentified salmon
Salmonidae	*Salvelinus malma*	Dolly Varden char
Gadidae	*Theragra chalcogramma*	Pollock
Cottidae	*Leptocottus armatus*	Staghorn sculpin
Cottidae	*Myoxocephalus polyacanthocephalus*	Great sculpin
Cottidae	unid. sculpin	unidentified sculpin
Sticheaidae	*Anoplarchus purpurescens*	High Cockscomb
Pholidae	*Pholis laeta*	Crescent gunnel
Pholidae	*Pholis sp.*	Unidentified gunnel
Pleuronectidae	*Platichthys stellatus*	Starry flounder
Pleuronectidae	*Lepidopsetta sp*	*Unidentified* rock sole
		Unidentified larval fish

A 1987 survey of subsistence use in Skagway provides indirect information on species found in the marine habitat adjacent to KLGO (Betts et al. 1994). Subsistence harvest in Taiya Inlet consists mainly of marine fish and invertebrates. Fish comprised 66 percent of the total harvest and consisted of salmon (35% total) and non-salmon species (31% total) (Betts et al. 1994). Halibut made up 40 percent of the non-salmon harvest. Marine invertebrates represented 23 percent of the total harvest, primarily consisting of king crab, Dungeness crab and shrimp from Taiya Inlet and clams harvested along beaches near Skagway. Most (79 % total) of the Skagway subsistence harvest of comes from the marine environment (Betts et al. 1994).

Vegetation in the Taiya estuary consists mainly of graminoids and forbs (yarrow [*Achillea millefolium var. borealis*], silverweed [*Potentilla anserine var. grandis*], beach pea [*Lathyrus japonicus var. glaber*], sedges [*Carex spp*.]), with shrubs and spruce moving in along the forested side of the estuary (Paustian et al. 1994). The more uplifted areas of the estuary are somewhat atypical in that there is not much flooding. Plant communities can be easily disturbed by flooding, all-terrain vehicles (ATVs), hikers and campers, and the Taiya estuary shows impacts from ATV use, including "ruts and lines of trampled and sparse vegetation within more lush communities" (Paustian et al. 1994).

A3b. Wetlands

Wetlands in the Dyea area of the lower Taiya River are delineated and ecological characteristics are described by Bosworth (2000). Wetlands were delineated based on vegetation, hydrology and soils, and wetland units were classified by criteria taken from The Canadian Wetland Classification System (National Wetlands Working Group 1997) and the USFS Tongass National Forest's Channel Type Users Guide (Paustian et al. 1992). Wetland units in the lower Taiya River valley include riverine wetlands (alluvial fan, large river, and riverine floodplain sloughs), estuarine wetlands (wetlands associated with flats, river bar or islands and sloughs), fens, and human-caused wetlands (Bosworth 2000). Vegetation within wetlands ranges from grasses, herbs and aquatic plants to shrubs and trees, and dominant species are listed in Table 3.

KLGO has recently begun restoring impacted wetlands in the lower Chilkoot Unit. Nelson Sough, a small tidal wetland that was historically used as an access corridor for the Taiya River Delta, was the subject of a restoration project in the summer of 2004 (see NPS NPS PMIS 91341). The purpose of the project was to restore the natural bank structure and native aquatic vegetation in order to improve anadromous fish habitat. Portions of the slough were filled and re-graded, and subsequently replanted with wetland and upland plants that had previously been collected at the site (Figure 15). In addition, water quality monitoring was done before, during, and after the project, and four photo points were established to track the long term progress of the project (Klondike Goldrush NHP 2004).

Amphibian diversity is expected to be high in KLGO because the ranges of several species converge in the area encompassing the park. One amphibian species, the western toad (*Bufo boreas),* has been documented within the boundaries of KLGO, and a breeding site for this species was discovered on Dyea flats in 2002 (Anderson 2004). In 2005, the western toad was found to be breeding at six of thirty-nine wetlands sites surveyed within KLGO (Payne 2005). Two amphibian species have been found near park boundaries in the Chilkoot Trail National Historic Site: the wood frog (*Rana sylvatica)* and the Columbia spotted frog (R*ana pretiosa)*) (Anderson 2004). However, it is unlikely that these species have crossed over the coast range into KLGO.

Table 3. Dominant vegetative species in lower Taiya River valley wetlands (Bosworth 2000).

Aquatic	Herb	Spore
Callitriche verna	**Caltha palustris**	**Atherium felix-femina**
Caltha palustris	**Chrysanthemum arcticum**	**Cystopteris fragilis**
Caltha palustris asarifolia	**Cicuta douglassii**	**Equisetum arvense**
Hippuris vulgaris	**Circaea alpine**	**Equisetum variegatum**
Menyanthes trifoliate	**Circium alpinum**	
Montia fontana fontana	**Coneoselinum chinense**	Tree
Potamogeton gramineus	**Epilobium latifolium**	**Alnus rubra**
Ranunculus cymbalaria	**Epilobium sp.**	**Betula papyrifera**
Sparganium angustifolium	**Equisetum variegatum**	**Picea sitchensis**
Sparganium hyperboreum	**Galium triflorum**	
	Glaux maritime	Tree/shrub
Grass	**Gonkenya pepeloides**	**Alnus sinuata**
Agropyron violaceum	**Iris eminens**	
Agrostis borealis	**Iris setosa**	
Agrostis exarta	**Lathyrus maritima**	
Alepocurus aequalis	**Lomatogonium rotatum**	
Arctagrostis latifolia	**Panassia palustris**	
Arctagrostis latifolia	**Plantago maritime**	
arundinacea	**Polygonum sp.**	
Calamagrostis canadensis	**Potentilla egedii**	
Cinna latifolia	**Potentilla palustris**	
Deschampsia beringensis	**Ranunculus cymbalaria**	
Deschampsia	**Rhinanthus minor**	
Caespitosa	**Rorippa islandica**	
Elymus aeroenarius	**Rubus arcticus**	
Festuca rubra	**Rumex fenestratus**	
Glyceria pauciflora	**Sanguisorba stipulate**	
Hordeum brachyatherum	**Stellaria crassifolia**	
Poa eminens	**Tolmiea**	
Poa palustris	**Menziesii**	
Puccinellia sp.	**Triglochin maritime**	
	Triglochin palustris	
Grass-Like	**Viola glabella**	
Carex disperma		
Carex gmelini	Moss	
Carex kellogii	**Sphagnum sp.**	
Carex lyngbyei		
Carex macrocheata	Shrub	
Carex pluriflora	**Alnus sinuate**	
Carex rostrata	**Cornus stolenifera**	
Carex sitchensis	**Echinopanax horidum**	
Eleocharis palustris	**Echinopanax horridum**	
Eriophorum russeolum	**Myrica gale**	
Juncus alpinus	**Ribes lacustre**	
Juncus arcticus	**Salix alexensis**	
Juncus bufonius	**Salix barclayi**	
Juncus castaneus	**Salix sitchensis**	
Juncus palustris	**Vibernum edule**	

Nelson Slough Restoration
Fish Habitat Permit FH04-I-0022

Nelson Slough prior to restoration - 11 May 2004

Nelson Slough post restoration and revegetation – 8 August 2004

Figure 15. Photos of Nelson Slough restoration project. Natural bank structure and aquatic vegetation were restored in this one acre tidal wetland. Photos from Klondike Gold Rush NHP (2004).

A3c. Upland

The Taiya and Skagway valleys provide short corridors through glacier-free mountain passes that function as an ecological exchange between interior and coastal biota. As such, terrestrial biological diversity is high in the region surrounding KLGO. The area is a center of rich botanical diversity (Pojar and MacKinnon 1994), and several species of mammals (MacDonald 1999), plants (Furbish and Jorgensen 2001) and lichens (Geiser 2000) are found in this area and are not found in other parts of Southeast Alaska (Curran and Hahr 2005).

A3c1. Upland flora

KLGO is located at the northern end of a maritime hemlock-spruce-cedar temperate rainforest, and flora in KLGO are a mixture of old growth coniferous forest, peatlands, alpine vegetation, and successional communities (Paustian et al. 1994). Vegetation is dependent on elevation and ranges from coastal rainforest to boreal and sub-alpine forests Western hemlock (*Tsuga heterophylla*), mountain hemlock (*tsuga mertensiana)*, Sitka spruce (*Picea sitchensis*), and lodgepole pine (*pinus contorta*) are the main coniferous tree species in KLGO (Paustian et al. 1994). The main deciduous tree species are red alder (*alnus rubra)*, black cottonwood (*Populus trichocarpa)*, and paper birch (*Betula papyrifera)*. Common shrubs include Sitka alder (*Alnus crispa ssp. sinuata*), blueberry (*Vaccinium alaskaense*), devil's club (*Oplopanax horridum*), red-osier dogwood (Cornus sericea), willow (*Salix spp.),* and rusty menziesia (*Menziesia ferruginea*).

A3c2. Upland fauna

An inventory created from a survey of the literature lists 45 species of mammals for KLGO, 33 of which are definitely present in the park (Lenz et al. 2001). Notable species include moose (*Alces alces*), mountain goat (*Oreamnos americanus*), brown bear (*Ursus arctos*), black bear (*Ursus americanus*), wolf (*Canis lupus*) , wolverine (*Gulo gulo*), porcupine (*Erethizon* dorsatum), hoary marmot (*Marmota caligata)*, and snowshoe hare (*Lepus americanus*). In a 2003 Environmental Assessment of flood damage at Sheep Creek along the Chilkoot Trail unit of KLGO, mountain goat and black bear were reported to be the most common large wildlife species, while brown bear and wolves are seen infrequently (NPS 2003a). Other animals that may be found in the Sheep Camp area include mink (*Mustela vison*), snowshoe hare, pine marten (*Martes martes*), fox (*Vulpes vulpes*), lynx (*Felis lynx*), coyote (*Canus latrans*), red squirrel (*Tamiasciurus hudsonicus*), and numerous small mammals (NPS 2003a).

Of the 165 species of birds entered into the NPSpecies database for KLGO, 138 are definitely present (Lenz et al. 2001). Before early May and after mid-October, the Taiya River valley is used as resting and feeding habitat for migratory birds, including Mallard ducks (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), widgeon (*Anas americana*), common goldeneye (*Bucephala clangula*), barrow goldeneye (*Bucephala islandica*), common merganser (*Mergus merganser*), and Canada geese (*Branta Canadensis*) (NPS 2003a). Varied thrush (*Ixoreus naevius*), common raven (*Corvus corax*), chestnut-backed chickadee (*Poecile rufescens*), northern goshawk (*Accipiter gentiles*), sapsucker (*Sphyrapicus sp*.), blue grouse (*Dendragapus obscurus*), spruce grouse (*Falcipennis Canadensis*), ptarmigan (*Lagopus lagopus*), bald eagles (*Haliaeetus leucocephalus*) and a variety of raptors and songbirds are also found along the Taiya River (NPS 2003a). During April and May, and again during the fall coho salmon spawn 10-20 eagles are often observed in the area, and two bald eagle nests are known to be located in the lower Taiya River valley (NPS 2003a).

A3d. Freshwater

A3d1. Anadromous fishes

The Taiya and Skagway Rivers both have relatively high suspended sediment loads resulting from glacial inputs. As a result, these rivers are less biologically productive than similarly sized clearwater rivers, however both rivers, as well as Pullen Creek, are listed by the ADFG in the *Catalog of Waters Important for the Spawning, Rearing and Migration of Anadromous Fishes* (ADFG 2005).

The Taiya River supports three of the five species of pacific salmon: chum salmon (*Oncorhynchus keta*), pink salmon (*Oncorhynchus gorbushca*), and coho salmon (*Oncorhynchus kisutch*) as well as anadromous and resident Dolly Varden char (*Salvelinus malma*) (Curran and Hahr 2005). Dolly Varden and coho salmon populations in the Taiya River are known to be present from the mouth to approximately 1 mile north of Canyon City historic site where waterfalls prevent further upstream movement (NPS 2003a). In addition to the main stem of the Taiya, fourteen tributaries of the river are catalogued as anadromous streams including West Creek and the Nourse River. Pink salmon spawn up to the northern confluence of the Nourse and Taiya Rivers (NPS 2003a). West Branch Creek is an important rearing area, especially for coho salmon, and the Nelson Creek tributary near the mouth of West Branch Creek is used for spawning and rearing pink and chum salmon (Paustian et al. 1994). Eulachon are reported to run up the Taiya River to West Creek (Bethers, 2003).

The Skagway River is listed as an anadromous stream by ADFG, and has a small fall run of chum salmon (*Oncorhynchus keta)* and coho salmon (*Oncorhynchus kisutch*) (Buzzell 2004). In addition, the Alaska Department of Transportation and Public Facilities (ADOT & PF) has documented the presence of Chinook salmon (*Oncorhynchus tshawytscha*) (Bethers 2002). ADFG has previously stocked pink salmon (*Oncorhynchus gorbuscha)* in the Skagway River, and eulachon runs have been reported in the lower reaches of the river. Anadromous fish are limited to approximately the lower 10 miles of the Skagway River below the confluence with the East Fork because of a steep gradient with an abundance of waterfalls above this point (ADOT&PF 1999). As a result, the White Pass unit of KLGO does not receive runs of spawning salmon. Overall, the Skagway River has a relatively low potential for fishing because of limited numbers of salmon and degraded stream habitat in the lower reaches (Buzzell 2004). In addition to the main stem, the Skagway River has six tributaries that are catalogued as anadromous (City of Skagway 2005).

Pullen Creek is known to contain coho salmon (*Oncorhynchus kisutch)*, pink salmon (*Oncorhynchus gorbuscha)*, chum salmon (*Oncorhynchus keta)*, Dolly Varden char (*Salvelinus malma)*, and sea-run cutthroat trout (*Oncorhynchus clarkii*), as well as non-native Chinook salmon (*Oncorhynchus tshawytscha)* (Skagway Traditional Council 2004). Of these species, coho salmon and Dolly Varden are native to Pullen Creek. Chinook salmon are not native to Pullen Creek and were originally planted by the Douglas Island Pink and Chum (DIPAC) hatchery in Juneau. Both Chinook and pink salmon runs in Pullen Creek are enhanced through a school-run community hatchery (Skagway Traditional Council 2004). Pullen Creek is cataloged for chum salmon, however, the history of this species is unknown for the creek. The entire population of spawning salmon (coho, pink and chum) was estimated at less than 100 fish in the early 1990s (Merrell 1993).

Little is known about the possible ecological effects of a proposed commercial-scale Chinook salmon hatchery in the upper Taiya Inlet. This issue is poorly studied in all of Alaska, even in an area such as Prince William Sound which has been studied intensively and has a very high density of hatchery salmon that may impact the ecosystem within an enclosed body of water. Effects of the proposed Skagway Chinook hatchery on fisheries would likely be positive because of the high demand for Chinook salmon. Run timing and life history are very different among salmon species, which makes interactions among different salmon species unlikely.

The maintenance of healthy salmon stocks and appropriate fish passage in coastal streams and rivers in Southeast Alaska is important not only for fisheries resources but also because spawning salmonids have significant impacts on biological resources in both terrestrial and freshwater aquatic ecosystems (Gende et al 2002). When salmon return to their natal streams to spawn, they transport marine nutrients and energy across ecosystem boundaries and their carcasses release large quantities of "marine-derived nutrients" to freshwater and terrestrial ecosystems (Willson et al. 1998, Cederholm et al. 1999, Johnston et al. 2004). These nutrients are important for the overall health of coastal watersheds (Bryant and Everest 1998) and can greatly affect stream productivity (Wipfli et al. 1998, Chaloner and Wipfli 2002). In particular, the seasonal pulse of salmon carcasses can dramatically elevate streamwater nutrients levels (Mitchell and Lamberti 2005) and thereby affect primary and secondary productivity in receiving streams. In addition, carcasses that end up in the riparian zone as a result of scavenger or bear activity provide a substantial input of nutrients such as nitrogen and phosphorus to riparian soils (Gende et al in prep). These nutrients can rapidly be assimilated by microbial communities and vegetation in the riparian environment (Bilby et al 1996) and have been hypothesized to increase the growth rate of trees in the riparian forest (Helfield and Naiman 2001). These findings highlight the ecological importance of salmon coastal ecosystems and suggest that fisheries management decisions related to salmon have the potential to affect terrestrial and aquatic biological resources within the Chilkoot unit of KLGO.

A3d2. Macroinvertebrates

Macroinvertebrates can be used as biological indicators of the health of an aquatic ecosystem over time (Gabrielson 1993), however bio-assessment protocols should be developed that take into consideration the effects of high sediment glacial runoff on macroinvertebrate density (Paustian et al 1994). A wide variety of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT taxa) are typically found in unimpaired streams. EPT taxa become reduced in number as the water quality of a stream becomes impaired. Another group, the Chironomids (midges), can be found in pristine waters but commonly dominate samples as water quality degradation increases. Gabrielson (1993) collected macroinvertebrates (Table 4) at seven sites within KLGO in order to assess the water quality of each site and found a wide range of diversity in EPT taxa. Streams with large sediment loads from glacial runoff had lower EPT values and were dominated by Chironomids. Macroinvertebrate sampling indicated impaired water quality in West Branch Creek, however the low diversity of EPT taxa in this location may be a result of periodic inundation by brackish estuarine waters in this area (Paustian et al. 1994). The Warm Pass Fork of the Skagway River was found to have poor water quality with few EPT taxa and high numbers of Chironomids, which may reflect high amounts of glacial silt (Paustian et al. 1994). The Upper Taiya River was found to have fair water quality since it had mid-range values of EPT taxa. All other locations sampled showed good water quality within KLGO.

Table 4. Macroinvertebrates sampled in KLGO (Gabrielson 1993).

Insects	**Ephemeroptera**	**Leptophlebiidae**
		Ephemerellidae
		Baetidae
		Heptageniidae
	Plecoptera	**Capniidae**
		Nemouridae
		Chloroperlidae
		Perlodidae
	Tricoptera	**Rhyacophilidae**
		Glossosomatidae
		Limneolilidae
		Hydropsychidae
	Diptera	**Chironomidae**
		Tipulidae
		Simuliidae
		Empididae
Non Insects	**Oligochaeta**	

Macroinvertebrates were also sampled by Taiya Inlet Watershed Council in conjunction with the environmental consulting firm POWTEC in spring 2004 (Skagway Traditional Council 2004). Below Pullen Pond, macroinvertebrates were dominated by caddisflies and midges, while mayflies and stoneflies were relatively more abundant above the Alaska Power and Telephone tailrace (Table 5).

Table 5. Macroinvertebrates survey at two sites in Pullen Creek by the Taiya Inlet Watershed Council in 2004 (Skagway Traditional Council 2004).

	Below Pullen Pond		Above APT Tailrace	
	Estimated number	Number of different types	Estimated number	Number of different types
Mayflies	13	4	100	2
Stoneflies	15	3	128	2
Caddisflies	115	4	14	4
Midges	200	6	400	6
Craneflies	0	0	5	2
Aquatic Mites	4	1	8	1
Worms	60	1	12	1
other	2	1	8	1

B. Water Resources Assessment

B1. Water Quality

There has not been a consistent or long-term effort to monitor water quality in KLGO. The comprehensive report on water quality for the park published by the NPS Water Resources Division (NPS 1998) details all of the available water quality data entered into the Environmental Protection Agency's Storage and Retrieval (STORET) water quality database management system. The report contains data on 157 separate parameters from 70 monitoring stations (13 within the park boundaries) in and around the park. The majority of these stations were monitored for short time periods (one time or intensively for a single year), however two stations within the park boundary have longer term records for important water quality parameters. In addition, a limited number of water quality data (primarily field parameters and nutrients) were collected at several locations on the Skagway and Taiya River as part of an ecological inventory of the park (Paustian et al.1994).

The Chilkoot unit of the park contains two monitoring stations with long-term water quality records from the 1960s and 1970s: West Creek (USGS gage #15056200) and the Taiya River (USGS gage #15056200) (Figure 6). There are no stations with long term records for the Skagway River in the White Pass unit, however there is a monitoring station on the Skagway River approximately 8 miles downstream from the KLGO boundary that has water quality information from 1949 to the mid 1980's. The data from all three of these stations with multi-year records were collected by the US Geological Survey Water Resources Division (USGS-WRD). Furthermore, approximately two thirds of the water quality data published in the NPS-WRD Report (1998) came from the USGS-WRD. Additional sources for data in the report were the US EPA (Region 10) and the NPS.

Water Quality information for Pullen Creek in the Skagway Historic Unit was obtained from the Pullen Creek Watershed Assessment conducted by the Skagway Traditional Council (Skagway Traditional Council 2004). This report provides data on basic water quality parameters as well as heavy metals and BTEX Hydrocarbons. Data were collected at 5 sites on Pullen Creek within and immediately outside the boundaries of the town unit of KLGO. Water quality data presented here are compared to EPA standards as well as State of Alaska water quality criteria for the growth and propagation of aquatic life and wildlife (Appendix 1).

B1a. Freshwater

B1a1. Skagway and Taiya Watersheds

<u>Turbidity</u> (NPS 1988)
Turbidity was measured twenty eight times in the Skagway River (KLGO 0018) and three times in the Taiya River (KLGO 0029) during the period 1976 through 1985. For the Skagway River more than half of the measurements were <2 formazin turbidity units (FTU) although the mean was 10.3 FTU because of several high measurements, two of which exceeded the EPA standard of 50 FTU (NPS, 1998). There were only three turbidity measurements on the Taiya River which ranged from 1 to 25 FTU. These limited data suggest that turbidity levels in KLGO watersheds are typically low but can become episodically elevated to the levels seen in silt-laden glacial rivers in Southeast Alaska (50-200 FTU). It is likely that the infrequent elevated turbidity levels in the Skagway and Taiya rivers

are associated with either elevated streamflow during heavy rainfall events or increased contributions of glacier melt (particularly during episodes of glacial lake drainage) to streamflow.

Fecal Coliform (NPS 1988)
There are few measurements of fecal coliforms in KLGO watersheds, and none of the measurements in freshwaters in or around the park in the Skagway and Taiya watersheds approached the EPA standard of 200 Colony Forming Units (CFU)/100 ml (NPS, 1998). Thus it appears likely that fecal coliforms are not an issue of concern in the Skagway and Taiya Rivers.

Metals
Copper, silver, and zinc were measured approximately 100 times at monitoring stations in the Skagway and Taiya watersheds (Table 6). Samples rarely equaled or exceeded (<5% of samples) EPA acute freshwater criteria for any of these metals (NPS, 1998). Concentrations of cadmium, lead, and mercury were measured consistently in the Skagway River for 7 years and also rarely exceeded EPA criteria. Considering the date of these sampling efforts, it is likely that the few cases of elevated metals concentrations were a product of sampling and analytical contamination problems. In the past 15 years, several studies have effectively invalidated almost all trace metal work done pre-1990 due to the discovery of major contamination problems associated with standard sampling protocols (Benoit, 1994; Taylor and Shiller, 1995). The data suggest that metals contamination is not an important concern in the two primary KLGO watersheds. However, it is important to note that no data are available for the last two decades and that sampling for copper, silver, and zinc has a limited temporal extent and sampling for cadmium, lead, and mercury was limited to a single point in the Skagway River watershed.

Table 6. Skagway and Taiya Rivers metal concentrations in and around KLGO for the period 1978-1985. Data extracted from NPS (1998).

Metal	# Samples	# Monitoring Stations	EPA criteria	% samples ≥ EPA criteria
Copper	104	49	18 μg/L	2
Silver	101	49	4.1 μg/L	2
Zinc	102	49	120 μg/L	4
Cadmium	50	1 (KLGO18)	3.9 μg/L	2
Lead	52	1 (KLGO18)	15 μg/L	8
Mercury	53	1 (KLGO18)	2.0 μg/L	2

Nutrients
Elevated levels of inorganic nitrogen and phosphate can lead to eutrophication in freshwater systems. Data from both the Skagway (KLGO 0018) and Tiaya Rivers (KLGO 0029) indicate that inorganic N and P are not a concern in these systems (NPS, 1998). Concentrations of inorganic N (ammonium + nitrate) rarely exceeded 1.0 mg N/L in either watershed. Similarly, levels of dissolved P were uniformly below 0.15 mg/L at the KLGO site.

B1a2. Pullen Creek Watershed

The Skagway Traditional Council with funding from the Alaska Clean Water Action Program collected surface water, bank soil, and stream sediment samples in the Pullen Creek watershed in 2003 and 2004 (Figure 16; Skagway Traditional Council 2004). Bank soils at five

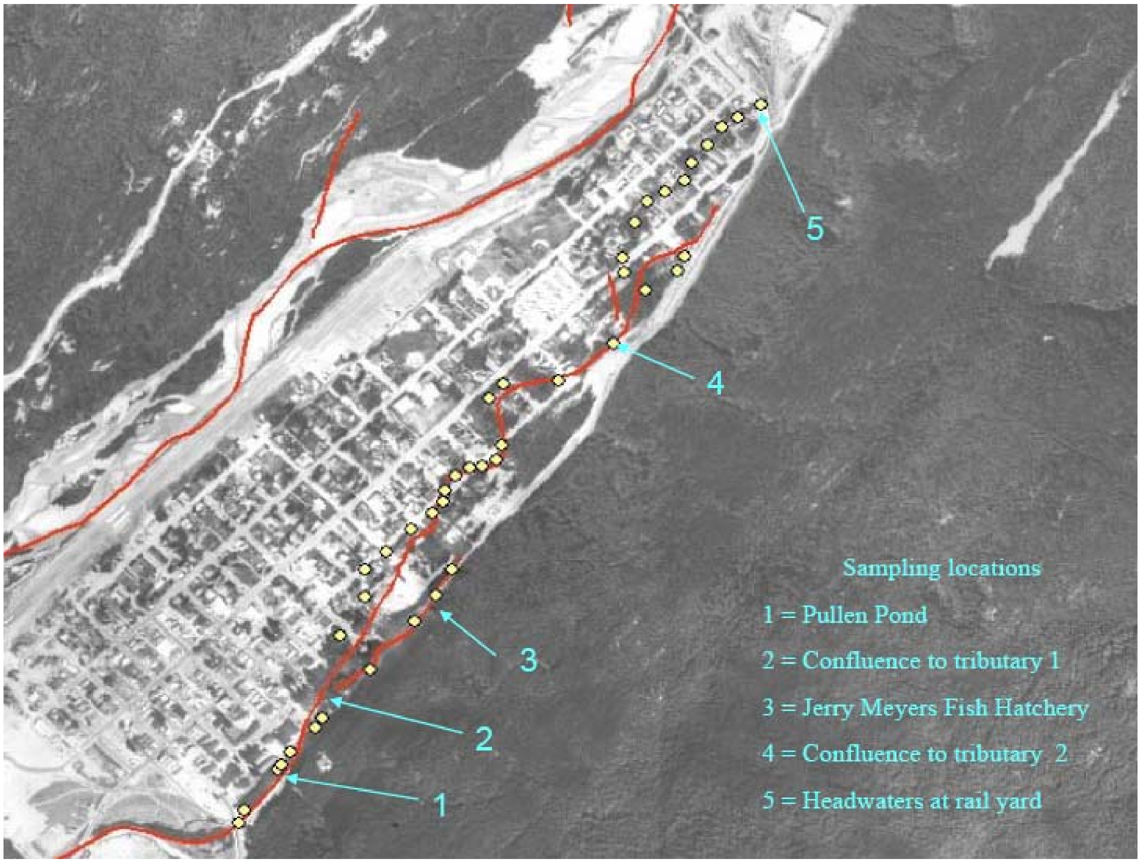

Figure 16. Location of sampling sites for surface water, bank soil, and stream sediments on Pullen Creek. Photo from Skagway Traditional Council (2004).

locations on Pullen Creek exceeded the State of Alaska method 2 clean-up levels for arsenic, lead and barium. Similarly, stream sediments at those locations exceeded clean-up levels for arsenic, barium, chromium, and lead. Despite the contaminated soils, water samples collected at three locations showed heavy metal levels far below state standards for groundwater clean-up levels. Hydrocarbons were well below state standards in both sediments and surface waters in Pullen Creek. Finally, three synoptic surveys of basic water quality parameters on Pullen Creek showed that water temperature and dissolved oxygen easily fell within state standards for aquatic life across a range of stream discharge spanning two orders of magnitude (Table 7). Of the fourteen measurements of pH during these surveys, two of the low flow measurements were slightly below the state standard of 6.5. Fecal coliform data are not available for Pullen Creek, however Pullen is far more likely than other watersheds within KLGO to be at risk for fecal coliform contamination because of the urbanized nature of its watershed.

Table 7. Field parameter water quality data collected for Pullen Creek. Data were collected at 5 sites on three dates in 2003-2004. Sample site locations are shown in Figure 16. From Skagway Traditional Council (2004).

	Pullen Pond			Tributary 1			Fish Hatchery			Tributary 2			Whitepass Pond		
	Nov, 03	Feb, 04	May, 04	Nov, 03	Feb, 04	May, 04	Nov, 03	Feb, 04	May, 04	Nov, 03	Feb, 04	May, 04	Nov, 03	Feb, 04	May, 04
Air Temp (°C)	-6	7	13.5	-	7	14.5	-4	7	15	-	6	-	-2	6	-
Water Temp (°C)	0.25	2.2	5.45	-	4.59	6.06	3.12	4.33	5.62	3.72	4.32	5.38	4.13	4.21	4.43
DO (mg/L)	28.2	14.7	-	-	14.05	-	18.34	10.75	10.2	11.36	9.4	-	10.72	-	-
pH	6.17	7.42	7.46	-	7.72	7.55	7.11	7.65	7.58	6.61	7.32	7.24	6.14	7.28	7.03
Conductivity (µS/cm)	0.099	0.131	0.081	-	0.192	0.233	0.202	0.227	0.285	0.154	0.166	0.205	0.154	0.167	0.201
Discharge (cfs)	0.135	5.282	34.37	-	1.872	2.436	0.018	0.723	0.388	0.056	1.945	2.608	0.003	0.149	0.5

B1b. Precipitation

The chemistry of precipitation is not currently being monitored in KLGO, however a new National Atmospheric Deposition Program (NADP) site was established on the Lynn Canal north of Juneau in 2004. The NADP is a nationwide network contains more than 200 precipitation chemistry monitoring in the continental United States, Alaska, Puerto Rico, and the Virgin Islands. There are 4 NADP sites in Alaska, two of which are administered by the NPS (Denali and Gates of the Arctic). The NADP site near Juneau (NADP #AK02) is located 50 km south of KLGO and is likely representative of precipitation received in KLGO. Preliminary data from the Juneau NADP site show a predominance of marine aerosols (chlorine, sulfate, and sodium) and very low levels of nitrogen (ammonium and nitrate) compared to sites in the contiguous United States (Eran Hood, University of Alaska Southeast, unpublished data). Data on precipitation chemistry in Alaska are available through the NADP website at: http://nadp.sws.uiuc.edu/sites/ntnmap.asp?

B1c. Marine Waters

Water quality in marine waters was recently surveyed by the Environmental Monitoring and Assessment Program (EMAP), using a national protocol developed by the EPA (http://www.epa.gov/emap/). EMAP in Alaska is sponsored by ADEC, who sampled throughout Southeast Alaska in 2004, including two stations in Lynn Canal (Figure 17). At 40 stations, physical properties (conductivity, temperature, salinity, pH, dissolved oxygen, chlorophyll fluorescence), water (nutrients, chlorophyll a, and total suspended solids), sediment (contaminants, infauna), and benthic fish and invertebrates (trawl) were sampled. At 11 additional stations, water was sampled for bacteria as a part of the ADEC cruise ship program. The final report for Southeast EMAP is expected to be released in 2007 from ADEC. The two sites sampled by EMAP in Lynn Canal will be unable to characterize water quality at those two sites specifically. Rather, they are meant to be representative of conditions within the Southeast Alaska region. Note that these two sites are quite distant (approx 100 km (60 mi)) from KLGO.

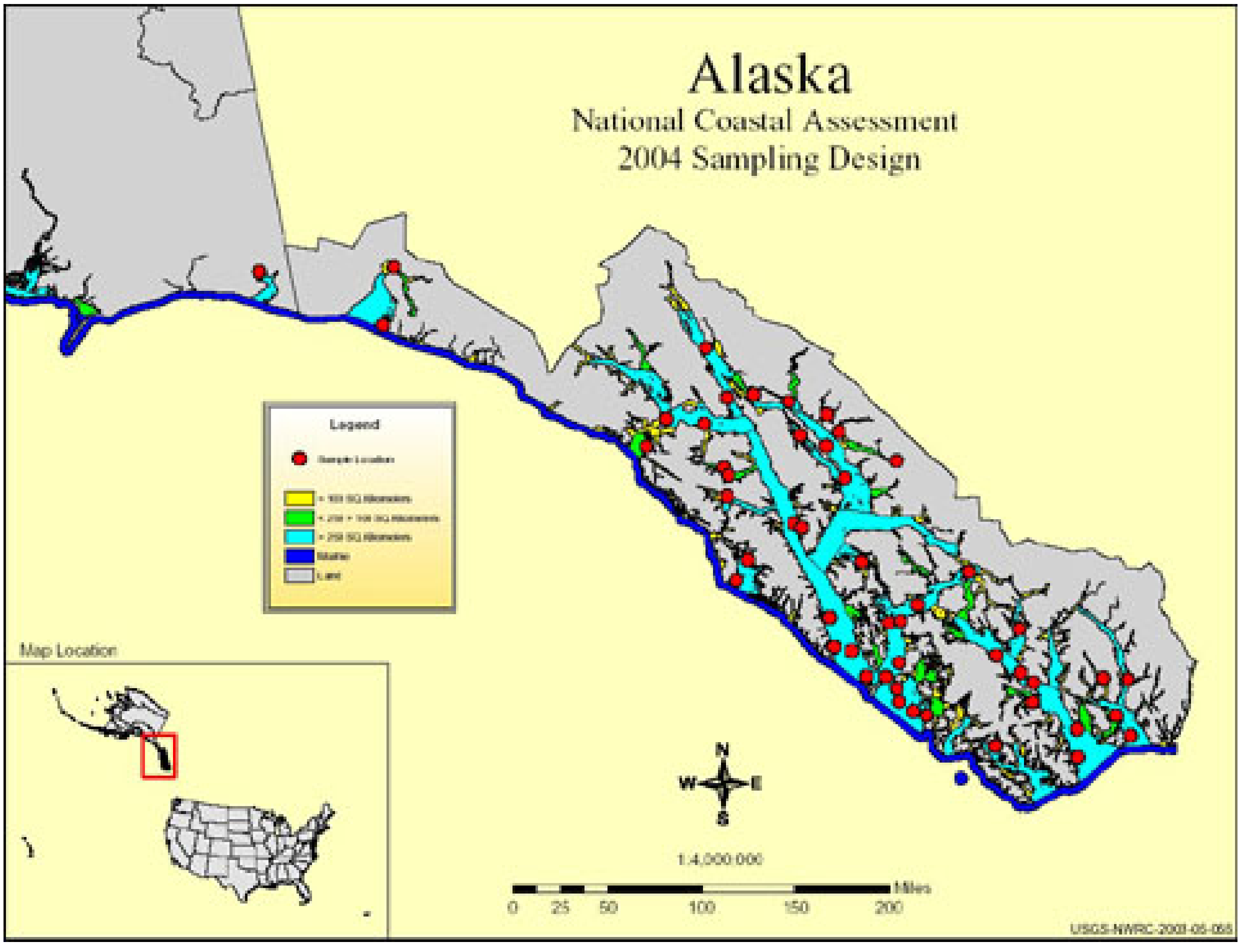

Figure 17. Sites sampled by EMAP in Southeast Alaska in 2004 (from http://www.dec.state.ak.us/water/wqamp/emap_se.htm).

B2. Water Quality Impairments

B2a. Pullen Creek

Pullen Creek suffers from many factors that harm aquatic biotic including heavy metal and hydrocarbon contamination and hydrologic impairments. Pullen Creek is currently listed on the EPA's 2002/2003 303(d) list of impaired waterbodies for heavy metal contamination (ADEC 2003). As a result, the Skagway Traditional Council and the Taiya Inlet Watershed Council are working with the ADEC to collect water quality data. The primary water quality concern for Pullen Creek is heavy metal contamination, in particular lead, zinc, cadmium, and mercury. These metals have been found in Skagway Harbor and are thought to originate from an ore transfer facility associated with the railroad in the town of Skagway. Other potential sources of metals in Pullen Creek are formerly used defense sites (FUDS) from World War II and urban runoff. Additional water quality concerns in Pullen Creek include hydrocarbons and basic parameters such as pH, temperature, and dissolved oxygen that are important for aquatic biota. There are 12 sites listed as hydrocarbon contaminated by the ADEC in the City of Skagway, and runoff from impervious surfaces is also likely an important contributor to water quality impairments. In addition to heavy metals contamination, other hydrologic impairments in Pullen Creek include fish passage obstructions and debris accumulation. The creek currently runs through 31 culverts, many of which do not provide for adequate fish passage. The Taiya Inlet Watershed Council (TIWC), a community group in Skagway, is currently working with the Skagway Traditional Council to assess, remediate and restore Pullen Creek. Work done by the TWIC on Pullen Creek includes: education and outreach within Skagway, restoration of impaired reaches, and development of a Pullen Creek Action Plan (Skagway Traditional Council 2004).

B2b. ADEC-listed Contaminated Sites

B2b1. Skagway Hoover's Chevron/Corner Station

The former Hoover's Chevron Corner Station in Skagway is located at 444 4th Avenue, near the Skagway River. ADEC (2005) reports that contamination occurred at this site in 1993 when four underground gasoline tanks, total capacity of 8,000 gallons, were replaced with an 18,000 gallon tank. During the transfer, petroleum leached into the soil. In result, 24-cubic yards of contaminated soil were excavated and transferred to the Skagway Landfill. Unfortunately, samples taken show that petroleum is still present within the contaminated area (ADEC 2005). Contaminants include diesel, gasoline, and gasoline components. The site is located down gradient from municipal drinking water wells; however, potential impacts to groundwater have not been determined. The current status of this site is unknown and additional site assessments have not been performed (ADEC 2005).

B2b2. Skagway's State Street Mystery Site

A vacant lot located on 20th and State Streets in Skagway was observed to have diesel products floating in groundwater near a fire hydrant in 1998. Diesel-range organics and polycyclic aromatic hydrocarbon contaminants were found in nearby soil, groundwater, surface water, and in stream sediments. The source of the pollutants is unknown, which makes further leaching of hydrocarbons into the environment possible. After the initial discovery of the site, approximately 100 gallons of free product were recovered, but the area is still contaminated. As of 2004, the ADEC is in the midst of determining which entity is responsible for the clean-up (CH2M Hill 2003).

B2b3. White Pass 6-mile Pacific and Arctic Railway Site

This site, located on the East Fork of the Skagway River downstream of the White Pass Unit of KLGO, was contaminated in 1994 when a pipeline transporting diesel fuel was broken by heavy equipment. The resulting fuel spill contaminated approximately between 1000 and 2,500 cubic yards of soil at the site (Golder and Associates 1996a). This site was remediated by Golder and Associates via the application of fertilizers to enhance biodegradation of soil hydrocarbons. It is unlikely that this site presents a substantial contamination risk for the Skagway River.

B2b4. White Pass 14-mile Pacific and Arctic Railway Site

After the collapse of the Skagway dock in 1994, the Pacific and Arctic Railway and Navigation Company transported approximately 200-300 cubic yards of creosote treated timbers, rail ties, and oily sorbent booms to a storage location along the Skagway river close to the east boundary of the KLGO White Pass unit. Samples of wood from the from the rail ties and timbers showed low levels of total cresol and moderate to high levels of semi-volatile organic compounds (Golder and Associates 1996b). The debris pile was removed and the site was remediated by Golder and Associates in 1997-1998. This site is unlikely to pose any future contamination risk for the Skagway River.

B3. Sources of Pollutants

B3a. Point Source

B3a1. Petroleum Spills

Petroleum poses a range of environmental risks when released into the environment, whether as catastrophic spills or chronic discharges. In addition to physical impacts of large spills, the toxicity of many of the individual compounds contained in petroleum is significant, and even small releases can kill or damage organisms. Petroleum can enter marine waters and thus affect the shoreline along KLGO through the following mechanisms:

- Leaks, spills, or discharge of bilge or ballast water.
- Discharge from two-stroke engines.
- Accidental release through a vessel grounding or collision.

The impact of a release of petroleum from any of the above mechanisms would greatly depend on the size of the spill, the location of the spill, the type of petroleum product, and the effectiveness of the response to the spill. The port of Skagway is heavily used by marine vessels and receives more than 80,000 tons of petroleum products as freight annually (see *C2 Marine Vessel Impacts* below). Although KLGO only has 3.2 km (2 mi) of coastline, this area is vulnerable to petroleum spills because of its close proximity to the port of Skagway. Moreover, the high tidal range and strong currents in the Upper Lynn Canal have the potential to transport a spill over relatively large distances.

Geographic Response Strategies (GRS), created through the ADEC and other agencies, are spill response plans tailored to protect specific sensitive areas from oil impacts following a marine vessel spill. The Upper Lynn Canal is located in Zone 8 within Southeast Alaska and has a Geographic Response Plan that reviews spill response equipment and strategies to protect near-shore resources in the area (Shannon and Wilson 1999). The plan identifies five individual sensitive areas in the region and outlines site specific response strategies for each of the areas (Figure 18). The Taiya Inlet in the Chilkoot Unit of KLGO is identified as a sensitive area and has a plan in place to deploy containment booms at both Tiaya Point and along Dyea flats to protect the area around and including the mouth of the Taiya River. Skagway Harbor is also identified as a sensitive area and has a site specific protection plan in place.

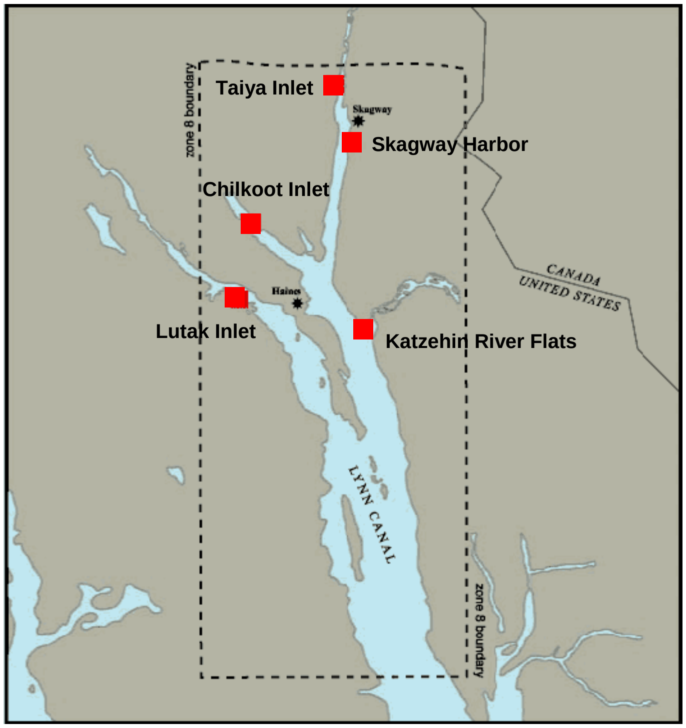

Figure 18. Geographic Response Strategy for Zone 8 – Upper Lynn Canal showing sensitive areas that merit special protection (ADEC 2004).

B3a2. Backcountry Toilets

The Chilkoot Trail receives over 3000 visitors during the period between May and September each year. These visitors are concentrated at camps along the trail in KLGO and the Chilkoot Trail National Historic Site (CTNHS) in Canada. At present, all five of the Dyea and Chilkoot trail campgrounds are located next to the Taiya River. The most heavily used of these camps is Sheep Camp, the last camp on Chilkoot Pass. Currently, KLGO uses two pit toilets for human waste disposal at Sheep Camp, however the camp is located at a site where the groundwater table is relatively close (3-4 feet) beneath the land surface along the Taiya River (Steidel 2005). As a result, both current and historic pit toilet sites at this and other similarly located camps pose a threat to groundwater and nearby surface water resources. Although a project to monitor groundwater/surface water interactions and water quality around NPS outhouses has been proposed (see NPS PMIS 55163), no monitoring actions have been undertaken as of February, 2006 (Meg Hahr, Natural Resource Specialist, Klondike Gold Rush National Historical Park, personal communication 2006).

KLGO is currently exploring alternative waste disposal methods and in summer 2005, two composting (or moldering) privies were installed at Sheep Camp. The advantage of these human waste disposal systems is that end waste products are removed and incinerated off-site (in Skagway). In addition, the human waste is contained in an above ground enclosure instead of in the ground, which greatly limits the potential for groundwater pollution. The extent to which these composting privies are appropriate for the climate in KLGO is unknown, however similar toilets have been used on the Appalachian Trail in Vermont (Steidel 2005).

B3a3. Pollution from the White Pass & Yukon Railway

The primary concerns for water quality impairments associated with the operation of railways include:

- Leaks and spills of toxic materials being transported by railway
- Fuel leaks from railroad engines
- Leaks and spills associated with railroad fueling facilities
- Use of herbicides in right of way maintenance along railroad tracks

The White Pass and Yukon no longer transports ore shipments from mining operations in Canada, as it is primarily a passenger railway that carries tourists from Skagway to Fraser, British Columbia. No evidence was found for this report that the present operation of the railway is adversely affecting water quality in KLGO. However, the railroad follows the Skagway River to its headwaters at White Pass (Figure 2); therefore future fuel spills or the use of chemicals to clear vegetation along this route could pose a threat to water quality in the Skagway River.

B3b. Non-point Source

B3b1. Urban Runoff

Urbanization and ongoing development pose a threat to water quality and habitat in the Pullen Creek watershed and the Skagway River basin downstream of the White Pass unit of KLGO. In addition, planned development in the Taiya watershed has the potential to adversely affect water quality. Urban development dramatically alters the hydrology of rivers and streams. Impervious surfaces such as roads and parking lots have little to no storage resulting in an increase in surface runoff compared to native ground cover, which can absorb rainfall and snowmelt via infiltration. Previous research in the Pacific Northwest has shown that, without the placement of effective riparian buffers, biological integrity and habitat condition decline rapidly in urban watersheds that have greater than 5% impervious cover (May et al., 1997). At the present time, nearly the entire area of the Pullen Creek watershed has been developed and both the Taiya and Skagway watersheds contain some area of impervious surfaces.

The primary water quality concern associated urban development is runoff from urban surfaces (Makepeace et al 1995). In urban environments, motor vehicles act as a source of oil and grease, hydrocarbons, and heavy metals, all of which can be transported into surface waters via overland flow during storm events. Sediment loading from soil erosion, construction sites and road sanding as well as nutrient loading (nitrates and phosphates) from fertilizers and septic systems are also common pollution problems associated with urban runoff. In addition water quality impacts, urban development can alter in-stream habitat by decreasing the recruitment of large woody debris (LWD), increasing bank erosion and stream temperatures, and decreasing stream baseflows.

At the present time, the majority of surface water that drains from paved surfaces and buildings in Skagway is transmitted into city storm drains that empty into Pullen Creek or the

Skagway River (City of Skagway 2005). The water quality information in section B1 suggests that runoff from urban surfaces and industrial sites is a problem in Pullen Creek. A majority of the main stem of Pullen Creek is subject to direct runoff from impervious surfaces (Skagway Traditional Council 2004). In addition, the hydrology of Pullen Creek has been altered dramatically by urban development as evidenced by the extensive movement and channelization of the creek. Current water quality impairments associated with urbanization have not eliminated salmonid-rearing habitat within the creek, however decreases in stream complexity, large woody debris inputs, and groundwater recharge are all limiting rearing habitat. In the Skagway and Taiya Rivers, the extent to which runoff from impervious surfaces is impairing water quality is likely limited, although recent water quality data are not available to assess potential problems.

B3b2. Air Pollution

Local and Regional Sources

Skagway is located in a Class II airshed as classified by the provisions of the Clean Air Act (City of Skagway 2005). Class II airsheds are defined by the ADEC as being relatively free of air pollution but subject to some industrial emissions. Despite its relatively pristine setting, KLGO is exposed to a variety of air pollution sources including: air and motor vehicle transportation, residential and commercial open-air burning, and solid waste incineration. In addition, there are several sources of air pollution that are relatively unique to the Skagway area including: emissions from cruise ships and diesel tourist trains operating during the summer months and dust enriched in heavy metals that is a legacy of ore transport operations through Skagway during much of the 20th century.

The results of a recent air quality assessment that sampled the concentrations of chemicals in lichen tissues at 4 locations in and around KLGO indicate that the Klondike-Skagway airshed has high levels of heavy metals and sulfur compared to unpolluted areas of Southeast Alaska (Furbish et al 2000). Lichen samples collected in this study were also compared to a Pacific Northwest dataset consisting of 1200 sites in 11 National Forests. A majority of the Klondike-Skagway lichen data exceeded the 97.5 quantile of the Pacific Northwest dataset for the following chemical parameters: cadmium, calcium, lead, sulfur, and zinc. The exceedence rate for these parameters was highest for the lichen sampling plot located closest to downtown Skagway and was lower for plots in the Taiya River valley (Furbish et al 2000). Calcium is associated with naturally occurring marine aerosols, however sulfur is a strong indicator of air pollution. The elevated levels of heavy metals are likely indicative of air pollution and possibly elevated levels of wind-blown dust. Air pollution in the KLGO area has the potential to influence soil chemistry and degrade water quality. The limited water quality data available do not suggest that aquatic resources were being affected by wet and dry chemical deposition in the mid-1980s, however there are not sufficient data available to evaluate the effects of air pollution on aquatic resources after this time period.

KLGO has requested funding to conduct a follow-up lichen assessment similar to the 1998-1999 study (see NPS PMIS 92107). This follow up study would have several benefits including: improving estimates of the timing of the heavy metal accumulation documented in the original survey, allowing park resource managers to begin to track temporal trends in air quality within the park, and providing the opportunity to develop a consistent protocol for lichen biomonitoring that can be used in future studies.

Long-range atmospherically-derived contaminants

Evidence is mounting that Alaska and other arctic and sub-arctic regions are not immune to contamination by chemicals that are able to travel far from their original sources (Fitzgerald et al. 1998, Heiman et al. 2000, AMAP 2002, AMAP 2004). Mercury (Hg) and a group of chemicals known as Persistent Organic Pollutants (POPs) are the two major subjects of concern within Alaska in terms of global contaminants. Mercury, a strongly toxic heavy metal, is emitted primarily by fossil fuel burning (Pacyna and Pacyna 2002), while POPs comprise a variety of highly toxic and stable organic compounds such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), dioxins, furans, and chlordane that are derived from pesticides, industrial chemicals and industrial waste products (EPA 2002).

Highly volatile POPs may travel directly to Alaska by long-range atmospheric transport, and less volatile POPs reach the region due to the “grasshopper effect”, in which they are deposited and revolatilized in a successive northbound pattern (Wania and Mckay 1996). Mercury deposition is particularly favored in high altitude and high latitude regions due to cold condensation processes (Schindler 1999). Anthropogenic mercury deposition to Alaska appears to be similar in magnitude to that in temperate latitudes (Fitzgerald et al. 2005). Elevated levels of methylmercury in fish have led to consumption advisories throughout most of the USA and much of Canada (Pilgrim et al. 2000, Environment Canada 2004). However, little is known about the extent of Hg pollution in Southeast Alaska.

Although Hg and POPs have not been studied in within KLGO, two studies in Southeast Alaska indicate the region as a whole is being impacted by these contaminants. The first study looked at seabird eggs from islands around Alaska and found that concentrations of POPs in common murre eggs from two islands in the Gulf of Alaska were significantly higher than in eggs from three colonies in the Bering Sea (Christopher et al. 2002, Day et al. 2004). Eggs from St. Lazaria (in Sitka Sound) had higher concentrations of SPCBs (sum of 46 congeners of PCBs) than eggs from any other Alaskan colonies. In addition, findings from this study indicated that mercury pollution may be more of a concern in Southeast Alaska compared to other regions of Alaska. A second study looking at dated sediment cores collected at three lakes in Glacier Bay National Park and Preserve (GLBA) suggests that modern Hg accumulation rates in sediments are approximately double pre-industrial accumulation rates (Engstrom and Swain 1997). Additionally, Hg deposition in GLBA did not show the recent declines (since the1960s) observed at sites in the continental US where regional mercury emissions have been reduced. These results suggest that Southeast Alaska is being affected by mercury emissions from remote sources (e.g. in Asia), that are steadily increasing their output (Pacyna and Pacyna 2002). Overall, the limited studies to date strongly suggest that the threats posed by mercury and POPs to ecosystems such as those in KLGO in southern Alaska are significant and deserve further evaluation and monitoring.

C. Other Areas of Concern

C1. Coastal Development Trends

C1a. Population

Unlike many areas of the United States, coastal zones in Southeast Alaska are not presently experiencing rapid rates of population growth and development. The population of Skagway in and around KLGO has remained relatively stable for the last two decades, growing from 760 people in 1980 to 814 people in 1999 (City of Skagway 1999). In summer months tourism-related employees and tourists triple the City's year-round population. Research in the Anchorage area has shown a strong statistical correlation between urbanization and important water quality parameters including benthic macroinvertebrate diversity, water chemistry, and bed sediment metal loads (Ourso 2001). At present, only Pullen Creek and the Taiya Inlet adjacent to Skagway appear to be at risk for water resource impairments resulting from urbanization. The Chilkoot Unit of KLGO could also be affected by development, however the City of Skagway Dyea Flats Land Management Plan has the explicit goal of maintaining the scenic quality and protecting the biological values of the flats. In addition, the plan prohibits camping outside of designated areas and prohibits residential, commercial, and industrial development in the flats (City of Skagway 1999). Skagway's future growth plan designates large areas for low density residential development along the Dyea Road on the east side of the Taiya River, and residences developed in this area would be outside of City water and sewer service with potential to affect water quality in the Taiya River. Overall, the population of the Skagway is estimated to grow at a modest rate of 1-2% over the next several decades (City of Skagway 1999), therefore extensive urbanization of the area around KLGO does not appear to be an issue in the near future.

C1b. Juneau Road Access to Skagway

The ADOT & PF plans to build a road from Juneau to Skagway. The Juneau Access 2005 Supplemental Draft Environmental Impact Statement included the preferred alternative as a road to Skagway (Figure 19), however on August 10, 2005, the ADOT &PF released a press statement changing the alternative so that the road terminated at the proposed Katzhein ferry terminal with ferry access to Skagway and Haines (Figure 20). The change in the preferred alternative resulted from the Federal Highway Administration declaring lands surrounding Skagway as Section 4(f) lands which include significant public parks, recreation areas, wildlife and waterfowl refuges, and historic sites. The preferred alternative will not affect KLGO, however NPS should monitor potential changes to this project.

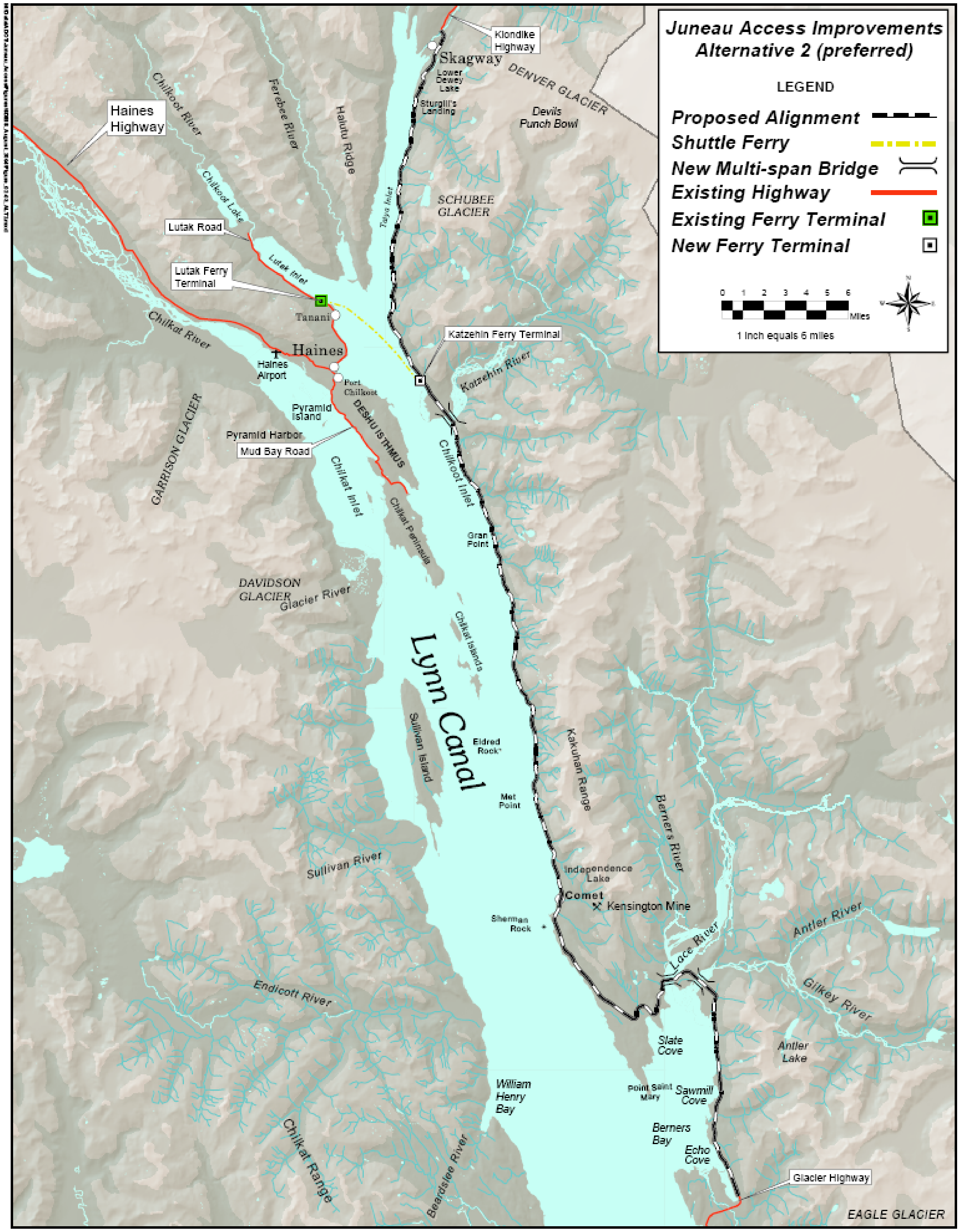

Figure 19. The State of Alaska's preferred alternative proposal to build a road from Juneau to Skagway prior to August 10, 2005.
http://www.dot.state.ak.us/stwdplng/projectinfo/ser/juneau_access/documents.shtml

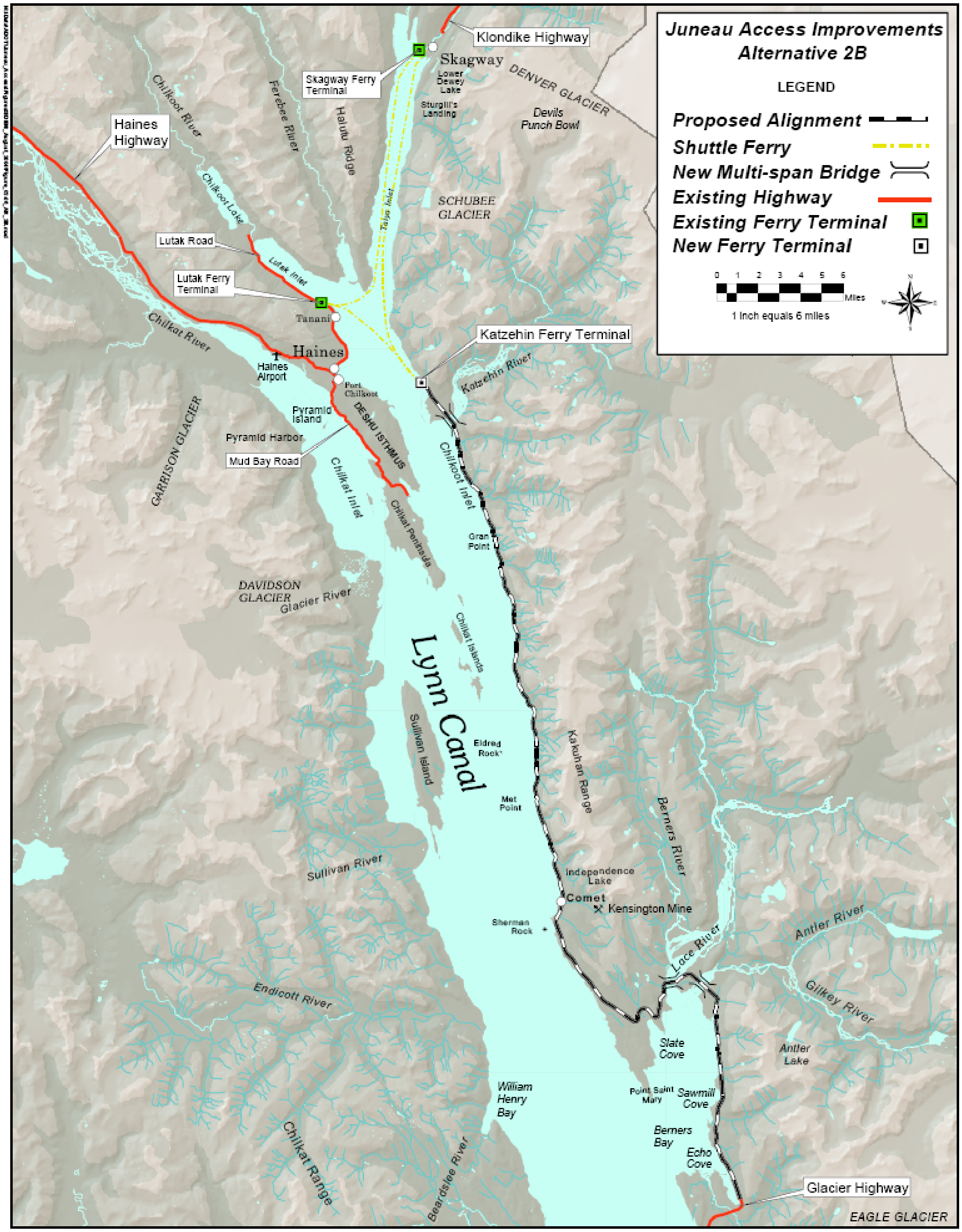

Figure 20. The State of Alaska's preferred alternative proposal to build a road from Juneau to Skagway after August 10, 2005.
http://www.dot.state.ak.us/stwdplng/projectinfo/ser/juneau_access/documents.shtml

C1c. Land Use

C1c1. Dyea Road Maintenance and Erosion Control at Dyea Townsite

The Taiya River was identified as a major threat to cultural resources at the Dyea townsite before the establishment of KLGO. At present, erosion caused by the Taiya River is threatening the Dyea road and townsite both within and outside of the Chilkoot Unit of KLGO. In 2000, the Alaska Department of Transportation initiated a project to control erosion along the Dyea road which involved installing riprap along a 100 ft section of road to the south of the Dyea campground (ADOT&PF 2000). The riprap installation by ADOT does not currently appear to be affecting erosion rates at upstream sites within KLGO (Meg Hahr, Natural Resource Specialist, Klondike Gold Rush National Historical Park, personal communication 2005), however the Dyea townsite is still threatened by the Taiya River (see section *C5b*).

C1c2. Skagway River Scour Control

In 1998, the ADOT&PF was permitted to modify the Skagway River and divert streamflow away from the Skagway airport. A scour control structure was installed upstream of the airport, immediately below the Klondike Highway bridge. The Skagway River is an anadromous fish stream and the effects of the scour control structure on fish passage were monitored after completion of the scour control project. An evaluation of fish passage on the river in 2002-3 indicated that sufficient numbers of king and coho salmon and Dolly Varden were passing through the scour control structure to seed upstream rearing areas (Bethers 2002 & 2003). The study was not able to determine the extent to which the control structure may be impeding the upstream movement of eulachon during their spring run.

C1c3. Pullen Creek Fish Passage Improvements

In an effort to improve fish passage, the ADOT&PF replaced upstream culverts and rebuilt the lower section of Pullen Creek in 2000. This purpose of this project was to mitigate for impacts to the Skagway River associated with the airport expansion and flood control project undertaken in 1999. A post-project evaluation of fish passage in 2002-3 determined that adult and juvenile salmon and Dolly Varden are able to negotiate all of the improved areas on the creek (Bethers 2002 & 2003). The only area of concern identified was the new culvert at 2nd Street, which was described as a potential impediment to passage during high water flows (Bethers 2002).

C1c4. Skagway River Flood Control Improvements

The City of Skagway is currently implementing the Skagway River Flood Control Master Plan to protect the city and Klondike Highway from inundation during a 100 year flood event. This project involves constructing dikes upstream from the Klondike Highway bridge on the Skagway River, improving the existing dike on the west bank of the river, and implementing a gravel mining program to direct streamflow away from river banks and maintain the present low flow channel. This project will reduce the extent of lateral channel migration and has the potential to cause a small increase in stream velocity due to channel constriction

(Montgomery Watson 1998). These changes are not likely to affect KLGO water resources and should provide protection from flooding for the KLGO unit in the Skagway historic district.

C1d. Surface and Groundwater Withdrawals

Groundwater resources in and around KLGO are not presently at risk from unsustainable levels of groundwater mining and the associated intrusion of saltwater into coastal aquifers that is common in coastal areas of the contiguous United States. The City of Skagway currently gets its water from three wells located at 15th avenue that range in depth from 75 to 120 feet. These wells have been in use since 1966 and are recharged by water from the Skagway River and several proximate tributary streams. The present population and level of water usage in Skagway are not at a level that they will affect groundwater resources. In addition, the nearby Dewey Lakes are seen as a likely source for future development of municipal water resources.

C2. Marine Vessel Impacts

KLGO's 3.2 km (1.99 mi) of marine coastline in Taiya Inlet are located approximately 7 km (4.3 mi) from the port of Skagway. In 2004, the port of Skagway was visited by 850 vessels, the majority of which were cruise ships and Alaska State Ferries (Table 8). In addition, 77 freight and petroleum barges visited the port carrying more than one hundred thousand tons of freight and petroleum products (Table 8). The Upper Lynn Canal receives traffic from charter and recreational boats. Cruise ship visits to Skagway have increased by 300% in the last 15 years and overall vessel activity has increased by more than 150% in the same time period (City of Skagway 2005). The increase in vessel traffic has the potential to affect marine and coastal wildlife as well as air and water quality in the Taiya Inlet and Skagway regions of KLGO. Direct impacts from marine vessels include water quality degradation through petroleum (see *B3a1. Petroleum spills*), waste discharges, and noise pollution from vessel engines. The primary concerns for waste discharges are wastewater (greywater and blackwater), hazardous waste, such as paint and cleaning solutions, and solid waste, such as fluorescent lights and batteries (NPS 2003b). Concerns associated with noise pollution include disruption of marine mammal communication signals and echolocation (Erbe and Farmer 1998, Erbe 2003).

C3. Harmful Algal Blooms

Harmful algal blooms (HABs) are caused by a few dozen marine phytoplankton that produce toxins. Although commonly called red tides, this term is misleading as with many HABs, there is no discoloration to the water, and many seaweeds produce colored blooms. HABs cause significant ecosystem, human health, and economic impacts (Anderson et al. 2000). HABs have become a national and international research focus in the past decade. Most areas of the world have some form(s) of harmful algal bloom, although the frequency, severity and diversity vary greatly. What is certain is that HABs have been occurring more frequently and in more areas during the past few decades (Anderson 1995, Burke et al. 2000). HABs have caused mass mortalities of marine bird, mammal, and fish populations, and they cause a variety of human

Table 8. Vessel activity and freight shipments for the port of Skagway in 2004. Modified from City of Skagway (2005).

Type of Vessel	Number of Vessels		Type of Freight	Tons of Freight
Barges	52		General Freight	25,500
Petroleum Barges	25		Petroleum Products	82,540
Cruise Ships	454		Ore Concentrates	0
Alaska State Ferries	319		TOTALS	108,040
TOTAL	850			

illnesses that vary by type of toxic phytoplankton or diatom. Some cause respiratory problems in humansin certain geographic regions. Southwest Florida, for example, now issues health alerts and suggests that people with certain health problems stay inside and away from beaches during certain blooms. HABs are known to cause a variety of shellfish poisoning (SP), including paralytic (PSP), diarrhetic (DSP), neurotoxic (NSP), and amnesic (ASP). A fifth human illness, caused by finfish and not shellfish, is Ciguatera Fish Poisoning (CFP).

Harmful algal blooms have been documented for centuries. Early records from explorers and hunters describe outbreaks of illness after men ate local shellfish that are most likely the result of ingesting intoxicated shellfish. First recorded deaths due to PSP occurred during exploration of Puget Sound and Strait of Georgia in 1791-1792 when several members of Capt. George Vancouver's crew died after eating shellfish from a cove near modern day Vancouver, BC. The earliest recorded event in Alaska was in 1799 when a party of Aleut hunters under the command of a Russian fur trading company ingested mussels. Within minutes, half the party experienced nausea and dry mouth, and two hours later, 100 hunters had died. Alaska has figured prominently in the discovery of HABs and associated toxins, as the family of toxins responsible for PSP were named saxitoxins because they were extracted from the butter clam *Saxidomus giganteus* from Peril Strait, just northeast of Sitka.

Figure 21. *Alexandrium* sp., the dinoflagellate responsible for PSP.

The largest problem caused by HABs in Alaska is paralytic shellfish poisoning (PSP) from shellfish that have bioaccumulated the dinoflagellate *Alexandrium* sp. (Figure 21). Alaska has one of the highest incidences of reported PSP in the world (Gessner and Schloss 1996). Paralytic shellfish poisoning can cause paralysis, gastrointestinal problems, and respiratory arrest and can be fatal if prompt medical care and respiratory support is not available. There is no antidote. People have died in Alaska from PSP as recently as a decade ago, and there is at least one human health incident per year. Since 1973, there have been 176 incidences of PSP in Alaska from 66 outbreaks, with the majority in Southeast Alaska (Figure 22, Gessner 1996).

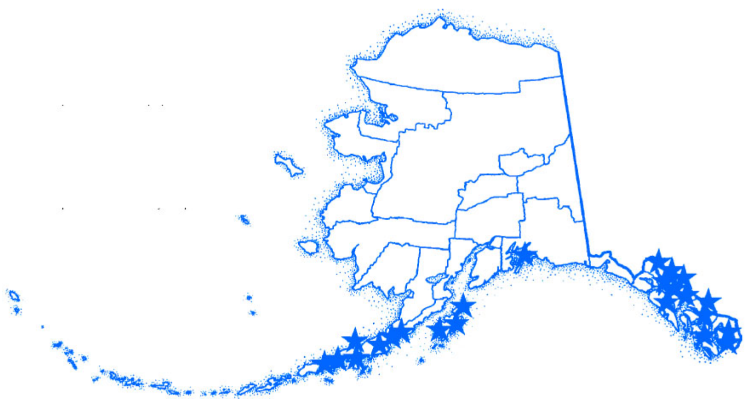

Figure 22. Location of PSP outbreaks in Alaska. Each star represents one or more outbreaks. Source: Gessner 1996.

Little is known about the distribution or abundance of PSPs in coastal areas of KLGO. The Alaska Department of Environmental Conservation (ADEC) is responsible for testing shellfish for PSP. Due to the geographic extent of Alaska (over 81,000 km (50,000 mi) of coastline) and the remote nature of many regions of the state, shellfish are only tested for PSP in association with a commercial harvest or mariculture facility. Non-commercial harvests are not tested, and people are advised not to eat shellfish that they collect. More information is needed in order to evaluate if HABs are an issue of concern in KLGO. Any unusual incidences of mass mortalities of marine bird, mammal, and fish populations should be suspected as possible HAB-related events. NPS should advise against non-commercial harvests of shellfish because of the risks associated with PSP.

C4. Invasive or Nuisance Species

The National Invasive Species Council, which was created by Presidential Executive Order 13112, defines invasive species as species that are "non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health." The introduction of invasive species into Alaskan waters may be either accidental or due to negligence, and pathways of introduction include fish farms, aquaculture, transport on or in ballast water from ships or fishing vessels, live seafood trade, or sport fishing gear (ADFG 2002a). In order to minimize the impact of invasive species in Alaska, the Alaska Department of Fish and Game (ADFG) has developed an Aquatic Nuisance Species Management Plan (ADFG 2002a) with the purpose of focusing on preventing the invasion of those invasive species that are considered the highest threat. This plan can be found on the ADFG Invasive Species Website at http://www.adfg.state.ak.us/special/invasive/invasive.php.

Non-indigenous aquatic invasive species that have been introduced or are moving into Alaskan waters include multiple species of fish, plants, and invertebrates (Appendix 2). Water bodies of Alaska are likely to be invaded by non-indigenous species because the temperature ranges of oceans, rivers and lakes vary much less than terrestrial temperature ranges (ADFG 2002a). Invasive fish species that have been introduced to some areas of Alaska include Northern Pike (*Esox lucius* (Linnaeus)), Atlantic Salmon (*Salmo salar*), yellow perch (*Perca flavescens*), and various ornamental species. Northern Pike are of great concern because they spread rapidly and cause widespread damage to resident species such as trout, grayling and salmon (ADFG 2002a). Farmed Atlantic salmon in Washington State and British Columbia are released into the North Pacific ocean each year and may affect native populations through disease, colonization, interbreeding, predation, habitat destruction, and competition (ADFG 2002b). These farmed fish are thriving in the wild with recoveries in both British Columbia and Alaska, with the first catches of Atlantic salmon in Southeast Alaska in 1991 (ADFG 2002b). ADFG has documented over 700 recoveries of Atlantic salmon throughout Alaskan waters which represent an estimated 3,000 immigrants per year. Atlantic salmon have been caught in many locations throughout Southeast Alaska including Lynn Canal, Icy Strait, Ketchikan, Petersburg, and Yakutat (ADFG 2002b).

Potential invasive invertebrate species of concern include the green crab (*Carcinus maenas*) from northern Europe, the New Zealand mudsnail (*Potamopyrgus antipodarum*), the Chinese mitten crab (*Eriocheir sinensis*), Zebra mussels (*Dreissena polymorpha*) from Europe, Signal crayfish (*Pacifastacus leniusculus*) from Canada, and the spiny water flea from Europe (Appendix 2). These invertebrates outcompete or displace native species and negatively impact the local ecosystem. Bacteria, viruses, and parasites are also a threat to Alaskan waters because these can be easily introduced through non-indigenous species. Whirling disease (*Myxobolus cerebralus*), a parasitic infection in trout and salmon, is as a potential threat in Alaska to these economically important species (ADFG 2002a).

Various invasive plants that are potential or actual threats in Alaska include hydrilla a/k/a water thyme (*Hydrilla verticillata*), dotted duckweed (*Landoltia* (*Spirodela*) *punctata*), purple loosestrife (*Lythrum salicaria*), Eurasian water-milfoil (*Myriophyllum spicatum*), Reed Canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*), salt marsh cordgrass (*Spartina alterniflora*), dense-flowered cordgrass (*Spartina densiflora*), foxtail barley (*Hordeum jubatum*), and swollen bladderwort (*Utricularia inflata*) (Appendix 2, ADFG 2002a).

Within KLGO, a primary water resource concern related to invasive species is that invasive plants such as white sweetclover (*Melilotus alba*) have the ability to invade gravel bars and riparian areas within river corridors. KLGO has a well-established exotic plant management program and has been active in surveying and managing exotic plants within the park (see NPS PMIS 109890). In 2000, a survey of exotic plants in the Chilkoot Trail Unit of the park identified twenty exotic plants and seven additional plants of uncertain exotic status (Furbish and Jorgensen 2001). Of these, six species: yarrow (*Achillea borealis*), quackgrass (*Agropyron repens*), pineapple weed (*Matricaria matricarioides*), sheep sorrel (*Rumex acetosella*), dandelion (*Taraxacum officinale*), and white clover (*Trifolium repens*) were found in the coastal Dyea Flats area. In 2004, a survey of all three park units identified twenty four species of exotic plants, three of which were present in all three park units (Delost, 2004). In 2005, over 300 hours were devoted exotic plant management in KLGO, with 114 hours devoted specifically to the removal of common eyebright (*Euphrasia nemorosa*) in Nelson Slough (Schultz, 2005).

C5. Physical Impacts

C5a. Skagway Harbor Landslide and Tsunami Hazard

The coast of Southeast Alaska is characterized by a relatively high risk of the occurrence of catastrophic tsunami waves caused by landslides. These landslides can be caused by tectonic events or hydrometeorological factors such as the failure of unstable sediments during extremely low tides (Kulikov et al. 1998). On November 3, 1994, a landslide associated with the collapse of a dock under construction for the Pacific and Arctic Railway and Navigation Company (PARN) on the east side of Skagway Harbor generated a tsunami wave estimated at 5-6 m high in Taiya Inlet and 9-11 m high at the shoreline. The tsunami claimed the life of one dock worker in Skagway, impacted the Alaska State Ferry Terminal, a cargo terminal, and 1.5 km of railway, and caused an estimated $21 million in damage (Rabinovich et al 1999). A similar landslide and associated tsunami occurred in Skagway Harbor in October, 1966. Both of these landslide-generated tsunami events were occurred during low tides, were associated with construction events, and likely had subaerial components (exposed intertidal sediments) (Thomson et al. 2001). These findings suggest that coastal construction activities that cause loading to slope material in the intertidal zone pose an ongoing tsunami risk for the region around Skagway Harbor.

C5b. Taiya River Erosion and KLGO Cultural Resources

The Dyea townsite, which is threatened by erosion from the Taiya River contains some of the most important cultural resources in KLGO. In 2002, specialists from the Water and Geological Resources Divisions of NPS examined the Dyea area and concluded that the Taiya channel bank needs to be stabilized to protect the remaining portions of the Dyea townsite.

The recommendation put forth was to use flow-deflector engineered log jams which are an ecologically sensitive method for flood and erosion control. Engineered log jams have several advantages: they are made of naturally occurring materials, they mimic existing conditions in the Taiya River, and they enhance habitat value in addition to stabilizing channel banks. Funding for this project was requested by KLGO in 2005 (see NPS PMIS 117398). Developing a better understanding of the geomorphic hazards and flood regime on the Taiya River (see section *C3b*) will be invaluable for assessing the extent to which engineered log jams or other erosion control methods will be effective over the long term (Curran and Hahr 2005).

C5c. Geomorphic Activity and Flooding on the Taiya River

The Taiya River is extremely dynamic and is subject to channel migrations and catastrophic flooding. During the last century, migration of the Taiya river channel, which is typical of sediment-laden glacial rivers, has caused the removal of more than 30% of the historic gold rush town of Dyea (Curran and Hahr 2005). The Taiya River is also prone to flooding from glacial outburst lakes. In July, 2002 a lateral moraine along the West Creek Glacier liquefied and slumped into a proglacial lake triggering an outburst flood on West Creek (Figure 23) that ran down the Taiya River. The peak discharge for the flood was estimated to be more than 16,000 cfs, which is nearly 150% of the predicted 500-year flood for West Creek (Capps 2004).

The 2002 outburst flood did not cause any serious injuries or deaths, however residents and campers at Dyea were evacuated and both private and KLGO property were damaged as well as roads and bridges (NPS 2004). KLGO repaired flood damage to the Sheep Camp Recreational Campground (see NPS PMIS 99848). This work included rehabbing trails and bridges, stabilizing existing campgrounds, and backfilling two pit toilets. Subsequent hydrological analyses have concluded that the present site of Sheep Camp will continue to flood as the Taiya River migrates eastward. As a result, KLGO has requested funds to relocate Sheep Camp out of the Taiya River floodplain (see NPS PMIS 113455). An Environmental Assessment of the proposed relocation has been completed and Sheep Camp is currently scheduled to be moved in the summer of 2006 (Meg Hahr, Natural Resource Specialist, Klondike Gold Rush National Historical Park, personal communication 2006).

Glacial outburst floods or johkelhops are unpredictable because they are triggered by events such as the enlargement of drainage cavities in glaciers or failures of landforms like moraines and alluvial fans. Historical photographs and geomorphological evidence collected in the Taiya River Valley indicate that this drainage has a history of large-scale floods stretching back over the last two centuries (NPS 2004). Following the 2002 flood event, outburst flood potential in both the Nourse River and West Creek was assessed by hydrologists from the Bureau of Land Management (BLM). The assessment involved aerial and ground observations aimed at detecting glacial landforms prone to sloughing or failure (Denton et al 2005). The BLM investigations determined that there is a relatively low potential for future glacial lake outburst flooding at the West Creek Glacier because the primary intact lateral moraine has a stable slope angle and is not located in a location that is prone to saturation. The glacial landforms in the Nourse River (Figure 23) appear to be similarly stable, however the large volume of water retained behind the Nourse Glacier moraine does pose a serious flood threat if the moraine were to fail. A model of the flood event resulting from the failure of this moraine suggests that the peak discharge at Dyea would have a magnitude of more than five times the estimated 500-year flood event on the Taiya. In early 2006, KLGO was in the process of reviewing a BLM report regarding the threat of outburst flooding from the Nourse drainage (Meg Hahr, Natural Resource Specialist, Klondike Gold Rush National Historical Park, personal communication 2006). In addition to the Taiya River, the Skagway River is also prone to outburst flooding, however, to date there have not been any investigations of the risk of glacial lake outburst in tributaries to the Skagway River.

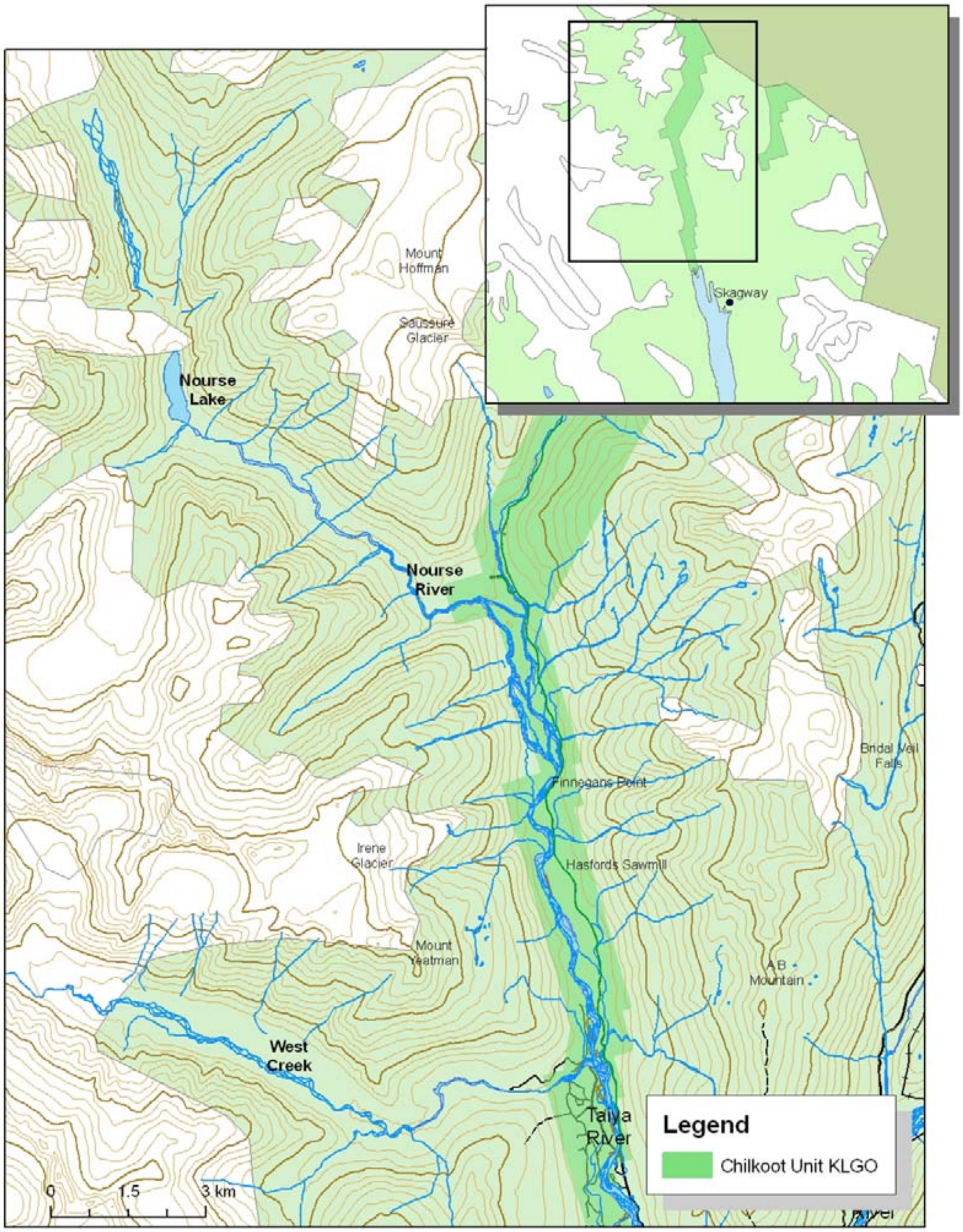

Figure 23. Location of West Creek, Nourse Lake, and the Nourse River, in the Taiya River Watershed. These tributaries have been the source of previous glacial outburst floods on the Taiya River.

There is a strong need for information on glaciofluvial hazards in the Taiya River watershed. As a result, KLGO is currently seeking funding to develop a model for predicting channel response to geohazards in this watershed (see NPS PMIS 55035). The proposed modeling effort will result in a comprehensive, spatially and temporally extensive, conceptual model of the fluvial dynamics of the Taiya River. Such a model would provide KLGO managers with a scientific basis for evaluating issues related to river channel dynamics within the entire flood plain of the river.

C5d. Land Surface Uplift

Active tectonics in Southeast Alaska as well as the increased thinning of glaciers are both contributing to the extremely high rates of land surface uplift in the region. Icefields in coastal Southeast Alaska have experienced rapid retreat and thinning in the last 100-200 years, and the rate at which ice is being lost appears to be increasing (Arendt et al 2002). The unloading of the earth's surface associated with this loss of ice has resulted in isostatic rebound of the earth's crust over a large area of Southeast Alaska (Hicks and Shofnos 1965, Clark 1977, Sauber et al. 2000, Larsen et al. 2004). Over the past 250 years, shorelines in the upper Lynn Canal south of KLGO have been raised between 3 and 5.7 meters primarily as a result of land surface uplift (Larsen et al 2004). Recent measurements of uplift in Southeast Alaska are among the highest ever recorded with rates of up to 25mm per year in Glacier Bay and 34 mm per year centered over the Yakutat Icefield (Larsen 2003). The active tectonic deformation of the Southeast Alaska region is also a possible source of uplift, however this effect is thought to be relatively minor compared to isostatic rebound (Larsen et al. 2004).

Measurements using global positioning systems (GPS) have shown that the land surface in the Skagway area is being uplifted at a rate of approximately 10-14 mm yr^{-1} (Figure 24). The effects of this uplift have not been well studied in the Skagway area, however in the Yakutat region to the west of KLGO, uplift is altering the landscape and causing dramatic changes in fisheries and wildlife habitat (Mills and Firman 1986). Changes in land surface elevation also have important implications for the hydrology of small coastal streams, many of which support salmon populations. Recent research in the Mendenhall Valley near Juneau has shown that water table levels have been decreasing at approximately 3.7 cm/yr during the last two decades, likely as a result of land surface uplift (Walter et al. 2004). This decrease in the water table appears to be affecting the hydrology of streams within the valley. In the last decade, Duck Creek, an urbanized salmon stream similar to Pullen Creek, has experienced a steady decrease in low flows of approximately 0.003 m^3/s/yr (Walter et al 2004). As a result, the lower reaches of Duck Creek often now run dry in the spring and summer. The Skagway area is currently experiencing similar uplift rates to Juneau, thus it is possible that Pullen Creek may experience similar reduced flows, particularly if the groundwater feeding the stream headwaters is derived from the Skagway River. Decreases in the flow of small coastal streams may also inhibit fish passage, limiting the range of certain anadromous stocks. The US Geological Survey office in Juneau is currently preparing a report on recent changes in the hydrology of Duck Creek resulting from land surface uplift (Edward Neal, Hydrologist, USGS, Juneau, Alaska, personal communication 2005).

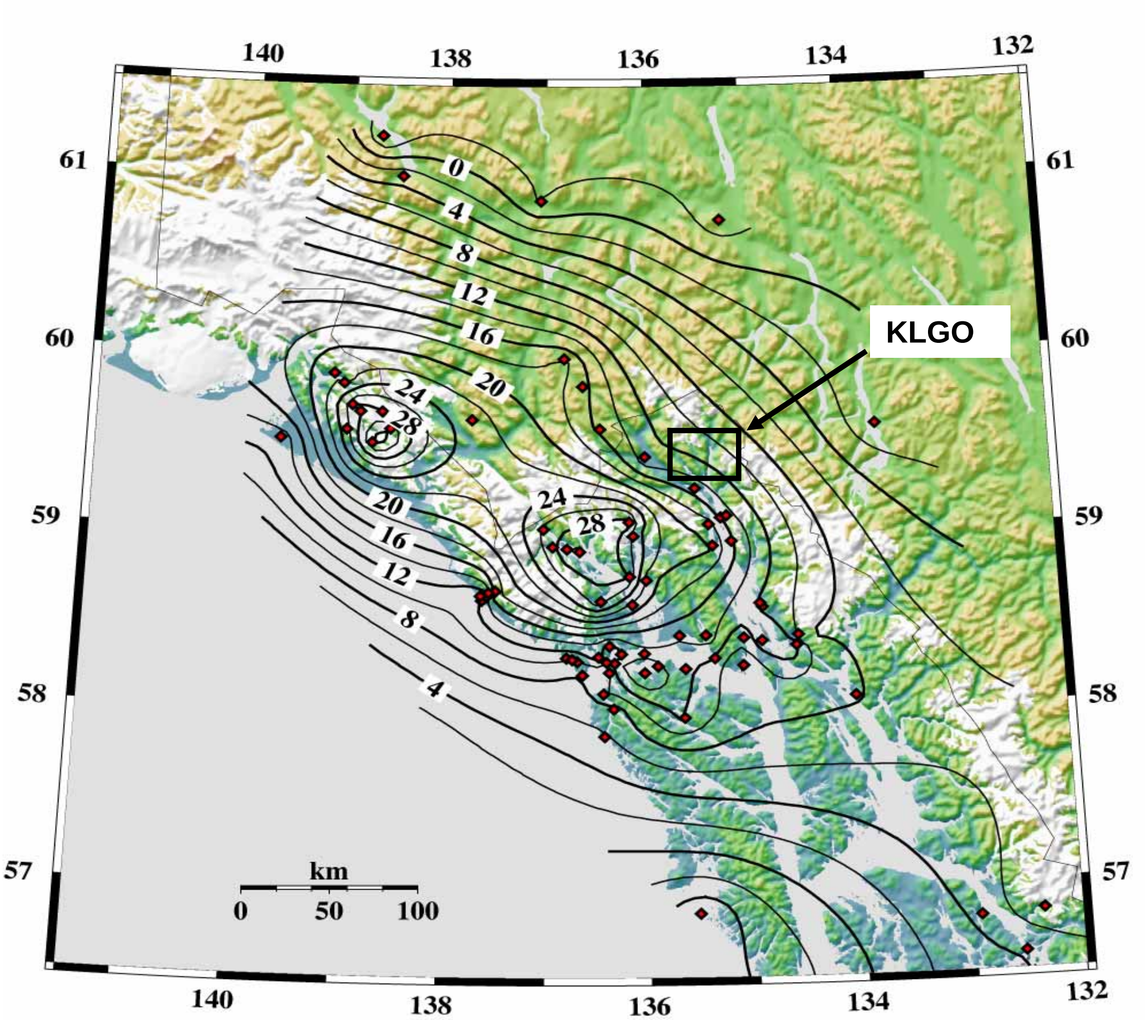

Figure 24. Land surface uplift rates in Southeast Alaska from GPS measurements. Red diamonds are measurement sites. Modified from Chris Larsen, University of Alaska Fairbanks Geophysical Institute (http://www.giseis.alaska.edu/Input/chris/gpsuplift.jpg).

C6. Climate Change

Climate change is an important natural resource issue for national parks in Alaska and recent research suggests that changes in climate may dramatically impact water resources in these parks. On a global scale, mean surface air temperature has risen by about 0.6 degrees Celsius in the last century and the best estimate of the International Panel on Climate Change is that temperatures will rise by another 1.7 to 4.0 degrees Celsius by 2100 (IPCC 2001). Recent climate change is dominated by human influences and there is now a relatively broad scientific consensus that the primary cause of climate change is human-induced changes in atmospheric composition (Karl and Trenberth 2003). In particular, there have been rapid increases in the concentration of greenhouse gases such as carbon dioxide and methane which absorb and re-radiate outgoing terrestrial longwave radiation. Models and recent observations both suggest that climate warming is amplified at higher latitudes (Hall 1988, Mitchell 1989, Serreze et al. 2000). Thus future changes in temperature are projected to be proportionally higher in high-latitude systems (Roots 1989). Over the past fifty years, Siberia, Alaska and northern Canada, and the Antarctic Peninsula have warmed more than any other regions on Earth, and the 20th century arctic is the warmest of the past 400 years (Overpeck et al., 1997; Serreze et al. 2000). The reasons for the observed temperature increases at high latitudes are not fully understood, but are thought to involve cyospheric feedbacks, coupled with changes in the atmospheric circulation, and possibly ocean currents.

This warming in high-latitude regions is already affecting the physical landscape in Alaska. The most obvious effects of climate change on hydrologic resources in Alaska are changes in the extent of permafrost, snow cover, glaciers, and sea and lake ice cover (Oswood et al. 1992). Glaciers in both maritime and continental regions of Alaska are thinning and retreating at rapid rates (Arendt et al 2002). Some projections suggest that increasing winter temperatures in high-latitude areas may lead to greater snow accumulation (Mayo and Trabant 1984, Mayo and March 1990). Future increases in snowfall could slow glacial retreat or even cause glacial advance. There are numerous mountain glaciers that provide runoff to the Skagway and Taiya rivers, and the majority of these glaciers are receeding, probably due to a warmer climate. The thinning rate for glaciers around KLGO as measured by airbourne laser altimetry is between 0-2 meters per year (Figure 25). This thinning is consistent with meteorological data from the nearby stations at Juneau, Sitka and Yakutat that show a tendency toward an increase in average summer air temperature since about 1940 when the meteorological record began (Motyka et al 2003).

One important effect of increased glacier melt is an increase in runoff from glaciers. Increased runoff can lead to the creation of new streams, and can alter the sediment, streamflow, and temperature regimes in the surrounding streams (Oswood et al. 1992, Weeks 2003). Moreover, stream channel morphology and stability can be altered by changes in runoff and sediment loads, as well as the composition of the substrate and habitat complexity of the stream (Williams 1989). Reduced stream temperatures from increased glacial runoff could also decrease primary production, impact or eliminate certain invertebrates, and lower salmonid rates of production (Lloyd 1987, Lloyd et al. 1987). Over longer time scales, glaciers in KLGO may produce less runoff as glacier mass decreases significantly.

It is also likely that climate change is affecting lakes and ponds within KLGO. A survey of ponds and lakes in nearby Wrangell-St Elias National Park and Preserve (WRST) found that the area of small lakes and ponds within in the park has decreased dramatically since the 1950's. The effects the decrease in lake area on the species populations dependent on these waterbodies is not known (Weeks 2003). Increasing air temperatures also have the potential to impact glacier-dammed lakes that contribute to streamflow in the Taiya and Skagway Rivers. The effects of climate change on the chemistry of lakes and streams are not well understood. Research on linkages between terrestrial and aquatic system suggests that elevated temperatures and carbon dioxide levels will affect the distribution and productivity of plants which will in turn affect the amount and quality of leaf litter entering streams and rivers (Meyer and Pulliam 1992). Because soil microbial activity is linked to soil temperature and moisture, climate shifts will affect microbial processing of organic material in terrestrial systems. Overall, changes in inputs from terrestrial systems to lakes and streams will lead to shifts in litter decomposition rates (Webster and Benfield 1986), as well as changes in the productivity of heterotrophic and invertebrate populations (Anderson and Sedell 1979, Oswood et al. 1992). Stream water quality could also be altered by changes in the frequency of disturbances such as forest fires, wind storms, coastal floods (Meyer and Pulliam 1992). Ultimately, changes to the quality and quantity of runoff in the Skagway and Taiya rivers will affect near-shore marine systems in the Upper Lynn Canal because the productivity of these systems is influenced by inputs of nutrients from these watersheds.

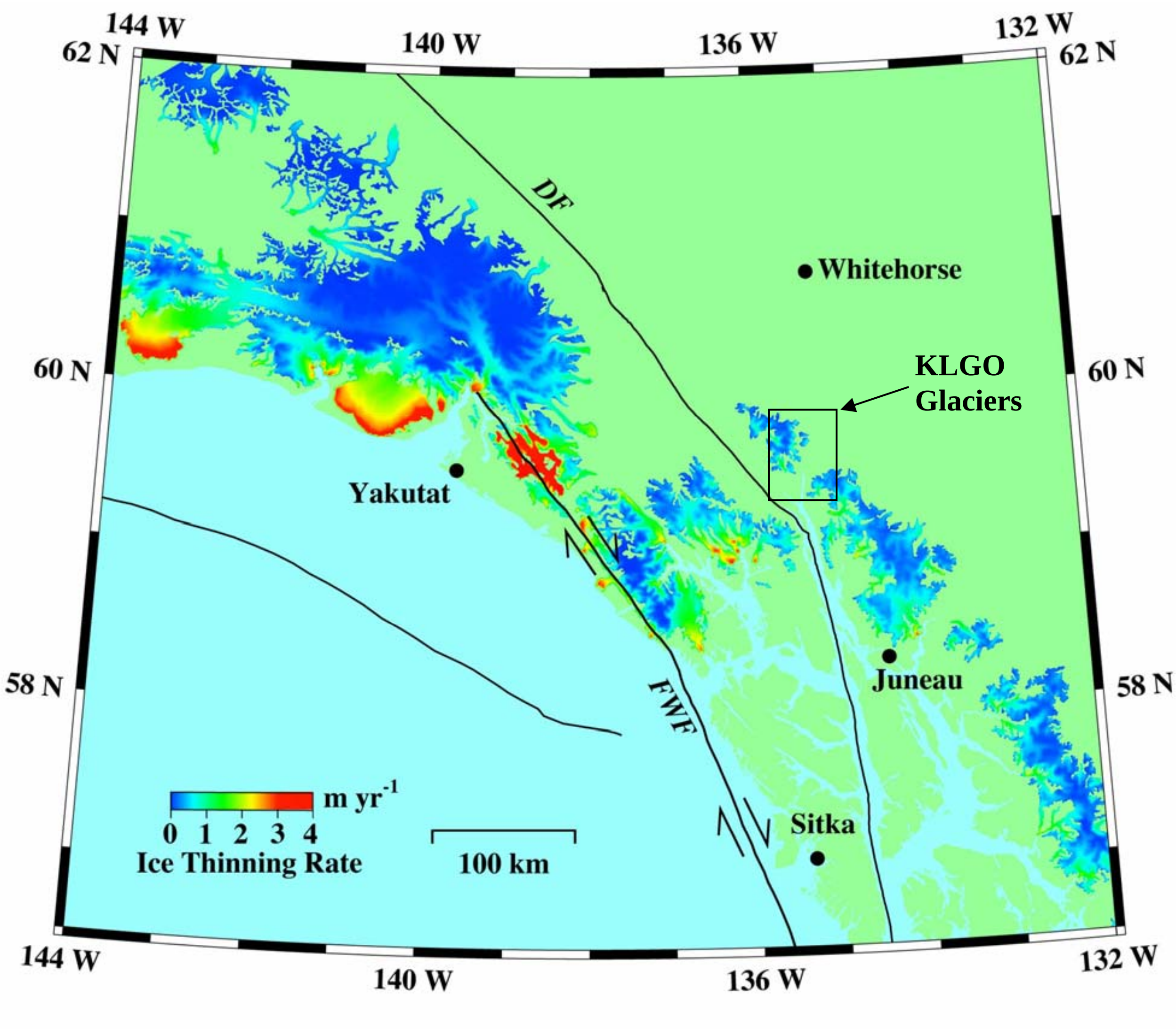

Figure 25. Current rates of glacier ice thinning in southeastern Alaska as measured by laser altimetry. Glaciers around KLGO are thinning at rates of 0-2 m per year. Modified from Motkya.

D. Recommendations

D1. Condition overview

Table 9. Potential for impairment of coastal KLGO water resources.

Indicator	Freshwater Taiya R.	Freshwater Skagway R.	Freshwater Pullen Cr.	Estuary	Marine/ Intertidal
Water Quality					
Eutrophication	OK	OK	OK	OK	OK
Contaminants	OK	OK	EP	OK	OK
Metals	OK	OK	PP	OK	OK
Turbidity	OK	OK	PP	OK	OK
Pathogens	OK	OK	OK	PP	OK
Hypoxia	OK	OK	PP	OK	OK
Habitat Disruption					
Physical benthic impacts	OK	OK	PP	PP	OK
Recreation/Tourism usage	PP	OK	PP	OK	OK
Altered flow	OK	OK	PP	NA	NA
Erosion/Sedimentation	EP	PP	PP	OK	OK
Other Indicators					
Harmful algal blooms	NA	NA	NA	PP	PP
Aquatic invasive species	PP	PP	PP	OK	OK
Impacts from fish/shellfish harvesting	OK	OK	OK	OK	PP
Terrestrial invasive species	EP	EP	EP	NA	NA
Climate change	PP	PP	PP	PP	PP
Glacial outburst flooding	PP	PP	OK	NA	NA
Fuel/Petroleum spills	OK	PP	PP	PP	PP
Atmospheric contaminants/Air pollution	PP	PP	PP	PP	PP

Definitions: EP= existing problem, PP = potential problem, OK= no detectable problem, shaded =limited data, NA= not applicable.

D2. Data access/management

Online archives of NPS publications and reports

Obtaining information for this report was arduous and difficult, however information could be more readily obtained if NPS were to generate online archives of NPS publications and reports. Such an archive should be searchable. Historical documents should be entered to the extent possible.

Integration of information into centralized and web-accessible GIS

Data from surveys, monitoring activities, impairments, and inventories should be integrated into a centralized and web-accessible GIS. ShoreZone GIS layers should be obtained and integrated into this centralized and web-accessible GIS.

D3. Freshwater Resources

Current water quality data are lacking for the two main watersheds within KLGO, the Taiya and Skagway Rivers. However, historic water quality data for these watersheds suggest that water quality is relatively good, and at the present time there is not a substantial threat to water quality from point sources of pollution in and around KLGO. There are a number of potential sources of non-point source pollution threatening park watersheds, the most significant of which include atmospheric deposition of pollutants and urban and road runoff. Water quality in the Pullen Creek watershed in the Skagway Unit of KLGO is currently listed as impaired by the EPA because of heavy metal contamination. Despite the EPA listing, water quality data for Pullen Creek are only available for several dates during a one-year period in 2003-2004. Other important impairments in Pullen Creek include barriers to fish passage, runoff from urban surfaces, and debris accumulation.

Recommendations for management and monitoring freshwater resources in KLGO include:

- Establish a freshwater quality monitoring program within the park. At the minimum, this monitoring program should include basic water quality parameters: pH, temperature, dissolved oxygen, conductivity, turbidity, and, if possible, suspended sediment. We also recommend implementing formalized biological sampling of macroinvertebrates and flora to detect any changes in community structure that may result from chronic or pulsed impacts. The purpose of this program would be to document water quality conditions and allow for the detection of future changes in baseline water quality. The Taiya River should be the focus of water quality monitoring efforts because the lower portion of the watershed is contained within the boundaries of KLGO and the river corridor is heavily used by hikers along the Chilkoot Trail.

- Continue to pursue funding for geomorphic assessment of the Taiya River. The Taiya River is an extremely dynamic system which is being influenced by glacial recession and periodic outburst flooding. The links between these processes and erosion and deposition patterns in the lower watershed are not well understood. This information is critical for KLGO resource managers because the majority of the park's visitor services facilities are located within the Taiya River floodplain and movement of the river channel is threatening both cultural (at the Dyea townsite) and natural resources that are central to the park's mission.

- Maintain the streamflow gage on the Taiya River when the current agreement lapses in 2007. The Taiya River gage that is currently being maintained by the USGS is the only active stream gage within the boundaries of KLGO. Information about water quantity is important both the in the context of understanding hydrogeomorphic hazards in this system and in the context of detecting changes in freshwater discharge to the upper Taiya Inlet that may result from changes in the area of snowfields and glaciers in the coast mountains in and around KLGO.

- Continue to evaluate the feasibility of converting the existing pit toilets along the Chilkoot Trail to moldering/composting toilets. The Chilkoot Trail is the most heavily used backcountry corridor in KLGO and eliminating the use of pit toilets will protect shallow groundwater aquifers in the Taiya River Valley.

- The Taiya River is the main spawning habitat in the park for anadromous fishes, yet relatively little information exists about spawning and rearing areas within the Taiya watershed. Additionally, because many coastal biological resources depend on healthy salmon returns, an effort should be made to monitor salmon returns in the Taiya watershed.

- Climate change is one of the major threats to water resources in Alaskan Parks. The hydrology of coastal parks such as KLGO is particularly sensitive to climate change because the air temperature at sea level in southeastern Alaska is often close to the freezing point of water. As a result a relatively small increase in temperature can shift precipitation from snow to rain which, in turn, shifts the annual pattern of streamflow in these coastal systems. KLGO should install several (2-3) automated climate stations along the Chilkoot Trail. These stations would provide baseline climate information and allow KLGO resource managers to detect future changes in climate. In addition, installing the stations at different elevations along the Chilkoot Trail will provide information about how climate change might be varying with elevation.

- The most extensive wetlands within KLGO lie in the Dyea flats area. The health of these wetlands should be monitored, and KLGO managers should work with local landowners to assure that they are protected from any future development in the Taiya River valley. In addition, the six identified breeding sites for western toads in Dyea should be protected.

- Glaciers and snowfields are one of the most important freshwater resources in and around KLGO, however the rate at which these resources are being affected by shifts in climate are not well understood. An effort should be made to monitor future changes in glacier and snowfield area within the Taiya and Skagway watersheds. The most likely avenue for this through repeat photography using available satellite products such as LANDSAT or ASTER in partnership with federal agencies such as NASA that have access to and expertise with these data.

- Pullen Creek is the primary water quality impairment within KLGO. KLGO staff should continue to work with the Taiya Inlet Watershed Council and the Skagway Tribal Council to obtain funding for the assessment and remediation of Pullen Creek.

- KLGO should continue to monitor lichens within and around the park for evidence of air quality impairments. The intervals for this monitoring should be determined by future changes in the sources of air pollution. For example, since the last lichen survey in 2000, cruise ship traffic in Skagway has increased nearly 30% with more than 150,000 additional visitors in 2004 compared to 2000.

- KLGO should partner with other parks in the SEAN network to assess the threat from global-scale pollutants such as mercury and POPs to network parks. Because these pollutants are not derived from localized sources, monitoring these pollutants in one park within the network would provide information that would be useful for assessing potential impacts in the other parks. These pollutants should be monitored in both water and biological resources.

- KLGO should work with the City of Skagway to ensure that planned development in the Taiya Valley and along the Dyea Road does not harm aquatic resources in the park. Primary concerns are affects of future development on wetlands in the area (mentioned previously) as well as increases in urban runoff to surface water and groundwater.

- Monitoring of invasive species in both the Skagway and Taiya watersheds should be continued. KLGO should also work with the City of Skagway and private landowners to prevent the spread and establishment of invasive species of concern such as white sweetclover, Japanese knotweed, and purple loosestrife. In addition, an aquatic invasive species study should be conducted so that aquatic invasive species can be identified, monitored, and potentially eradicated.

D4. Marine Resources

Marine resources within KLGO include estuarine and intertidal resources at the head of Taiya Inlet. Currently, these resources appear intact, however inventories and monitoring should be completed to establish baseline conditions in this region.

Recommendations for management and monitoring marine resources in KLGO include:

- Conduct an inventory of non-fish intertidal resources in Dyea flats (as the fishes have already been inventoried). Development an intertidal monitoring protocol to regularly survey intertidal resources (including fishes).

- Assess marine vessel traffic and other vehicle impact along the coastline in the Dyea Flats area that includes wetland and intertidal habitat.

- Marine vessels in other areas of Lynn Canal could impact KLGO resources through transport of pollutants, however very little is known about circulation in Lynn Canal. A basic circulation model that includes tidal circulation, bathymetry and freshwater input might help inform KLGO of risks of pollutant movement up the canal. The circulation model could also provide information on residence time of water within Taiya Inlet and exchange rate and extent of exchange with the Gulf of Alaska. Residence time will help inform flushing rate and exposure of pollutants, if they were to exist.

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F. Appendices

Appendix 1. Water quality standards for the State of Alaska (ADEC 2003). Standards for all parameters except fecal coliform bacteria refer to the criteria for the "Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife". Fecal Coliform bacteria refers to the "Water Recration – contact recreation" criterion.

Parameter	Criteria
Fresh Water Standards	
Fecal Coliform Bacteria (FC)	In a 30-day period, the geometric mean of samples may not exceed 100FC/100 ml, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200FC/100 ml.
Dissolved Gas	Dissolved Oxygen (D.O.) must be greater than 7 mg/L in waters used by anadromous or resident fish. In no case may D.O. be less than 5 mg/L to a depth of 20 in the interstitial waters of gravel used by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, D.O. must be greater than or equal to 5 mg/L. In no case may D.O. be greater than 17 mg/L or exceed 110% of saturation.
Dissolved Inorganic Substances	Total dissolved solids (TDS) may not exceed 1,000 mg/L. A concentration of TDS may not be present in water if that concentration causes or could reasonably be expected to cause an adverse effect to aquatic life.
Petroleum, Hydrocarbons, Oils and Grease	Total aqueous hydrocarbons (TAqH) in the water column may not exceed 15µg/L. total aromatic hydrocarbons (TAH) in water may not exceed 10 µg/L. There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
pH	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH units outside of the naturally occurring range.
Sediment	The percent accumulation of fine sediment (0.1-4.0 mm) in the spawning grounds of anadromous or resident fish may not be increased more than 5% by weight above natural conditions. In no case may the fine sediment range in those gravel beds exceed a maximum of 30% by weight (as shown from grain size accumulation graph). In all other surface waters, no sediment loads (suspended or deposited) that can cause adverse effects on aquatic animal or plant life, their reproduction or habitat may be present.
Temperature	May not exceed 20˚C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15˚C Spawning areas 13˚C Rearing areas 15˚C

	Egg and fry incubation 13˚C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent the appearance of nuisance organisms.
Turbidity	May not exceed 25 nephelometric turbidity units (NTU) above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
Marine Water Standards	
Fecal Coliform Bacteria (FC)	Same as fresh water standard.
Dissolved Gas	Surface dissolved oxygen concentration in coastal water may not be less than 6.0 mg/L for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/L at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/L. the concentration of total dissolved gas may not exceed 100% of saturation.
Dissolved Inorganic Substances	Maximum allowable variation above natural salinity (parts per thousand): Natural Salinity — Human-Induced Salinity 0.0 to 3.5 — 1 Greater than 3.5 to 13.5 — 2 Greater than 13.5 to 35.0 — 4
Petroleum, Hydrocarbons, Oils and Grease	Same as fresh water standard.
pH	May not be less than 6.5 or greater than 8.5. May not vary more than 0.2 pH units outside of the naturally occurring range.
Sediment	No measurable increase in concentration of settable solids above natural conditions, as measured by the volumetric Imhoff cone method.
Temperature	May not cause the weekly average temperature to increase more than 1C. the maximum rate of change may not exceed 0.5C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.
Turbidity	May not reduce the depth of the compensation point for photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.

The Alaska Water Quality Standards specify the degree of degradation that may not be exceeded in a waterbody as a result of human actions (ADEC 2003). The Alaska Water Quality Standards designate specific uses for which water quality must be protected, and specifies the pollutant limits, or criteria, necessary to protect these uses.

There are seven designated uses for fresh waters, and seven designated uses for marine waters specified in the Alaska Water Quality Standards (ADEC 2003). The seven freshwater uses are: drinking water; agriculture; aquaculture; industrial; contact recreation; non-contact recreation; and growth and propagation of fish, shellfish, other aquatic life, and wildlife. The seven marine water uses are: aquaculture; seafood processing; industrial; contact recreation; non-contact recreation; growth and propagation of fish, shellfish, other aquatic life, and wildlife; and harvesting for consumption of raw mollusks or other raw aquatic life. For each of these uses, the Alaska Water Quality Standards specify criteria for a variety of parameters or pollutants, which are both numeric and descriptive (ADEC 2003). According to the federal Clean Water Act Section 305(b) and Section 303(d), waterbodies are compared to the criteria for these parameters to determine if persistent water quality violations occur, and if so into which status category waterbodies are listed.

Appendix 2. Non-indigenous invasive species that have invaded or could soon invade Southeast Alaska. The species listed are all highly invasive, have caused severe impact in areas they have spread to, and are capable of living in Alaska's climate. Many of these species have already spread to the Pacific Northwest and are a risk to Alaska. From ADFG (2002a).

Species	Origin	Location in SE Alaska	Primary Concerns
Fish:			
Northern Pike	Alaska	Spreading to other areas of Alaska	Highest priority threat to Southcentral Alaska. They eliminate or greatly reduce the native species. Cause damage to resident species (rainbow trout and grayling). Potential impact to coho salmon stocks.
Atlantic Salmon	Escape from Fish farms in BC and Washington	Cordova Ketchikan Yakutat Bering Sea	Serious threat to native species due to competition in stream habitat. Displace native fish by out-competing for food and spawning habitat.
Yellow perch		Kenai Peninsula	Compete with all resident fish species and salmon fry. This population has been eradicated.
Ornamental aquarium fish			Compete with and may feed on native species.
Invertebrates:			
Green crab	N. Europe	California to Vancouver Island	Out-competes resident species for shoreline habitat. Very aggressive.
New Zealand mud snail	New Zealand	Europe Asia Idaho Montana Wyoming California Arizona	May impact the food chain for native trout and the physical characteristics of streams themselves. A serious threat to Alaska's sport fisheries.
Chinese mitten crab	China	San Francisco Bay/delta Possible it is in Oregon's Columbia River	Similar life history to American eel and can move upriver hundreds of miles displacing native species. Feeds on salmonid eggs.
Zebra mussel	Europe	Great Lakes	Out-compete resident mussels, clog water intake lines, sequester nutrients for primary production.
Signal crayfish	W. Canada	Kodiak Island	Out-compete stream fauna, eat everything, can survive extended periods of drought and famine.
Spiny water flea	Europe	Great Lakes California	Displaces existing zooplankton communities but is unpalatable to fish resulting in lower fish numbers.
Parasites:			
Whirling disease	Eurasian continent	Present in 22 states. Found in all western states except Arizona and Alaska.	Parasitic infection that attacks juvenile trout and salmon. Causes fish to swim erratically and in severe cases, to die.

Plants:			
Hydrilla or water thyme	Originally from S. India and Korea.	Present in 15 states including California and Washington	Hydrilla is a noxious water weed that can quickly spread to become an impenetrable mat. Fills lakes and rivers completely until i "tops out" at the surface. Native plants are out-competed. Greatly slows water flow and clogs the area. Can alter water chemistry and oxygen levels. Hinders fish development.
Dotted duckweed	Australia and Southeast Asia	Present in 22 states including Oregon	This small floating plant grows rapidly into dense masses in still water covering the entire surface in a green "bloom".
Purple loosestrife	Eurasia	Present in all states except Hawaii and Alaska Also found in Canada.	Loosestrife is able to rapidly establish and replace native vegetation with a dense, homogeneous stand that reduces local biodiversity, endangers rare species and provides little value to wildlife.
Eurasian water-milfoil	Europe and North Africa	Present in 46 states including Alaska	Found in a variety of habits, becoming established in both impoundments and natura waters, sometimes brackish water or in clear, cool, spring-fed rivers. Problems include displacement of native vegetation, disruption navigation and recreation by the formation o impenetrable mats, and decreased water flow
Reed Canary grass	Eurasia	All but the southeastern portion of the US including Alaska. Also found in Canada.	Is invading freshwater wetlands and in some places choking channels of small streams. It creeping rhizomes out-compete native grasses leading to less biodiversity.
Japanese knotweed	Great Britain	Sitka Juneau Other Southeast Alaska areas	Spreads rapidly, choking out native plants. Can spread along streambanks, shorelines, and estuaries. Loss of springtime cover and woody streamside vegetation causes destabilized stream banks and less woody debris in streams.
Foxtail barley	Western North America	Juneau Interior Alaska	Invades salt marsh habitats
Salt marsh cordgrass	Eastern seaboard of the US from Maine to Texas	Has spread to Canada and western US including Washington, Oregon, and California.	Able to trap sediment leading to higher deposition rates. Changes water circulation patterns. Competitive replacement of native plants and impacts native flora and fauna in intertidal zone. Also, decreases production o bottom-dwelling algae, changes bottom-dwelling invertebrate populations, and loss o shorebird foraging areas.
Dense-flowered cordgrass	Chile South America	California	Outcompetes native flora and impacts native fauna. Eliminates foraging habitat for shorebirds and waterfowl. Dense clusters slo the flow of water and increase sedimentation (raising the wetland).
Swollen bladderwort	Southeastern US	Western Washington	Grows in still or slow-moving water and forms dense beds of floating plants. Impacts native plants and animals and water quality.

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-122, March 2006