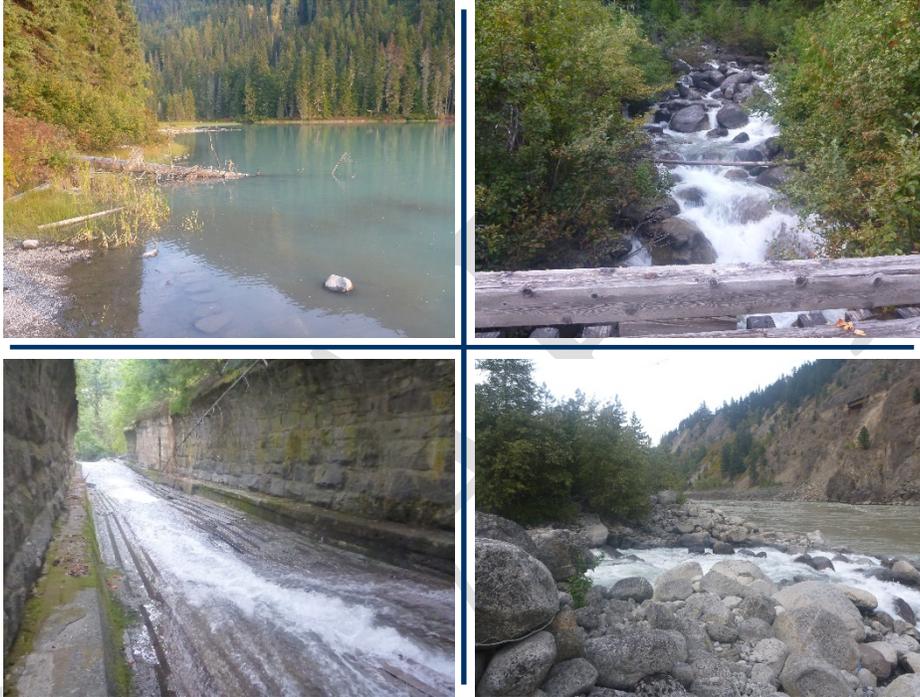


# **Kwoiek Creek Salmon Enhancement Opportunities**

## **Overview Assessment**

### **DRAFT V1**



Prepared for:

**Kanaka Bar Band  
2693 Siwash Road  
Kanaka Bar, BC, V0K 1Z0**

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## EXECUTIVE SUMMARY

Food sovereignty and security are one of the pillars of the Kanaka Bar Band's community vision and form part of their climate change adaptation strategy (Kanaka Bar Band 2018, 2020). Given that Fraser River salmon are a traditional food and that stocks are in decline (Cohen 2012a,b,c), Kanaka Bar Band retained Ecofish Research Ltd. (Ecofish) to identify and assess potential anadromous salmonid enhancement opportunities in the Kwoiek Creek system. This work involved: identifying target species for enhancement, identifying limiting factors to productivity, identifying potential enhancement opportunities, and conducting a high-level assessment of the limitations and relative value of the identified enhancement opportunities.

Existing literature was reviewed to determine occurrence and population status for the species of interest (anadromous salmonids), prioritize target species for enhancement, identify productivity limitations, and identify and gain information from previous enhancement projects. This involved compiling information on fish species currently and historically present in the Kwoiek Creek system and identifying fish habitat values and suitability for individual species and life stages, limiting factors to stream productivity, barriers to fish passage, and stream morphology and stability. This was supplemented with a site visit by an Ecofish field crew in fall 2020.

Kwoiek Creek is a challenging watercourse in which to enhance populations of anadromous salmonids through habitat restoration. The primary limitation is fish access: there is an existing barrier to upstream migration at the flume under the CN Rail bridge and upstream of this are numerous obstacles (cascades) that likely cumulatively form a barrier upstream areas of higher quality spawning and rearing habitat. Only 400 m of stream habitat is accessible to anadromous salmonids downstream of this barrier, and this has a steep gradient that increases engineering complexity and costs of habitat restoration. The next two upstream reaches of Kwoiek Creek are steep and turbulent, with multiple obstacles to fish passage. In the fourth through sixth reaches, habitat quality improves, and it is in these reaches (which include Kwoiek Lake) that a resident Bull Trout (*Salvelinus confluentus*) population is found. Rainbow Trout (*Oncorhynchus mykiss*), the most common species in the Kwoiek Creek system, are present throughout Reaches 1 through 6.

In consideration of habitat access and productivity limitations, behaviour and life history, and existing use of Kwoiek Creek, Coho Salmon (*O. kisutch*) were identified as the priority fish species for enhancement. Spawning and rearing habitat limits the population currently inhabiting the accessible lower 400 m of Kwoiek Creek. Other anadromous species are not recommended for enhancement due to their natural absence or low abundance: only Pink Salmon (*O. gorbuscha*) presence has been confirmed. Steelhead could be enhanced given the presence of the resident form (Rainbow Trout) throughout the watershed, but considering the endangered status in the middle Fraser are not considered an appropriate species for enhancement with the intention to harvest.

Based on the results of a literature review and field visit, 11 potential enhancement opportunities were identified, including access mitigation, off channel habitat development, and a hatchery. A significant increase in habitat productivity and natural production of anadromous salmonids in Kwoiek Creek

will require the mitigation of access limitations. Theoretically this could be achieved with a fishway at the flume and at the sites of obstacles upstream, but the cost will be high. An alternative approach is to transport adult salmon upstream through a trap-and-truck approach, to allow natural spawning, juvenile recruitment, and smolt emigration. This method is cost-effective and provides monitoring and harvest benefits, but may be impaired by mortality during adult transport and smolt downstream migration. Even if access limitations are mitigated, low productivity in the cold, low nutrient, and turbid water will limit fish growth and abundance. Moreover, there is uncertainty in the abundance of anadromous species returning to Kwoiek Creek and success of upstream habitats colonization. If the trap and truck program is of interest, we recommend a feasibility assessment to quantify habitat productivity in the upstream reach and confirm the target species/stocks. If a trap and truck program was advanced following feasibility assessment a pilot study with Coho Salmon being introduced into high quality upstream habitat (e.g. the constructed offsetting habitat in Reach 4) would allow success of smolt production to be measured, prior to expanding the program.

In Reach 1, presently accessible to anadromous fish, restoration of relic channels would provide spawning and rearing habitat for Coho Salmon. Given the short length of this reach (~200 m) these enhancements may not result in large Coho Salmon returns<sup>1</sup>, but could add resilience to the population<sup>2</sup>. Success would depend upon a reliable water source to maintain connectivity to both Kwoiek Creek and the Fraser River.

Other enhancement opportunities include habitat improvement opportunities upstream of the barrier in a number of upper reaches, by enhancing rearing habitat through enrichment and complexing, developing spawning habitat in side channels, and by rehabilitating logging impacts. Again, these habitat improvement options would may be of little value to anadromous fish if access limitations are not mitigated.

If the primary goal of enhancement is to provide fish as a food source for the community of Kanaka Bar Band, a hatchery may be the most feasible enhancement options. However, constraints should be carefully considered, as the cold, turbid water in Kwoiek Creek may limit incubation survival and growth at an on-site hatchery, unless groundwater is available in adequate quantity and acceptable quality. Partnership with a nearby hatchery may be a cost effective approach, with off-site incubation and rearing of Kwoiek salmonids and subsequent imprinting of reared fry in a holding pool at Kwoiek Creek, Feasibility assessments are required to confirm that these opportunities are viable given biological and economic constraints. The regulatory feasibility of each option must also be assessed, as permits and licenses will be required to implement the opportunities.

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<sup>1</sup>Current numbers of Coho Salmon returns to Kwoiek Creek are unknown, but are likely on the order of tens of fish.

<sup>2</sup> Kwoiek Creek forms part of the Fraser Canyon conservation unit; an identified limiting factor of this population is that it has only one major spawning stream (the Nahatlatch River).

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## 1. INTRODUCTION

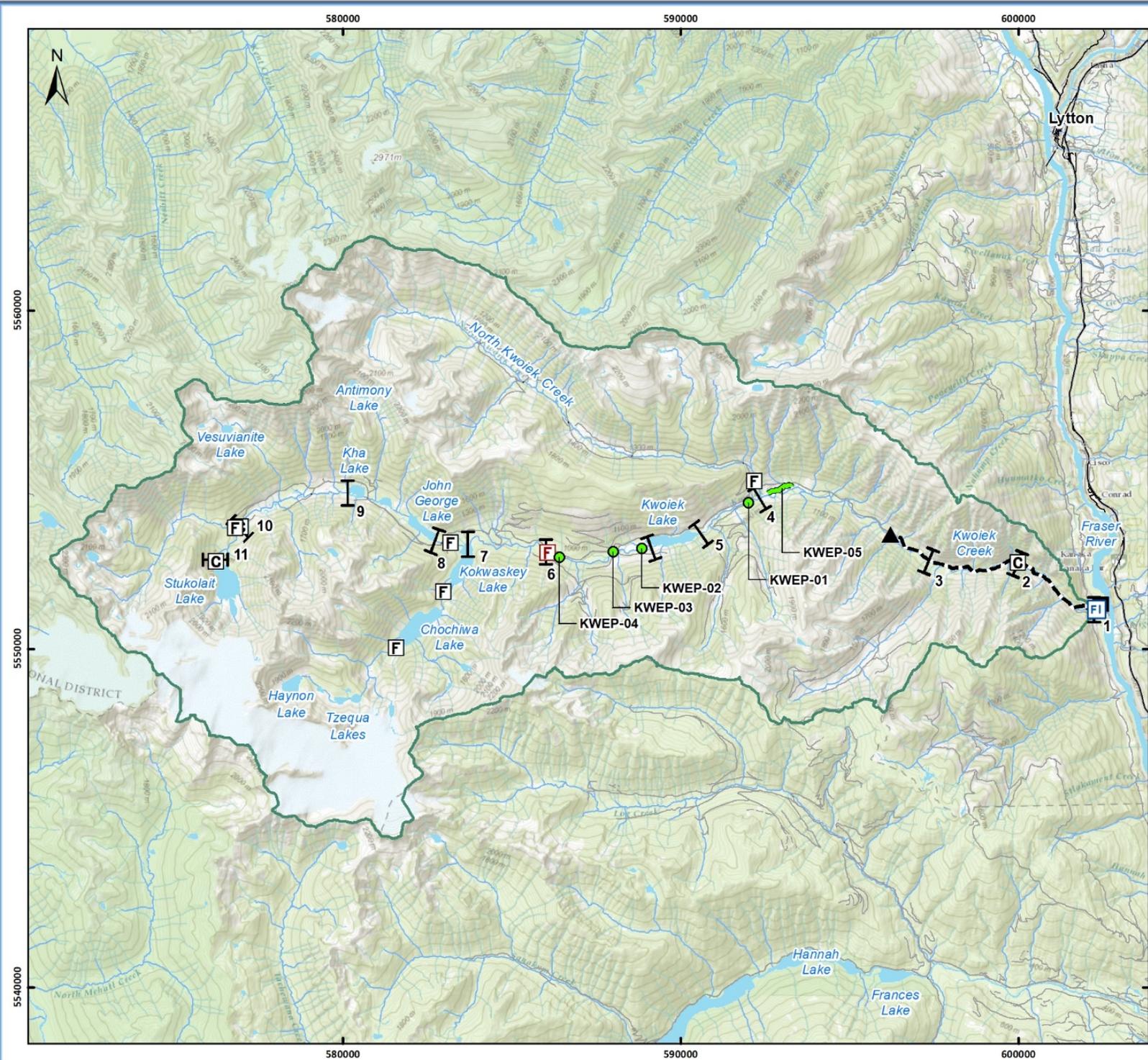
Food sovereignty and security (Figure 1) are one of the pillars of the Kanaka Bar Band's community vision and form part of their climate change adaptation strategy (Kanaka Bar Band 2018, 2020). Fraser River salmon are a traditional food for the Kanaka Bar Band and stocks are in decline (Cohen 2012a,b,c). One of the Kanaka Bar Band's goals is to have healthy salmon stocks available for future generations of their membership, as well as providing food security in the short term (Michell 2020, pers. comm.). Thus, they are looking for enhancement opportunities for anadromous salmonids (Pacific salmon and steelhead) in their territory, specifically in Kwoiek Creek (Map 1).

Kanaka Bar Band retained Ecofish Research Ltd. (Ecofish) to identify and assess potential salmon enhancement opportunities in the Kwoiek Creek system. This work involved:

- Identifying target species of anadromous salmonids for enhancement;
- Identifying limiting factors to productivity of target species in the Kwoiek Creek watershed;
- Identifying potential enhancement opportunities that would address one or more of the identified limiting factors; and
- Conducting a high-level assessment of the limitations and relative value of the identified enhancement opportunities.

**Figure 1 Kanaka Bar Food Forest, from Kanaka Bar Band (2020).**





## KWOIEK CREEK Project Overview

- Legend**
- Previous Enhancement Projects\*
  - Kwoiek Creek Hydroelectric Offsetting
- Barriers to Fish Passage**
- F Falls
  - FI CP Flume
- Obstacles to Fish Passage**
- C Cascade
  - F Falls
  - Reach Breaks
- Infrastructure**
- Kwoiek Creek Hydroelectric Project**
- ▲ Intake
  - Powerhouse
  - - - Penstock
  - Paved Road
  - · - · - Rough/Loose Road
  - Watershed Boundary

\*Approximate location based on description; neither coordinates nor a map showing locations were provided in Castellias et al. (2001).



**MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES**

0 0.5 1 2 3 4 5 6 km  
Scale: 1:160,000

NO.	DATE	REVISION	BY
1	2020-11-30	1657 Project Overview_3979_20201110	CBA
2			
3			
4			
5			

Date Saved: 2020-11-30  
Coordinate System: NAD 1983 UTM Zone 10N


Map 1

## 2. METHODS

Desktop review was the primary method used for data collection and synthesis, supplemented with a field visit in fall 2020 to collect photos and ground truth habitat characteristics in selected reaches of the Kwoiek Creek system (Kwoiek Creek and Kwoiek Lake). Information for the Kwoiek Creek watershed was reviewed to determine occurrence and population status for the species of interest (anadromous salmonids), prioritize target species for enhancement, identify general productivity limitations, and identify and gain information from previous enhancement projects. The possible historic anadromous reaches of the watershed (see Section 3.1) were studied in greater detail to identify more granular productivity limitations and scope potential enhancement opportunities. Mel Sheng, a fish habitat restoration biologist with 40 years of experience, was also consulted to provide feedback and input on the identified potential enhancement opportunities.

### 2.1. Desktop Review

The Kwoiek Creek system is relatively well-studied, as it benefitted from Forest Renewal BC funding and has been considered for hydroelectric development since the early 1990s, when attendant impact assessment studies began. Monitoring programs are currently ongoing for the Kwoiek Creek Hydroelectric Facility, which began operation in 2014. Existing literature on Kwoiek Creek was reviewed to compile information regarding fish species currently and historically present, fish habitat values and suitability for individual species and life stages, limiting factors to stream productivity, barriers to fish passage, and stream morphology and stability. Also reviewed were examples of previous enhancement activities in Kwoiek Creek, with an eye to factors contributing to success or failure.

Available information was collated to provide a description of the existing environmental setting and to identify potential enhancement opportunities and constraints. Sources included government inventory information, scientific literature, and previous consultant reports. Primary sources are described below.

#### Reconnaissance of Kwoiek Creek, BC Environment Memorandum, August 31, 1994 (Maricle 1994)

BC Environment staff conducted a one-day reconnaissance visit of Kwoiek Creek. A qualitative assessment was made of habitat values and water quality in Kwoiek Creek downstream of John George Lake, John George Lake, Kokwaskey Lake, and Kwoiek Lake. Fish sampling was conducted in Kwoiek Lake and at one location in Kwoiek Creek.

#### Kwoiek Creek Drainage Assessment of Fish Habitat and Production 1995 (Griffith 1997)

BC's Forest Renewal Program funded an assessment of fish habitat and production in the Kwoiek Creek watershed. Over the course of a 15-day field program in October 1995, R.P. Griffith and Associates (Griffith) conducted fish habitat surveys and fish and water quality sampling in Kwoiek Creek and its major tributaries between the confluence with the Fraser River and

Stukolait Lake. A total of seven lakes and eight tributaries were assessed, in addition to the Kwoiek Creek mainstem.

#### Fish Habitat Restoration in the Kwoiek Creek Watershed October 2000 (Castellas *et al.* 2001)

Four habitat restoration projects funded by Forest Renewal BC were completed in 2000. The report produced describes the completed projects, identifies priority restoration sites for 2001, and recommends future sites for consideration by Forest Renewal BC's Restoration Committee.

#### Kwoiek Creek Hydroelectric Project Amended Application for an Environmental Assessment Certificate (Focus 2008)

The Kwoiek Creek Hydroelectric Project received its environmental assessment certificate in 2009. Baseline studies conducted in support of the application included review of previous published and unpublished literature<sup>3</sup> and additional fieldwork<sup>4</sup>. Relevant appendices (reviewed by Ecofish) include traditional use (Douglas 2007), hydrology (Knight Piesold 2008), water quality (Golder 2007a), fish and fish habitat (Golder 2007b), and the instream flow requirements assessment (Focus and ARC 2008).

#### Kwoiek Creek Long-Term Monitoring Plan (Summit 2013, 2015a)

The Kwoiek Creek Hydroelectric Project's long-term monitoring plan (LTMP) includes monitoring programs for mitigation and compensation effectiveness, footprint impact verification, water temperature, stream morphology, fish abundance and behaviour, coastal tailed frogs, water quality, and the terrestrial environment. Ecofish reviewed long-term monitoring results from 2014 through 2018 (Summit 2015b; Associated Environmental 2016, 2017, 2018, 2019), as well as preliminary monitoring data from 2020 (Ecofish unpublished data).

### 2.2. Field Program

An Ecofish field crew visited Kwoiek Creek between September 30 to October 1, 2020, to conduct a reconnaissance survey and collect target site photographs. The trip was opportunistic, combined with field visits conducted for the Kwoiek Creek Hydroelectric Project 2020 LTMP field program, and as a result occurred before the desktop review was complete.

Efforts were focused on Kwoiek Lake and Reach 1 of Kwoiek Creek downstream of Kwoiek Lake. The crew looked for areas of groundwater recharge and historic side channels and evaluated indicators of constructability such as channel stability and ease of machine access. Observations and waypoints of sites of interest were recorded and photographs were taken. The information collected, along with

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<sup>3</sup> The fish and fish habitat baseline report (Golder 2007b) for the environmental assessment referenced five unpublished studies and three years of raw data not publicly available. As Golder's review of this information was thorough, we have not attempted to obtain copies and relied on Golder's review for these studies.

<sup>4</sup> Additional fieldwork was conducted for some disciplines (e.g., water quality, instream flow requirements) but not for fish and fish habitat.

photographs and results collected directly for the LTMP, aided in the office assessment by a qualified biologist of biological and physical limitations to productivity and suitability for enhancement projects.

### 3. RESULTS

Unless specifically noted, the results described below are sourced from the desktop review.

#### 3.1. Existing Aquatic Environment

##### 3.1.1. Overview

Kwoiek Creek (watershed code 100-180900) is a fourth order tributary to the Fraser River (Figure 2), draining a watershed of approximately 280 km<sup>2</sup>. Upper tributaries are steep, originating in high elevation snowfields and glaciers. Kwoiek Creek's middle reaches plateau (typically <3% gradient), before dropping steeply (~7% gradient) to the Fraser River. Kwoiek Creek has four main tributaries: Cedarbench Creek, North Kwoiek Creek, Chochiwa Creek, and Antimony Creek. The watershed also contains seven named lakes (Kwoiek, Kokwaskey, Chociwa, John George, Kelpt, Kha, and Stukolait), plus a number of smaller headwater lakes (Map 1). Reach breaks established by Griffith (1997) have been adopted by subsequent studies, and are shown in Map 1.

Flows in Kwoiek Creek from May through August are consistently high, and the low flow period occurs in the winter from November through March (Focus and ARC 2008). Kwoiek Creek is characterized by flashy flows and extremes between peak and low flows<sup>5</sup> and channel morphology is frequently altered by snow avalanches and mudflows. These attributes, combined with glacial runoff, result in relatively turbid water, except in winter when glacier-melt inputs diminish. The glacial melt influence on Kwoiek Creek also produces lower temperatures and reduced nutrient concentrations than streams predominantly influenced by snowmelt or groundwater (Moore 2006; Golder 2007a; Associated Environmental 2019). Unsurprisingly, primary productivity is low (Golder 2007a,b). Climate change will alter Kwoiek Creek's hydrograph in the future, as glacial inputs diminish and a greater proportion of winter precipitation falls as rain rather than snow (Knight Piesold 2008).

Currently, the flume beneath the CP Rail Bridge at the top of Reach 1 limits the upstream migration of anadromous fish. The fisheries literature records no presence of anadromous fish upstream of this point, although access must have existed decades or centuries in the past, given the upstream presence of trout and char. A large natural waterfall barrier (7.5 m high) is located in Reach 6 upstream of Kwoiek Lake, and reaches 2 and 3 have numerous potential barriers.

Upstream of the flume, Rainbow Trout (*Oncorhynchus mykiss*) are distributed throughout most of mainstem Kwoiek Creek<sup>6</sup>. A small adfluvial population of Bull Trout (*Salvelinus confluentus*) is also present upstream of the flume, concentrated primarily in Kwoiek Lake and in Reaches 5 and 6.

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<sup>5</sup> The possible range of flows are from 0.44 m<sup>3</sup>/s to 31.67 m<sup>3</sup>/s at the Kwoiek Creek Hydroelectric Project intake, according to hydrological modelling (Knight Piesold 2008).

<sup>6</sup> All reaches except Reach 11 (Griffith 1997).

Evidence suggests that Bull Trout mature and overwinter in the lake, and spawn and rear in the adjacent reaches of Kwoiek Creek (Griffith 1997; Golder 2007b). Downstream of the flume, Bull Trout, Rainbow Trout (steelhead), and Coho Salmon (*O. kisutch*) and Pink Salmon (*O. gorbuscha*) have been documented in Kwoiek Creek (Griffith, Golder 2007b, Faulkner *et al.* 2014). Traditional knowledge accounts indicate that Chinook Salmon (*O. tshawytscha*) and Sockeye Salmon (*O. nerka*) were also once present in the watershed (Castellas *et al.* 2001).

As the species of interest for potential enhancement are anadromous salmonids, we have identified potential enhancement opportunities on the (potential) historic anadromous reaches of Kwoiek Creek, i.e., Reaches 1 through 6, including Kwoiek Lake (Map 1). Golder (2007b) provides an excellent description of habitat in these reaches, summarized below. It should be noted that the sources for much of the description below are studies conducted in the 1990s and early 2000s (Maricle 1994; Griffith 1997; Castellas *et al.* 2001), and some morphological features may have changed since that time, particularly given the dynamic nature of Kwoiek Creek. Also, the Kwoiek Creek Hydroelectric Project diverts water from the lower portion of Reach 4, returning it to the stream in Reach 1 (Map 1). Thus, habitat attributes in this area will reflect the current reduced flows rather than the time period when much of the information presented below was gathered.

**Figure 2. Looking upstream at the Fraser River at Kwoiek Creek on October 1, 2020.**

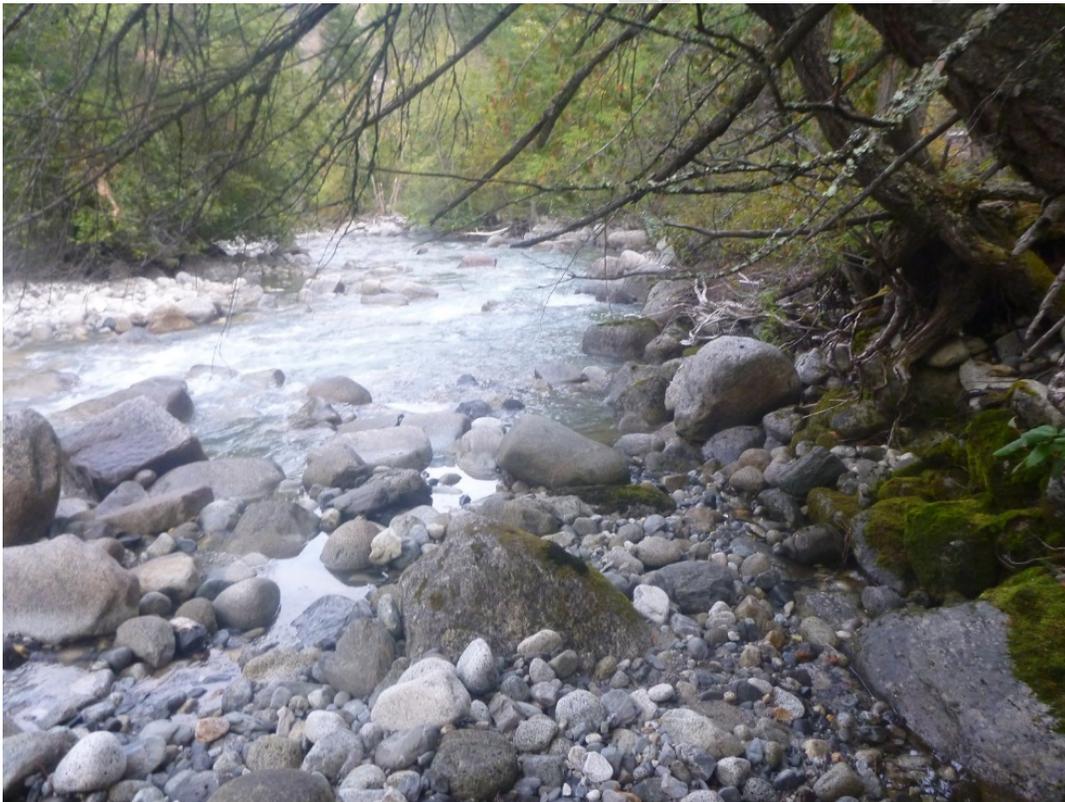


### 3.1.2. Reach 1

Reach 1, the 400 m stretch between the Fraser River and the CPR railway flume (km 0.0 to 0.4), is the current anadromous reach of Kwoiek Creek. At its mouth, Kwoiek Creek flows through an alluvial fan within the low gradient floodplain of the Fraser River. Substrate in this area consists of boulders, cobbles, and gravels (Figure 3).

Focus and ARC (2008) noted that connectivity through this area is poor during low flows in either Kwoiek Creek or the Fraser River. Above the alluvial fan, gradient steepens (average 7-10%) and hydraulic conditions become fast, turbulent, and dominated by rapids. The channel in this area is approximately 15 m wide. Rearing potential for both juveniles and adults is limited, and there is little viable spawning habitat. The left bank<sup>7</sup> of Reach 1 is stable and confines the channel, whereas the right bank is highly dynamic, and has several ephemeral side channels. These side channels potentially provide suitable spawning and rearing habitat for salmonids, although connectivity and water levels may constrain use of these habitats.

**Figure 3. Facing upstream in Reach 1 of Kwoiek Creek on October 1, 2020.**



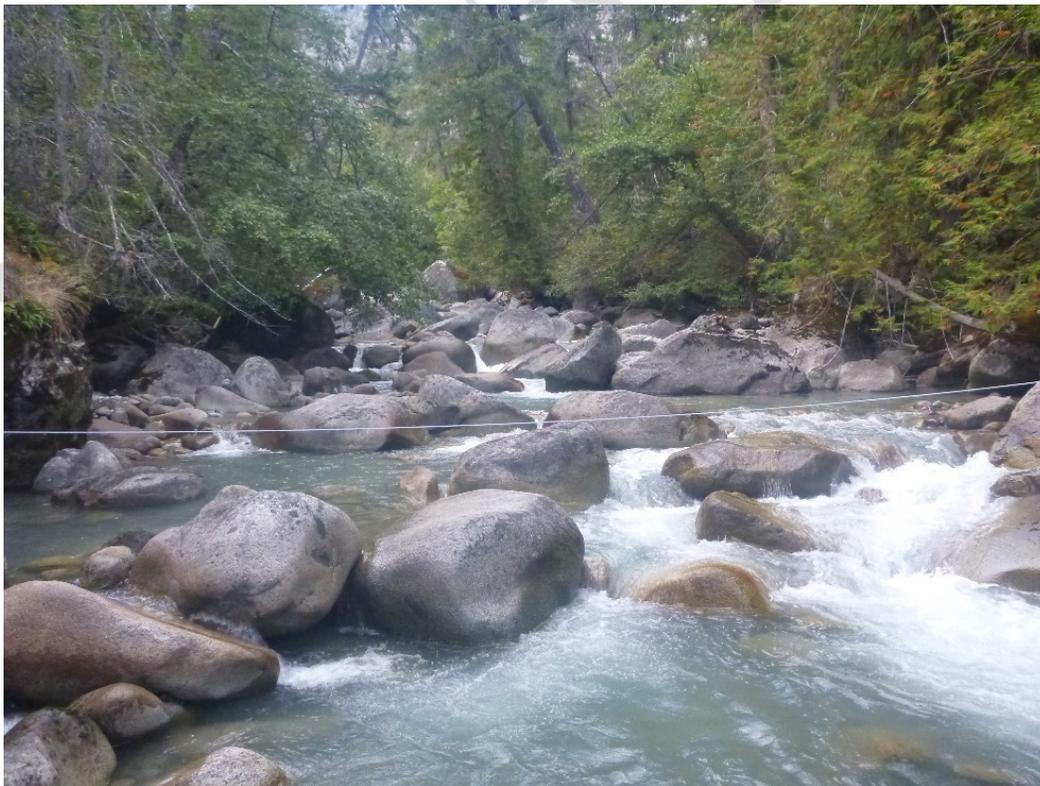
<sup>7</sup> “Left bank” and “right bank” refer to perspective facing downstream.

### 3.1.3. Reach 2

Reach 2 (Figure 4) extends upstream of the flume beneath the CP Rail Bridge to a series of cascades that pose a barrier to upstream fish migration, at least for smaller individuals, at low flow levels (km 0.4 to 3.4). At high flows, a stepped bypass channel (11 m channel width) may allow fish passage past the cascades<sup>8</sup>. This bypass channel contains good quality salmonid spawning and juvenile rearing habitat at its upstream end, along with more abundant pool habitat than the adjacent mainstem. Focus and Arc (2008) also identified an area of cascades and waterfalls 50 - 100 m upstream of the flume that may block upstream fish passage. In addition to these individual features, Reach 2's steep gradient (average 8%) suggests impassability to upstream migrating salmonids. Upstream migration has been shown to be impacted by the cumulative effect of multiple, small, partial barriers: this was demonstrated in a recent evaluation of steelhead upstream migration success using the frequency of migratory genomic markers in California (Apgar 2017).

Reach 2 has an average channel width of 13 m and is moderately confined, consisting of a series of step pools. Pools are somewhat more abundant than in Reach 1, providing limited rearing and holding habitat for juvenile and adult fish. Gravel is less abundant than in Reach 1, although gravel accumulations in high-water gravel braids may offer spawning potential during spring high flows.

**Figure 4. Facing upstream in Reach 2 of Kwoiek Creek, on September 22, 2020.**



<sup>8</sup> Based on the photos provided in Griffith (1997), adult Coho Salmon could potentially traverse this side channel.

#### 3.1.4. Reach 3

Reach 3 extends from the cascades at the upstream end of Reach 2 to a series of waterfalls (km 6.4 to 12.9)<sup>9</sup>. Similar to reaches 1 and 2, flows are swift and turbulent (Figure 5). Average gradient is 8.5%, which, given the length of the reach, suggests impassability to upstream migrating salmonids. Average channel width is 13 m. Unlike Reaches 1 and 2, the channel is only moderately confined, with an active floodplain approximately two to three times the bankfull width. Kwoiek Creek in this reach consists of a series of step-pools, although there are fewer pools than in the two previous reaches. Spawning gravel is very limited, and rearing potential is low for both juveniles and adult salmonids.

**Figure 5. Facing upstream in Reach 3 of Kwoiek Creek, on September 19, 2020.**



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<sup>9</sup> The literature reviewed does not specify if these falls are passable, but unlike other cascades and falls described in Kwoiek Creek, they are not mentioned in discussions of fish passage. We have assumed that fish can pass these falls.

### 3.1.5. Reach 4

Reach 4 extends from the waterfalls at the upstream end of Reach 3 to the confluence of North Kwoiek Creek and Kwoiek Creek (km 6.4 to 12.9). Reach 4 has a considerably lower gradient than downstream reaches, averaging 2.2%. The channel is unconfined, and meanders across its floodplain, with riffle-glide and riffle-pool morphology (Figure 6). Average channel width is 16 m, with the floodplain over six times the bankfull width. While pool habitat is limited, habitat suitability for juvenile fish rearing is considerably higher than in downstream reaches, particularly at the downstream end. Spawning habitat, while still relatively limited (2%) is also more abundant in this reach than in downstream reaches. The upper end of Reach 4 has a large, complex area of side-channels, ponds, and pools (side channel complex) on the left bank of the mainstem that provides good quality salmonid rearing and spawning habitat, and important velocity refugia during high flows. However, this area has experienced negative effects from logging (e.g., sedimentation, stream aggradation). Several similar but smaller side-channel complexes are also present elsewhere in the reach.

**Figure 6. Facing across and upstream in Reach 4 of Kwoiek Creek, on September 22, 2020.**



### 3.1.6. Reach 5

Reach 5 extends from North Kwoiek Creek to the outlet of Kwoiek Lake (km 12.9 to 15). The majority of this reach has an average gradient of 5.5%, with a moderately confined channel (average 18 m wide) and riffle-glide morphology (Figure 7). Water depth and abundant cover provide the best rearing habitat of any of the mainstem reaches downstream of Kwoiek Lake, and the most abundant spawning habitat (6.3% of wetted area). The uppermost 100 m of Reach 5 is steep (4-7%) and bedrock-confined, with step-pool morphology providing good quality rearing habitat for juvenile and adult fish, but very limited spawning habitat. Like many other reaches of Kwoiek Creek, Reach 5 was surrounded by multiple clearcuts and showed evidence of forestry-related impacts when surveyed twenty years' ago.

**Figure 7. Kwoiek Creek mainstem, lower Reach 5, from Griffith (1997) from October 1995.**



### 3.1.7. Kwoiek Lake

Kwoiek Lake (km 15 to 16.3) is a shallow glacial lake (Figure 8) with a surface area of 29 hectares. Griffith (1997) estimated that almost 16% of the lake is less than 2 m deep (maximum depth is 6.7 m, mean depth is 3.6 m), with the shallowest area located at the western (upstream) end of the lake near the Kwoiek Creek inlet. This shallow western area has a mud substrate colonized by sedges and rushes; the remainder of the lake's substrate is dominated by sand and silt, with numerous large boulders. The lake's shoreline is dominated by angular cobble/boulder rubble, except at the shallow western end where the lake transitions into a wetland area. Very little submerged vegetation is present except at the

western end, and low to moderate amounts of woody debris are present around the lake's perimeter. Cold temperatures and glacial till sedimentation likely limit primary productivity. This has not been verified through sampling in the lake; however, water quality, chlorophyll a, and benthic invertebrate sampling in sites in Kwoiek Creek both up- and downstream of the lake show low stream productivity (Focus and ARC 2008).

**Figure 8. Facing northwest from the southwest corner of Kwoiek Lake on September 30, 2020.**



### 3.1.8. Reach 6

Reach 6 extends from Kwoiek Lake to the upstream-most of two sets of waterfalls (km 16.3 to 19.7). These upstream falls are 7.5 m high, near-vertical, and present a definite barrier to all upstream fish passage. The gradient of Reach 6 increases in an upstream direction. The bottom section of the reach provides excellent rearing habitat for both adult and juvenile fish, with abundant cover, low gradients, and extensive off-channel habitat (Figure 9). Abundant spawning habitat for both spring and fall spawners is also present in side-channels. The upstream portion of Reach 6 is characterized by boulder-dominated rapids that may provide good cover for large fish but contains little spawning gravel. A bypass channel around the first set of falls also provides some spawning and juvenile rearing habitat.

**Figure 9.** Side channel in Reach 6 of Kwoiek Creek, from Griffith (1997) from October 1995.



### 3.2. Target Species

Kanaka Bar Band are interested in enhancement opportunities for all five Pacific salmon species, and steelhead, in Kwoiek Creek. Freshwater life history requirements for each of these species are described below, along with descriptions of threats, local population status, and an evaluation of their potential to benefit from enhancement.

#### 3.2.1. Coho Salmon

As noted in Section 3.1.1, Coho Salmon are currently spawning and rearing downstream of the CP Rail bridge and, prior to the flume's installation, were known to travel further upstream. Kwoiek Creek forms part of the Fraser Canyon Coho Salmon conservation unit (CU)<sup>10</sup> (PSF 2020), which in turn is part of the Coho Salmon: Interior Fraser population Designatable Unit (DU). The Interior Fraser population has been listed as Threatened by the Committee on the Status of

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<sup>10</sup> A CU is defined as “a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within an acceptable timeframe” (DFO 2008). DUs are units of a taxonomic species, whereby the unit is important to the evolutionary legacy of the species, and likely could not be replaced by natural dispersion (COSEWIC 2017b). While these definitions are similar, CUs are more granular than DUs (i.e., there may be multiple CUs within a single DU) although they do not always perfectly overlap.

Endangered Wildlife in Canada (COSEWIC), and is currently under consideration for addition to Schedule 1 of the *Species at Risk Act* (SARA) (Government of Canada 2021).

A number of threats to freshwater habitat have been identified for the Interior Fraser DU related to invasive species, drought, increased water temperatures, land use, and increased urbanization (COSEWIC 2016). The Fraser Canyon CU in particular is vulnerable because the Nahatlatch River is the only major spawning location (Decker *et al.* 2014; DFO 2015). Expanding the habitat range for Coho Salmon in Kwoiek Creek would increase resilience for this CU.

Interior Fraser Coho Salmon spawn during fall and early winter, emerging the following spring and remaining in freshwater to rear for a year before migrating to the ocean as smolts. Spawning habitat is often located at the head of riffles in small streams, and in side channels of larger rivers, where water is shallow (< 30 cm), rocks and gravel are less than 15 cm diameter, and there is good circulation of well-oxygenated water. Winter stream flow and temperature are instrumental in egg survival, favouring lake-headed systems and areas of groundwater input. Fry utilize side channels and small tributaries, with low gradients and velocities.

Given their presence and history in Kwoiek Creek, Coho Salmon are a priority target species for enhancement.

### 3.2.2. Chinook Salmon

Kwoiek Creek has not been identified as belonging to any Chinook Salmon CUs, although traditional knowledge indicates that Chinook Salmon were once present (Section 3.1.1). Kwoiek Creek is located between the Middle Fraser River (Spring 5-2) CU / Middle Fraser River Stream Spring (MFR+GStr) (in the Stein River watershed) and the Fraser Canyon-Nahatlatch (Spring 5-2) CU / Middle Fraser River Stream Spring (FRCany+GStr) DU (in the Nahatlatch River watershed). Both of these DUs have been listed as Threatened by COSEWIC and are currently under consideration for addition to Schedule 1 of SARA. Identified threats to freshwater habitat are similar to those for Coho Salmon, and include climate-change related impacts (i.e., timing of freshet, increased water temperature), land use and development, and mining impacts (ECCC 2019).

Chinook Salmon are highly variable and plastic in their freshwater habitat preferences, but generally spawn in moderate to large streams, with a preference for deep, low gradient areas, moderate depth and flow, and large substrate (McPhail 2007; ECCC 2019).

As a population of Chinook Salmon has not yet been confirmed to use Kwoiek Creek (Section 3.1.1), they should, at least initially, be a secondary target species for enhancement.

### 3.2.3. Sockeye Salmon

Sockeye Salmon strays also may occasionally be present in Kwoiek Creek (Section 3.1.1). Kwoiek Creek is located immediately north of the described range of the Nahatlatch-Early Summer CU / Nahatlatch-ES population, listed as Special Concern by COSEWIC and currently under consideration for addition to Schedule 1 of SARA. Identified threats to freshwater habitat include

forestry-related impacts (e.g., sedimentation, road crossings), reduced flows, and warming water temperatures (COSEWIC 2017a).

Sockeye Salmon typically rear in lakes, although there are many exceptions. River-type Sockeye Salmon prefer low-gradient slough and backwater or off-channel areas for rearing. They tend to spawn along gravelly lake shoals or in lake inlet or outlet streams, in areas of groundwater upwelling. Spawning areas typically have low to moderate flows, clean gravel, and range in depth from 0.3 to 9.2 m (McPhail 2007; COSEWIC 2017a).

As a population of Sockeye Salmon has not been confirmed to use Kwoiek Creek and given their habitat requirements a consistent run is unlikely, they should be a secondary target species for enhancement.

#### 3.2.4. Pink Salmon

Kwoiek Creek is situated within the Fraser River (odd) Pink Salmon (*O. gorbuscha*) CU. A single Pink Salmon adult was observed in Reach 1, approximately 150 m upstream of the Fraser River, in late August of 2013 during studies associated with the Kwoiek Creek Hydroelectric Project (Faulkner *et al.* 2014) but there is no history of a population in Kwoiek Creek.

Pink Salmon prefer to spawn in the lower reaches of streams and rivers and tend to avoid obstacles. Spawning usually occurs in or near riffles with low to moderate flows and clean gravel, in depths from 0.3 to 1 m. Fry begin downstream migration towards the estuary immediately after emergence (McPhail 2007; VIU 2009).

As a population of Pink Salmon has not yet been confirmed to use Kwoiek Creek, they should, at least initially, be a secondary target species for enhancement.

#### 3.2.5. Chum Salmon

Chum Salmon (*O. keta*) typically spawn within 200 km of the coast, although individuals occasionally travel up the Fraser River as far as the Bridge and Thompson Rivers (McPhail 2007). There is no history of Chum Salmon presence in Kwoiek Creek.

Chum Salmon prefer to spawn in gravel riffles with water velocities <0.8 m/s, preferably in areas of groundwater upwelling. Like Pink Salmon, Chum Salmon fry begin downstream migration towards the estuary immediately after emergence (McPhail 2007).

As Chum Salmon are unlikely to be present in the adjacent reach of the Fraser River, we recommend focusing habitat enhancement actions on other anadromous species.

#### 3.2.6. Steelhead

Steelhead have been reported in the lower reaches of Kwoiek Creek (Griffith 1997), although this has not been confirmed with site-specific spawner studies<sup>11</sup>. Steelhead travel the Fraser River to confirmed

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<sup>11</sup> Steelhead presence can be difficult to confirm, as juvenile steelhead and Rainbow Trout cannot be differentiated through field observations.

spawning areas higher up in the watershed, and two populations (the Thompson River and Chilcotin River DUs) were recently designated as endangered by COSEWIC during an emergency assessment (COSEWIC 2018).

Steelhead spawn in moderate to high gradient sections of streams at the head of riffles or the tail end of pools, in areas that have clean gravel and groundwater upwelling, at depths from 0.1 to 1.4 m. Juveniles typically rear in freshwater for two to three years, and display various habitat preferences (e.g., tributary stream, side channel, mainstem, lake) depending on size (McPhail 2007; VIU 2009).

As a population of steelhead has not yet been confirmed to use Kwoiek Creek, they should, at least initially, be a secondary target species for enhancement. Steelhead are likely to benefit from juvenile rearing habitat developed with Coho Salmon in mind.

### 3.3. Productivity Limitations

Good quality spawning habitat for salmonids in Kwoiek Creek is rare, due to high velocities and a lack of gravel, with the exception of the lower end of Reach 6 (Griffith 1997; Golder 2007b). Adequate holding areas for adult fish (i.e., deep and moderately complex pools) are available in Reaches 1 through 6, but little high flow refuge is present for juveniles. Further, during low flows in the Fraser River and/or in Kwoiek Creek, access by Coho Salmon (and other large salmonids) may be limited.

Cold water, low nutrients, high flow velocities and scour, and high turbidity during the summer growing season all limit primary productivity in Kwoiek Creek. Nutrient concentrations, chlorophyll a levels, and benthic invertebrate abundance were all low when measured during baseline studies for the Kwoiek Creek Hydroelectric Project (Focus and ARC 2008).

Previous studies have attempted to quantify productivity in the Kwoiek Creek system in terms of carrying capacity for fish. Griffith (1997) used hydraulic suitability metrics and sampling results to conclude that juvenile abundance (of Rainbow Trout) below Kwoiek Lake was at or above carrying capacity estimates; below the flume Coho Salmon juveniles were above carrying capacity. Focus and ARC (2008) based their calculation of carrying capacity on Ptolemy's (1991) method using water quality parameters; captured fish densities in 2007 were at or above the calculated carrying capacity.

For anadromous species a substantial limitation to productivity is access, which is limited by distinct barrier and high gradients.

### 3.4. Previous Enhancement Projects

FRBC funded a number of restoration projects in the watershed in 2000 (Map 2<sup>12</sup>), which mostly involved repair of logging impacts (Castellas *et al.* 2001). Castellas *et al.* (2001) recommended that effectiveness monitoring of these restoration projects occur in 2001, along with construction or feasibility assessment of a number of additional identified restoration projects, but we were unable to locate documentation as to whether these recommendations were implemented. Additional fish habitat enhancement in the Kwoiek Creek watershed occurred in 2013, when fish habitat compensation associated with the Kwoiek Creek Hydroelectric Project's *Fisheries Act* Authorization 00-HPAC-PA1-00177 was constructed. Effectiveness monitoring of this compensation project is currently underway as part of the LTMP (NHC 2011, 2014; Summit 2013).

Previous enhancement projects were intended to benefit resident fish species (i.e., Bull Trout and Rainbow Trout) but include features that would also benefit other salmonids, if present. A review of the siting, methods, and successes or failures of these projects provides meaningful information for scoping future projects targeting anadromous salmonids. A summary of previous enhancement projects in the Kwoiek Creek watershed is provided below, described by reach. It should be noted that effectiveness monitoring information was only available for one of these projects (see Section 3.4.2).

#### 3.4.1. Reaches 1 Through 3

We found no records of previous enhancement projects in Reaches 1 through 3.

#### 3.4.2. Reach 4

In 2013, the side channel complex located along the left bank in the upper end of Reach 4 (see Section 3.1.5) was partially developed into a compensation project for the Kwoiek Creek Hydroelectric Project. The constructed habitat is fed via an intake in the Kwoiek Creek mainstem, and consists of a series of alternating meandering riffles and pools that provide spawning, rearing and overwintering habitat for Rainbow Trout and Bull Trout (NHC 2011, 2014). The compensation site is located in one of the areas previously recommended by FRBC for restoration work (Castellas *et al.* 2001), and is shown in Maps 1 and 2 as KWEP-05.

Effectiveness monitoring has been conducted in 2014, 2015, 2016, 2018 and 2020, with a final year of monitoring scheduled for 2023. To date, the constructed habitat appears to be successful. It has been well-used by fish (mostly juvenile Rainbow Trout) since monitoring began in 2014, and habitat features are stable. Riparian plantings have established relatively well, although some competition from other species and some limited animal impacts have been observed (Summit 2015b; Associated Environmental 2016, 2017, 2019; Ecofish unpublished data).

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<sup>12</sup> Approximate locations were based on descriptions in Castellas *et al.* (2001); neither coordinates nor a map showing locations were provided.

**Figure 10. Kwoiek Creek Hydroelectric Project compensation habitat, September 18, 2020.**



#### 3.4.3. Reach 5

In autumn 2000, FRBC removed a partially collapsed bridge and associated debris jam, and widened and stabilized the stream channel to its historic width and added large woody debris and boulder complexing in the immediate vicinity of the collapsed bridge. Fish sampling two days after project completion showed use by Bull Trout of created back eddy pool habitat (Castellas *et al.* 2001). This site is described as K1 in Castellas *et al.* (2001) and is shown in Map 1 and Map 2 as KWEP-01.

#### 3.4.4. Kwoiek Lake

We found no records of previous enhancement projects in Kwoiek Lake.

#### 3.4.5. Reach 6

A large section of Reach 6 was identified as suffering from channel aggradation due to upslope forestry impacts<sup>13</sup> during habitat assessments conducted in 1999. As noted in Section 3.1.8, the lower end of

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<sup>13</sup> Multiple reports from the late 1990s and early 2000s describe forestry impacts to Kwoiek Creek, including channel aggradation, mass wasting, and cut blocks extending down to top of bank (Maricle 1994; Griffith 1997; Castellas *et al.* 2001). To some degree these impacts have lessened over time, due to revegetation and improved

this reach has extensive off-channel habitat and contains some of the best quality rearing and spawning habitat in Kwoiek Creek, likely providing a major role in Bull Trout recruitment (Griffith 1997). In autumn 2000, FRBC rehabilitated a relic side channel the inlet end of which had been blocked by mainstem channel aggradations. This side channel was located on the left bank of Kwoiek Creek, immediately upstream of Kwoiek Lake. Approximately 100 m of the relic side channel were excavated and complexed with two pools and large woody debris placement. This created 240 m<sup>2</sup> of complex rearing habitat for Rainbow Trout and Bull Trout (Castellas *et al.* 2001). This site is described as K2 in Castellas *et al.* (2001) and is shown in Maps 1 and 2 as KWEP-02.

At site KWEP-03, described as K3 in Castellas *et al.* (2001), FRBC addressed road fill slope failures. Works were limited to repair of the road and bank and did not include instream fish habitat enhancement.

FRBC removed a collapsed bridge and debris jam at site KWEP-04, described as K4 in in Castellas *et al.* (2001) and located at the top end of Reach 6. Restoration works also included stream widening, construction of a side channel on the right bank of Kwoiek Creek, and complexing with large woody debris and boulders, with associated scour pool formation along the left bank of Kwoiek Creek.

### 3.5. Potential Enhancement Opportunities

We have identified 11 potential enhancement opportunities, based on habitat suitability, previous habitat restoration projects in the watershed, and discussions with Chief Patrick Michell of Kanaka Bar Band (pers. comm. 2020), and with Mel Sheng (pers. comm. 2020) and Sean Bennett (pers. comm. 2020), retired and current restoration biologists with Fisheries and Oceans Canada's Salmonid Enhancement Program. As evaluated in Section 3.2, the primary target species for these enhancement opportunities was identified as Coho Salmon, although other salmonid species would likely benefit as well. **Note that the feasibility of opportunities identified in Reaches 2 through 6 is heavily dependent on overcoming fish passage constraints, and would be of value only to resident fish species if passage cannot be provided.**

Opportunities have been labelled KWEO-01 to KWEO-11 (shown on Map 2). They are described and evaluated by reach in the sections below along with recommendations for future feasibility assessments.

#### 3.5.1. All Reaches

##### *Access Enhancement - Trap and truck (KWEO-01)*

The primary limitation to anadromous fish habitat productivity is access: there is an existing barrier to upstream migration at the flume under the CN Rail bridge and upstream of this are numerous obstacles (cascades) that likely cumulatively form a barrier upstream areas of higher quality spawning

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forestry practices, however their legacy remains in numerous locations and active logging continues to occur in the watershed.

and rearing habitat. Only 400 m of stream downstream is accessible to anadromous salmonids downstream of this barrier, and this has a steep gradient that increases engineering complexity and costs of habitat restoration. The next two upstream reaches of Kwoiek Creek are steep and turbulent, with multiple obstacles to fish passage.

A significant increase in habitat productivity and natural production of anadromous salmonids in Kwoiek Creek will require the mitigation of access limitations. Theoretically this could be achieved with a fishway at the flume and at the sites of obstacles upstream. Restoration of passage through partial barrier mitigation was identified as a cost-effective tool to promote upstream migration for steelhead in California (Apgar 2017), however, considering the gradient, length and confinement of Kwoiek Creek, the cost is likely to be prohibitive. An alternative approach is to transport adult salmon upstream through a trap-and-truck approach, to allow natural spawning, juvenile recruitment, and smolt emigration. A trap could be set up in Reach 1 to capture adult Coho Salmon (or other species that may be present) attempting to migrate through the flume. These fish could be transported to an upstream reach with suitable spawning and rearing habitat (e.g., the constructed offsetting habitat in Reach 4, which contains high quality Coho Salmon rearing habitat; or upper Reaches (5 and 6) and Kwoiek Lake), where juveniles would rear before down-migrating to the Fraser River as smolts. Returning adult fish would be imprinted on Kwoiek Creek and would be expected to congregate in Reach 1 where they could be trapped, enumerated, harvested (if appropriate), and trucked upstream and released to spawn naturally.

A more detailed feasibility study would be required to assess the potential production from this option, which would include assessment of available habitat in the upstream reach for outplanting of adults, and confirming whether anadromous salmonids other than Coho Salmon are using Reach 1 of Kwoiek Creek. If the trap and truck program were to be initiated, a pilot study focussed on Coho Salmon being transported to high quality upstream habitat (e.g. the constructed offsetting habitat in Reach 4) would allow determination of success of smolt production. Depending on the outcome of the pilot study, additional species could also be considered for this program and outplanting of adults could also occur in additional reaches. An assessment of potential interactions with Rainbow Trout and Bull Trout will be a key component of further investigating the feasibility of this option.

#### *Nutrient enhancement (KWE0-02)*

Salmon carcasses provide nutrients, supporting aquatic productivity and the next generation of fish (Slaney and Zaldokas 1997; Reimchen 2017). Nutrient enrichment would increase juvenile productivity in Kwoiek Creek and tributaries given the naturally low nutrients: this technique has been consistently successful in BC (Slaney and Zaldokas 1997). Nutrient enrichment could benefit both natural and restored habitats above and below the migration barrier.

Nutrient enrichment must be developed with care to avoid algal blooms and impacts to water quality. Further assessment of the nutrient status of the target reaches of Kwoiek Creek would be required prior to development of a fertilization strategy. Nutrient enhancement, like trap and truck, would

require ongoing effort and expense. The low temperatures and frequent streambed scouring of Kwoiek Creek may limit the effectiveness of nutrient enhancement; additional study is warranted to determine the potential gains that may result in comparison to the cost and effort.

### 3.5.2. Reach 1

#### *Relic channel restoration (KWE0-03)*

Reach 1 has a number of relic or high water only side channels along the right bank (Figure 11 and Figure 12) that could be deepened, complexed, and better connected to the mainstem of Kwoiek Creek and/or to the Fraser River. This would address the spawning and rearing habitat limitation in Kwoiek Creek for anadromous salmonids, particularly Coho Salmon (Griffith 1997).

The right bank of Kwoiek Creek is easily accessed by existing roads, minimizing the cost and complexity of construction and monitoring. Relic channel restoration in Reach 1 was one of the FRBC's proposed future restoration projects for Kwoiek Creek and their preliminary investigation was favourable, although they identified securing a constant and adequate source of water as a challenge (Castellas *et al.* 2001). Siting an intake in the Kwoiek Creek mainstem would be difficult and costly, given the high energy nature of the watercourse. Water could potentially be sourced from the CP Rail flume.

Future feasibility assessments would include scoping potential water intake locations, monitoring of groundwater levels in the area, and assessment of specific prescriptions for enhancement.

Figure 11. Dry side-channel outlet to Fraser River alluvial fan, on right bank of Kwoiek Creek. September 30, 2020.



**Figure 12. Dry side-channel in Reach 1, on right bank of Kwoiek Creek. September 30, 2020.**



*Access Enhancement - Flume removal (KWE0-04)*

Removing the flume underneath the CP Rail bridge (Figure 13) and replacement with a fishway (natural pass or other), which currently is an anthropogenic barrier to fish passage<sup>14</sup>, would restore the historic range of anadromous fish in Kwoiek Creek. Although this structure has been in place for over 100 years, salmonids (assumed Coho Salmon based on timing, colouration and size) were observed in the fall of 2020 attempting (and failing) to migrate upstream at this location (Figure 14). However, substantial gains in habitat from flume removal would only result if anadromous fish are able to access Reaches 4 through 6, because Reaches 2 through 3 have minimal refuge, spawning, and juvenile rearing habitat and would mainly be used as migration routes. Thus, the passability of mainstem obstructions should in Reaches 2 and 3 should be assessed, including confirmation of overall gradient and the potential for side channels to be used as bypass migration routes. Focus and ARC (2008) identified a

<sup>14</sup> Based on measured velocity and depth in the flume and reported swimming capabilities of salmonids, the flume is an impassable barrier to Pacific salmon. Steelhead may be able to negotiate the velocity but water depth would be a serious deterrent, as would the drop at the bottom of the flume (Castellas *et al.* 2001).

barrier to upstream fish passage 50-100 m upstream of the flume not described in earlier studies, which, if confirmed, would further limit potential habitat gains from flume removal.

Flume removal, and construction of fishway, is likely to be costly given the high gradient and confinement of the site, and the requirement to protect the existing infrastructure (railway crossing). There may be potential for CP to contribute funding to mitigation of this legacy impact. An assessment of potential interactions with Rainbow Trout and Bull Trout will be a key component of further investigating the feasibility of this option.

**Figure 13.** Upstream view of the CP Bridge flume on Kwoiek Creek. September 30, 2020.



**Figure 14.** Fish (likely Coho Salmon) attempting to pass through the flume on Kwoiek Creek on September 30, 2020.



#### *Hatchery (KWE0-05)*

Salmon abundance can be increased through hatchery supplementation, by increasing egg-smolt survival and in turn adult returns. Reach 1 is the best location for hatchery, with accessible flat land. Hatcheries can increase salmon production by increasing survival and growth and avoiding freshwater habitat bottlenecks, and they play an important role in supplementing natural production in the Fraser River and tributaries. However, not all hatchery programs have been successful (Poirier and Olson 2017). Negative consequences of hatchery supplementation are increased risk of disease transfer, genetic diversity loss, low survival, competition with wild fish, and mixed stock fishery effects that increase harvest on wild populations (Riddell *et al.* 2013). However, these risks can be mitigated through staggered releases and other management techniques. A feasibility study is recommended to consider these risks and the effectiveness of mitigation strategies.

Hatcheries need clean water of the appropriate temperature for incubation of the target species. The water in Kwoiek Creek is too cold and too turbid to be optimal for this purpose. Groundwater may be an alternative water source of water, or supplementary source. However, groundwater may also be of insufficient quality (dissolved oxygen, dissolved metals) or suboptimal temperature for egg incubation. Sourcing of an appropriate water supply will be critical in determining the feasibility of a hatchery.

One alternative to constructing a hatchery adjacent to Kwoiek Creek would be to partner with a nearby community in the Fraser River watershed, preferably upstream of Kwoiek Creek<sup>15</sup>, where a hatchery already exists or is planned and a more suitable water source exists. In this case, an imprinting pond could be constructed in Reach 1, sourced by water from the Kwoiek Creek Hydroelectric Project tailrace or an intake at the flume, and smolts could be briefly held in this pond prior to release (Sheng 2020, pers. comm.).

### 3.5.3. Reach 2

#### *High flow bypass channel improvements (KWEO-06)*

Griffith (1997) identified a side channel potentially providing a bypass to the cascades located at the upper end of Reach 2. This side channel also provided higher quality juvenile rearing habitat than did the mainstem. Castellás *et al.* (2001) noted that in the intervening years the channel had been impacted by mass wasting and was flowing only intermittently in the summer of 2000. FRBC recommended rehabilitating this channel to improve fish access to higher quality habitat in upstream reaches, and to enhance rearing and spawning habitat in the channel itself.

### 3.5.4. Reach 3

We have not identified any potential enhancement projects in Reach 3. Kwoiek Creek in this reach is high energy and somewhat confined, with limited opportunities for fish habitat enhancement.

### 3.5.5. Reach 4

#### *Side channel complex improvements (KWEO-07)*

Reach 4 contains a large complex of side channels and ponds that has experienced logging impacts (i.e., contains degraded habitat that could be restored). Given the success of the existing compensation site in Reach 4, it seems probable that building upon the existing site, or implementing similar enhancement efforts in the side channel complex, would prove effective.

### 3.5.6. Reach 5

#### *Lake outlet (KWEO-08) and Rehabilitate logging impacts (KWEO-09)*

Reach 5 currently has good quality habitat (Section 3.1.6), but few enhancement opportunities are evident. The channel is surrounded by relatively steep-sided slopes, limiting room to construct side-channel or back-channel habitat. The exception may be near the outlet of Kwoiek Lake, where there is potentially room to construct rearing habitat (e.g., wetland habitat, side-channel habitat) for Coho Salmon juveniles. Although Reach 5 is of gentler gradient than reaches 2 and 3, it remains high-energy enough to limit the longevity of any in-channel improvements. However, there may be opportunity to repair legacy forestry-related impacts in the mainstem.

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<sup>15</sup> This strategy tends to have more success when the hatchery used to source the smolts is located upstream of the watershed with the imprinting pond.

Reaches 5 through 6 form the core habitat area for Kwoiek Creek's Bull Trout population. Avoiding negative impacts to Bull Trout will need to be a consideration in developing enhancement options in these reaches.

### 3.5.7. Kwoiek Lake

#### *Rearing Sockeye Salmon or kokanee in Kwoiek Lake (KWE0-10)*

There may be opportunity to rear fish (e.g. Sockeye Salmon or kokanee (*O. nerka*)) in Kwoiek Lake. For Sockeye Salmon, this would involve annual trapping of adult fish from the Fraser River or a nearby system and trucking them to Kwoiek Lake (see also trap and truck (KWE0-01)). The adults would then spawn in the lake or adjacent reaches of Kwoiek Creek, with juveniles rearing in the lake before down-migrating to the Fraser River as smolts. Returning adult fish would be imprinted on Kwoiek Creek and would congregate in Reach 1 where they could be fished. Kokanee would be introduced as a potentially self-sustaining population.

High quality spawning habitat for Sockeye Salmon/kokanee is not abundant in the lake or in downstream Reach 5. The upstream Reach 6 potentially has suitable spawning habitat, but this is also critical spawning habitat for the resident Bull Trout population. The glacial-influenced water in Kwoiek Lake is likely cold and has low primary productivity. The lake also provides critical rearing and overwintering habitat for Kwoiek Creek's Bull Trout population. Sockeye Salmon/ kokanee smolts could potentially provide food for adult Bull Trout; juvenile Sockeye Salmon/kokanee may also potentially compete with Bull Trout juveniles for resources. An assessment of potential interactions with Bull Trout will be a key component of further investigating the feasibility of this option.

### 3.5.8. Reach 6

#### *Connectivity and habitat improvements to side channel / wetland complex (KWE0-11)*

Reach 6 has an extensive side channel and wetland complex near the inlet to Kwoiek Lake; this area was the site of a previous FRBC enhancement project (Section 3.4.5) and FRBC identified numerous future restoration opportunities to build upon the work already completed. If trap and truck is implemented, there may be opportunity to provide spawning, rearing, and overwintering habitat to anadromous salmonids through connectivity improvements and complexing of existing features. Reach 6 also has the largest area available where enhancement activities are relatively easy from an engineering standpoint.

Reach 6 provides critical spawning habitat to Kwoiek Creek's Bull Trout population. Avoiding negative impacts to Bull Trout will need to be a consideration in developing enhancement options in this reach.

Next steps in assessing feasibility in developing this option would be effectiveness monitoring of the 20-year old FRBC enhancement project and mapping and assessment of the area to determine current fish use and identify specific opportunities for enhancement activities.

#### 4. SUMMARY AND RECOMMENDATIONS

Kwoiek Creek is a challenging watercourse in which to enhance populations of anadromous salmonids through habitat restoration. The primary limitation is fish access: there is an existing barrier to upstream migration at the flume under the CN Rail bridge and upstream of this are numerous obstacles (cascades) that likely cumulatively form a barrier to upstream areas of higher quality spawning and rearing habitat. Only 400 m of habitat is accessible to anadromous salmonids downstream of this barrier, and this has a steep gradient that increases engineering complexity and costs of habitat restoration. Accordingly, a significant increase in habitat productivity and natural production of anadromous salmonids in Kwoiek Creek will require the mitigation of access limitations. Theoretically this could be achieved with a fishway at the flume and at the sites of obstacles upstream, but the cost will be high. An alternative approach is to transport adult salmon upstream through a trap-and-truck approach, to allow natural spawning, juvenile recruitment, and smolt emigration. Even if access limitations are mitigated, low productivity in the cold, low nutrient, and turbid water will limit fish growth and abundance.

Within Reach 1, with a goal of providing fish as a food source for the community of Kanaka Bar Band, a hatchery may be the most feasible option. However, constraints should be carefully considered, as the cold, turbid water provided by Kwoiek Creek may limit the productivity and success of a hatchery program and it is unknown if groundwater is a suitable alternative water source. Partnership with an established nearby hatchery may be a more successful and cost-effective option.

Restoration of relic channels in Reach 1 may be an effective enhancement. This relic channel restoration would provide spawning and rearing habitat for the Coho Salmon in Kwoiek Creek. The area for enhancement is relatively small (approximately 200 m long, although meander bends could triple the length of a side channel). Moreover, this additional habitat could add resilience to a population (the Fraser Canyon CU), which has only one major spawning stream (the Nahatlatch River). Careful design and adequate feasibility studies to evaluate water sources, constructability, and construction and maintenance costs are recommended to ensure any such project is successful, and that connectivity to both Kwoiek Creek and the Fraser River are maintained.

#### 5. CLOSURE

Overall, Kwoiek Creek is a challenging watercourse in which to increase productivity of anadromous salmonids through habitat enhancement. We have examined options for each reach of the watershed based primarily on literature review. Feasibility assessments are required to confirm that these opportunities are viable given biological and economic constraints. The regulatory feasibility of each option must also be assessed, as permits and licenses will be required to implement the opportunities. We look forward to discussing options further with Kanaka Bar Band.

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### **Personal Communications**

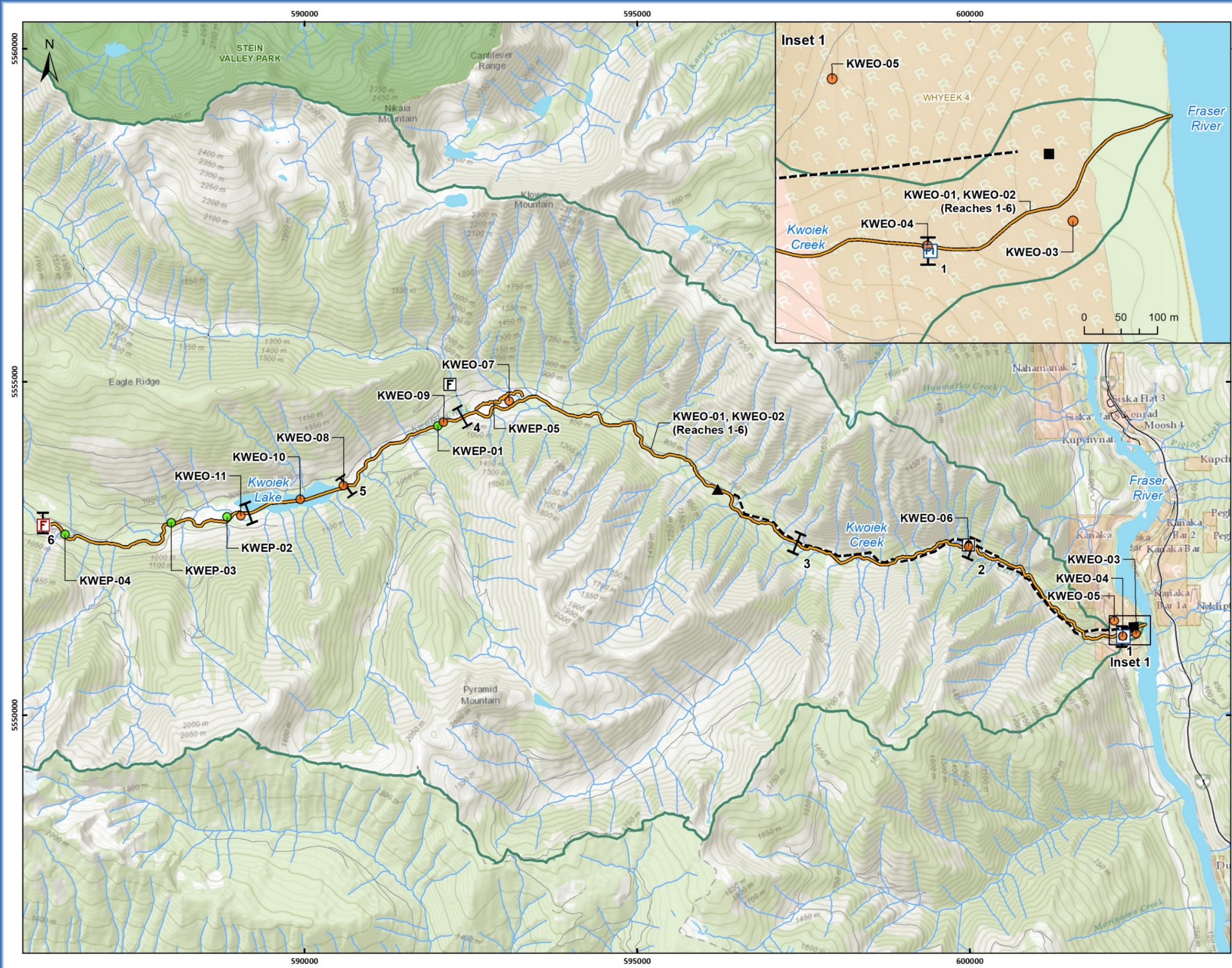
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**PROJECT MAPS**

DRAFT



## KWOIEK CREEK

### Potential Enhancement Opportunities

- Legend**
- Previous Enhancement Projects\*
  - Potential Enhancement Opportunities
  - Potential Enhancement Opportunities
- Barriers to Fish Passage**
- F Falls
  - FI CP Flume
- Obstacles to Fish Passage**
- C Cascade
  - F Falls
  - Reach Breaks
- Infrastructure**
- Kwoiek Creek Hydroelectric Project**
- ▲ Intake
  - Powerhouse
  - Penstock
  - Paved Road
  - Rough/Loose Road
  - Watershed Boundary
  - First Nation Reserve
  - Parks and Protected Areas

\*Approximate location based on description; neither coordinates nor a map showing locations were provided in Castellas et al. (2001).



**MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES**



NO.	DATE	REVISION	BY
1	2021-02-11	1457_PotentialEnhancementOpportunities_3979_20210211	CGA
2			
3			
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Date Saved: 2021-02-11  
Coordinate System: NAD 1983 UTM Zone 10N