SOCIETY FOR ECOSYSTEM RESTORATION IN NORTHERN BRITISH COLUMBIA

Restoring Fish Passage in the Peace Region - 2022 - PEA-F23-F-3761-DCA

Prepared for
Fish and Wildlife Compensation Program
and
Fish Passage Technical Working Group

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on behalf of
Society for Ecosystem Restoration in Northern BC

Version 0.0.1 2023-06-21

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Acknowledgement

Modern civilization has a long journey ahead to acknowledge and address the historic and ongoing impacts of colonialism that have resulted in harm to the cultures and livelihoods living interconnected with our ecosystems for many thousands of years.

1 Background

The study area includes the Parsnip River watershed group (Figure 1.1) and is within the traditional territories of the Tse'khene First Nations.

1.1 Tse'khene

The Parsnip River watershed is located within the south-eastern portion of the 108,000 km^2 traditional territory of the Tse'khene from the McLeod Lake Indian Band. The Tse'khene *"People of the Rocks"* are a south westerly extension of the Athabascan speaking people of northern Canada. They were nomadic hunters whose language belongs to the Beaver-Sarcee-Tse'khene branch of Athapaskan ("History Who We Are" 2023). Extensive work is underway to preserve the language with resources such as First Voices available online and in app form for iphone and ipad devices.

The continental divide separates watersheds flowing north into the Arctic Ocean via the Mackenzie River and south and west into the Pacific Ocean via the Fraser River (Figure 1.1). The Parsnip River is a 6th order stream with a watershed that drains an area of 5597km^2. The mainstem of the river flows within the Rocky Mountain Trench in a north direction into Williston Reservoir starting from the continental divide adjacent to Arctic Lakes. Major tributaries include the Misinchinka, Colbourne, Reynolds, Anzac, Table, Hominka and Missinka sub-basins which drain the western slopes of the Hart Ranges of the Rocky Mountains. The Parsnip River has a mean annual discharge of 150.4 m^3/s with flow patterns typical of high elevation watersheds on the west side of the northern Rocky Mountains which receive large amounts of precipitation as snow leading to peak levels of discharge during snowmelt, typically from May to July (Figures 1.2 - 1.3).

Construction of the 183 m high and 2134 m long W.A.C. Bennett Dam was completed in 1967 at Hudson's Hope, BC, creating the Williston Reservoir (Hirst 1991). Filling of the 375km^2 reservoir was complete in 1972 and flooded a substantial portion of the Parsnip River and major tributary valleys forming what is now known as the Peace and Parsnip reaches. The replacement of riverine habitat with an inundated reservoir environment resulted in profound changes to the ecology, resource use and human settlement patterns in these systems (Hagen et al. 2015a; Pearce 2019; Stamford, Hagen, and Williamson 2017a). Prior to the filling of the reservoir, the Pack River, into which McLeod Lake flows, was a major tributary to the Parsnip River. The Pack River currently enters the Williston Reservoir directly as the historic location of the confluence of the two rivers lies within the reservoir's footprint.

1.2 Project Location

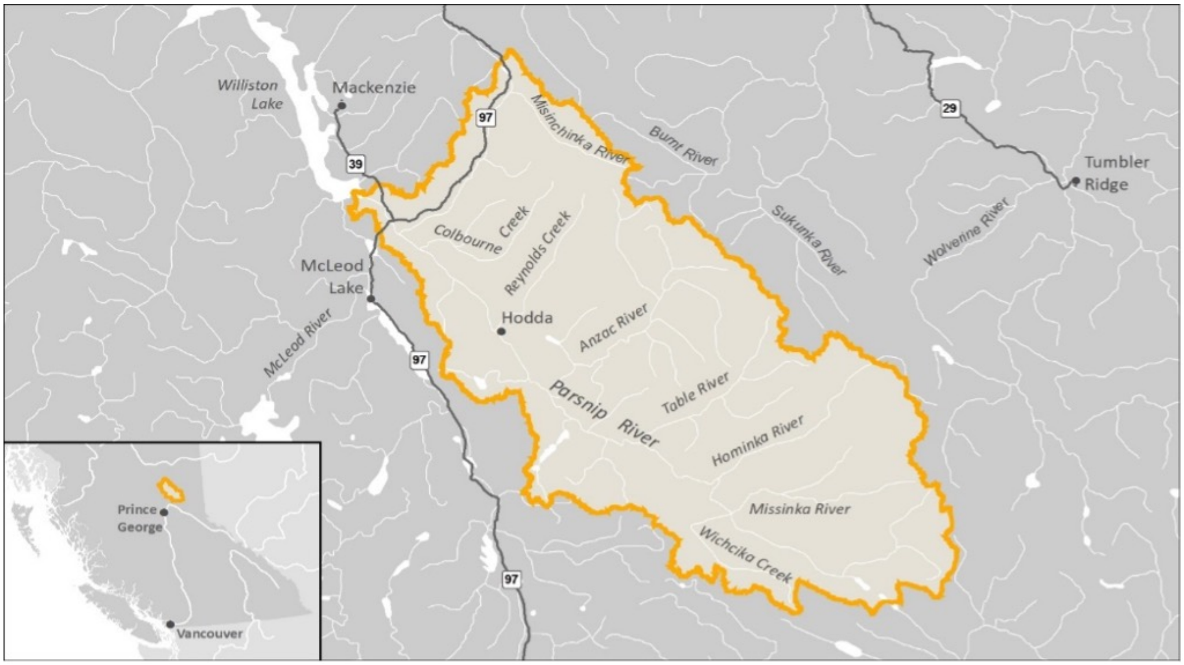

Figure 1.1: Overview map of Study Area

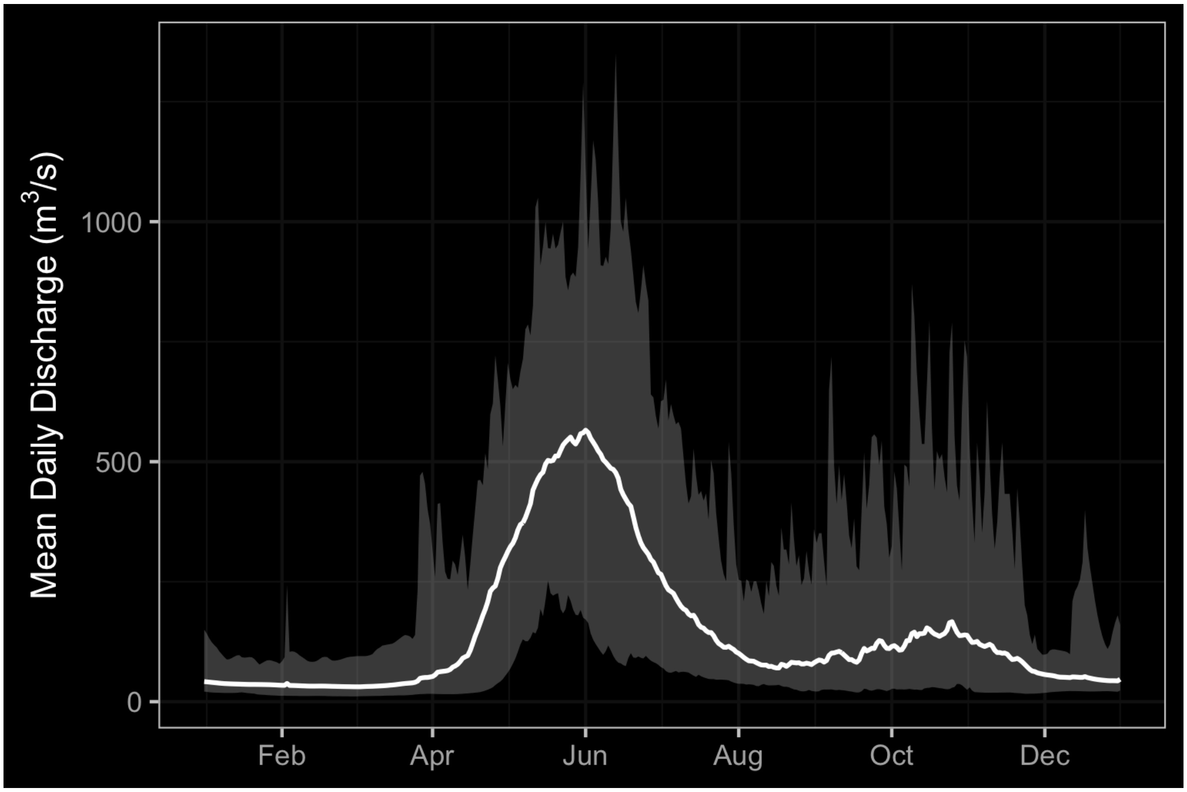

Figure 1.2: Parsnip River Above Misinchinka River (Station #07EE007 - Lat 55.08194 Lon -122.913063). Available daily discharge data from 1967 to 2019.

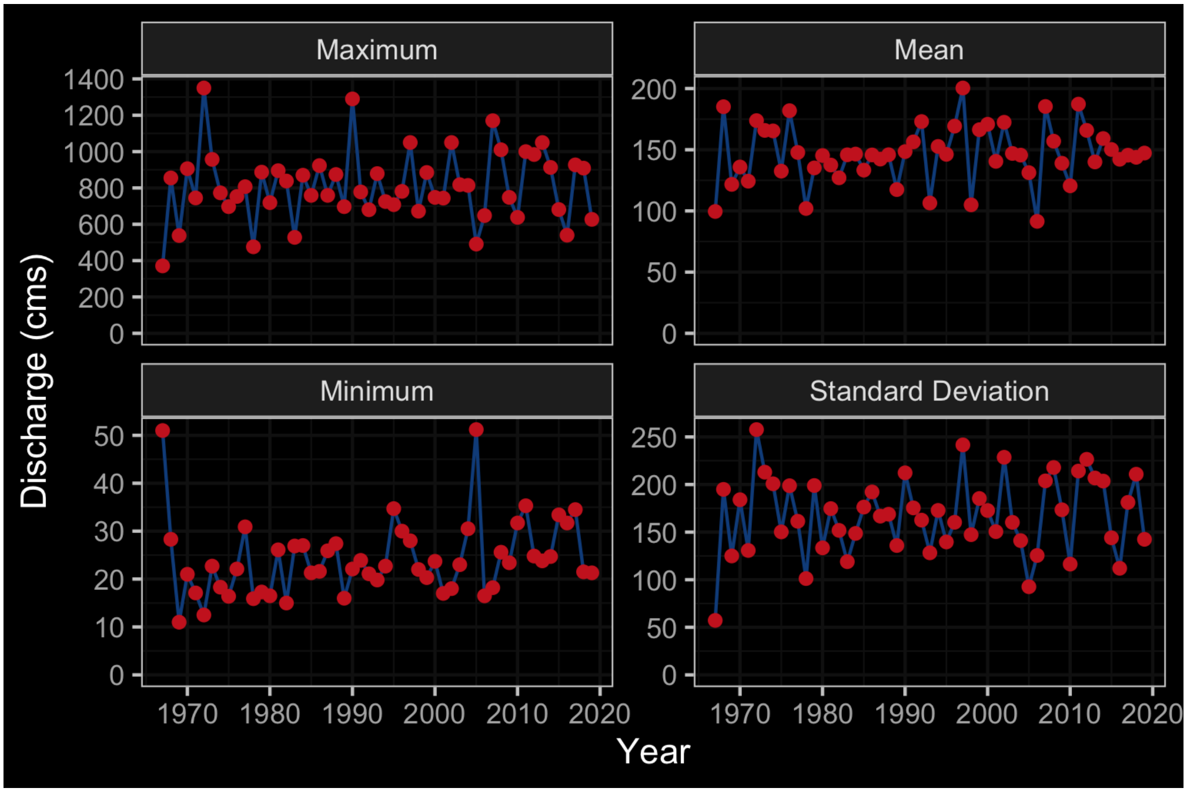

Figure 1.3: Summary discharge statistics (annual maximum, minimum, mean and standard deviation) for Parsnip River at hydrometric station #07EE007.

Fisheries

Fish species recorded in the Parsnip River watershed are detailed in Table 1.1 (MoE 2019a). In addition to flooding related to the formation of the Williston Reservoir, transmission lines, gas pipelines, rail, road networks, forestry, elevated water temperatures, interrupted connectivity, invasion from non-native species and insect infestations affecting forested areas pose threats to fisheries values in the Parsnip River watershed (Hagen et al. 2015b; Stamford, Hagen, and Williamson 2017b; Hagen and Weber 2019a; Comittee on the Status of Endangered Wildlife in Canada 2012). A brief summary of trends and knowledge status related to Arctic grayling, bull trout, kokanee, mountain whitefish and rainbow trout in Williston Watershed streams is provided in Fish and ildlife Compensation Program (2020) with a more detailed review of the state of knowledge for Parsnip River watershed populations of Arctic grayling and bull trout provided below.

Table 1.1: Fish species recorded in the Parsnip River watershed group.

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA
Catostomus catostomus	Longnose Sucker	LSU	Yellow	–	–	–
Catostomus commersonii	White Sucker	WSU	Yellow	–	–	–
Catostomus macrocheilus	Largescale Sucker	CSU	Yellow	–	–	–
Coregonus clupeaformis	Lake Whitefish	LW	Yellow	–	–	–
Cottus aleuticus	Coastrange Sculpin (formerly Aleutian Sculpin)	CAL	Yellow	–	–	–

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA
Cottus asper	Prickly Sculpin	CAS	Yellow	–	–	–
Cottus cognatus	Slimy Sculpin	CCG	Yellow	–	–	–
Couesius plumbeus	Lake Chub	LKC	Yellow	–	DD	–
Lota lota	Burbot	BB	Yellow	–	–	–
Mylocheilus caurinus	Peamouth Chub	PCC	Yellow	–	–	–
Oncorhynchus mykiss	Rainbow Trout	RB	Yellow	–	–	–
Oncorhynchus nerka	Kokanee	KO	Yellow	–	–	–
Osmerus dentex	Rainbow Smelt	RSM	Unknown	–	–	–
Prosopium coulterii	Pygmy Whitefish	PW	Yellow	–	NAR (Nov 2016)	–
Prosopium cylindraceum	Round Whitefish	RW	Yellow	–	–	–
Prosopium williamsoni	Mountain Whitefish	MW	Yellow	–	–	–
Ptychocheilus oregonensis	Northern Pikeminnow	NSC	Yellow	–	–	–
Rhinichthys cataractae	Longnose Dace	LNC	Yellow	–	–	–
Richardsonius balteatus	Redside Shiner	RSC	Yellow	–	–	–
Salvelinus confluentus	Bull Trout	BT	Blue	Y (Jun 2006)	SC (Nov 2012)	–
Salvelinus fontinalis	Brook Trout	EB	Exotic	–	–	–
Salvelinus malma	Dolly Varden	DV	Yellow	–	–	–
Salvelinus namaycush	Lake Trout	LT	Yellow	–	–	–
Thymallus arcticus	Arctic Grayling	GR	Yellow	–	–	–

Bull Trout - sa’ba

Bull Trout populations of the Williston Reservoir watershed are included within the Western Arctic population ‘Designatable Unit 10’, which, in 2012, received a ranking of ‘Special Concern’ by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2012). They were added to Schedule 1 under the Species of Risk Act in 2019 (Species Registry Canada 2020) and are also considered of special concern (blue-listed) provincially (BC Species & Ecosystem Explorer 2020). Some or all of the long-term foot survey index sections of four Williston Reservoir spawning tributaries (Davis Creek, Misinchinka River, Point Creek, and Scott Creek), have been surveyed within 16 of the 19 years between 2001 and 2019 (16 of 19 in Davis River, 10 years over a 13-year period in the Misinchinka River, 11 years over a 14-year period for Point Creek, and 9 years over an 11-year period for Scott Creek (Hagen, Spendlow, and Pillipow 2020).

A study of sa’ba critical habitats in the Parsnip River was conducted in 2014 with the Misinchinka and Anzac systems identified as the most important systems for large bodied bull trout spawners accounting for a combined total of 65% of spawners counted. The Table River was also highlighted as an important spawning destination accounting for an estimated 15% of the spawners. Other watersheds identified as containing runs of large bodied bull troutspawners included the Colbourne, Reynolds, Hominka and Missinka River with potentially less than 50 spawners utilizing each sub-basin (Hagen et al. 2015a). Hagen and Weber (2019b) have synthesized a large body of information regarding limiting factors, enhancement potential, critical habitats and conservation status for bull trout of the Williston Reservoir and the reader is encouraged to review this work for context. They have recommended experimental enhancements within a monitoring framework for Williston Reservoir bull trout (some spawning and rearing in Parsnip River mainstem and tributaries) which include stream fertilization, side channel development, riparian restoration and fish access improvement.

In 2018, sub-basins of the Anzac River watershed, Homininka River, Missinka River and Table River watersheds were designated as fisheries sensitive watersheds under the authority of the *Forest and Range Practices Act* due to significant downstream fisheries values and significant watershed sensitivity (Beaudry 2013a, 2014a, 2014b, 2013b). Special management is required in these watersheds to protect habitat for fish species including bull trout and Arctic grayling including measures (among others) to limit equivalent clearcut area, reduce impacts to natural stream channel morphology, retain old growth attributes and maintain fish habitat/movement (Forest and ange Practices Act 2018).

Tse'khene Elders from the McLeod Lake Indian Band report that sa'ba (bull trout) size and abundance has decreased in all rivers and tributaries from the reservoir with more injured and diseased fish captured in recent history than was common in the past (Pearce 2019).

Arctic Grayling - dusk'ihje

A detailed review of dusk'ihje life history can be referenced in Stamford, Hagen, and Williamson (2017b). Since impoundment of the Williston Reservoir, it appears that physical habitat and ecological changes have been the most significant factors limiting Arctic grayling productivity. Although these changes are not well understood they have likely resulted in the inundation of key low gradient juvenile rearing and overwintering habitats, isolation of previously connected populations and increases in abundance of predators such as bull trout (Shrimpton, Roberts, and Clarke 2012; Hagen, Pillipow, and Gantner 2018).

Migration of mature adult dusk'ihje (Arctic grayling) occurs in the spring with arrival at known spawning locations coinciding with water temperatures of 4°C. Spawning in the Parsnip watershed appears to occur between late-May and late-June within sites located primarily within the lower reaches of the Anzac and Table rivers as well as within the Parsnip River mainstem. Side-channel and multiple-channel locations containing small gravels appear to be selected for spawning. Currently, the primary distribution of Williston Arctic grayling appears to be among fourth order and larger streams (Williamson and Zimmerman 2005; Stamford, Hagen, and Williamson 2017b). Stewart et al. (2007) report that Arctic grayling spawn in large and small tributaries to rivers and lakes, intermittent streams, within mainstem rivers as well as lakes, most commonly at tributary mouths. Although past study results indicate that 0+ grayling appeared to overwinter in lower reaches of larger tributaries (i.e. Table, Anzac rivers) as well as the Parsnip River and that few age-1+ grayling have been sampled in tributaries, habitat use in small tributaries and the extent they are connected with the mainstem habitats of all core areas is not well understood. Between 1995 and 2019, Arctic grayling population monitoring has been conducted in the Table River in nine out of 25 years (8 years for the Anzac) using snorkel surveys. Results from 2018 are 2019 are intended to contribute to the assessment of the conservation status of the species in the Parsnip Core area (Hagen, Pillipow, and Gantner 2018).

Tse’khene Elders from the McLeod Lake Indian Band report that Arctic grayling numbers have declined dramatically since the flooding of the reservoir and that few dusk’ihje (Arctic Grayling) have been caught in the territory in the past 30 years (Pearce 2019).

A review of available fisheries data for the Parsnip River watershed stratified by different habitat characteristics can provide insight into which habitats may provide the highest intrinsic value for fish species based on the number of fish captured in those habitats in past assessment work (Figures 1.4 - 1.6). It should be noted however that it should not be assumed that all habitat types have been sampled in a non-biased fashion or that particular sites selected do not have a disproportionate influence on the overall dataset composition (ie. fish salvage sites are often located adjacent to construction sites which are more commonly located near lower gradient stream reaches).

Table 1.2: Summary of historic salmonid observations vs. stream gradient category for the Parsnip River watershed group.

species_code	Gradient	Count	total_spp	Percent
BT	0 - 3 %	160	236	68
BT	03 - 5 %	29	236	12
BT	05 - 8 %	21	236	9
BT	08 - 15 %	20	236	8
BT	15 - 22 %	6	236	3
GR	0 - 3 %	224	230	97
GR	03 - 5 %	2	230	1
GR	05 - 8 %	2	230	1
GR	08 - 15 %	2	230	1
KO	0 - 3 %	17	17	100
RB	0 - 3 %	327	415	79
RB	03 - 5 %	32	415	8
RB	05 - 8 %	22	415	5
RB	08 - 15 %	27	415	7
RB	15 - 22 %	7	415	2

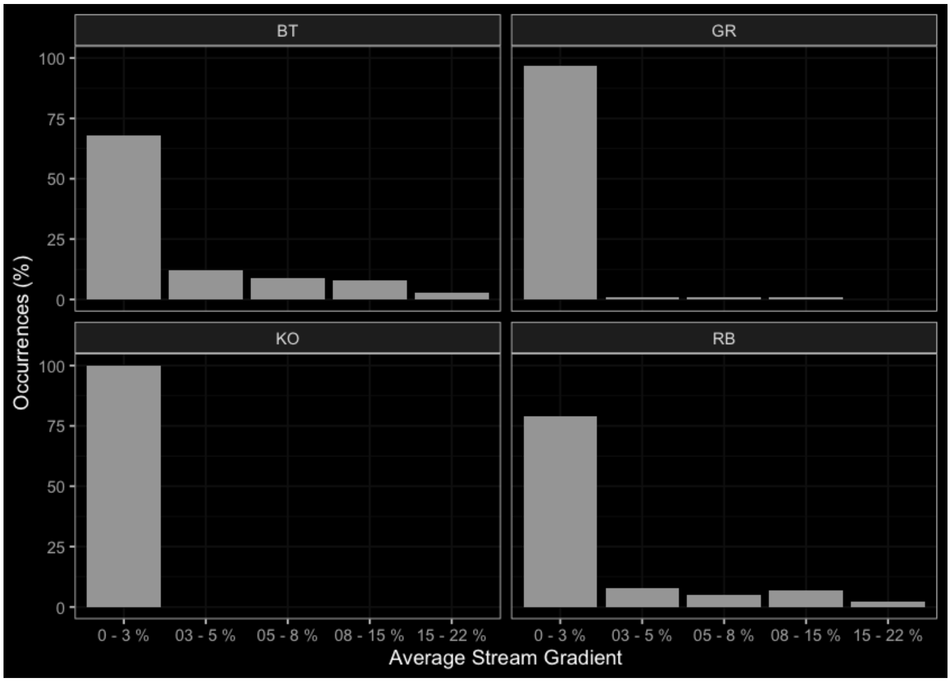

Figure 1.4: Summary of historic salmonid observations vs. stream gradient category for the Parsnip River watershed group.

Table 1.3: Summary of historic salmonid observations vs. channel width category for the Parsnip River watershed group.

species_code	Width	Count	total_spp	Percent
BT	0 - 2m	11	236	5
BT	02 - 04m	25	236	11
BT	04 - 06m	29	236	12
BT	06 - 10m	35	236	15
BT	10 - 15m	30	236	13
BT	15m+	103	236	44
BT	–	3	236	1
GR	04 - 06m	5	230	2
GR	06 - 10m	7	230	3
GR	10 - 15m	14	230	6
GR	15m+	200	230	87
GR	–	4	230	2
KO	0 - 2m	1	17	6
KO	06 - 10m	3	17	18
KO	15m+	1	17	6
KO	–	12	17	71
RB	0 - 2m	23	415	6

species_code	Width	Count	total_spp	Percent
RB	02 - 04m	51	415	12
RB	04 - 06m	37	415	9
RB	06 - 10m	36	415	9
RB	10 - 15m	34	415	8
RB	15m+	141	415	34
RB	–	93	415	22

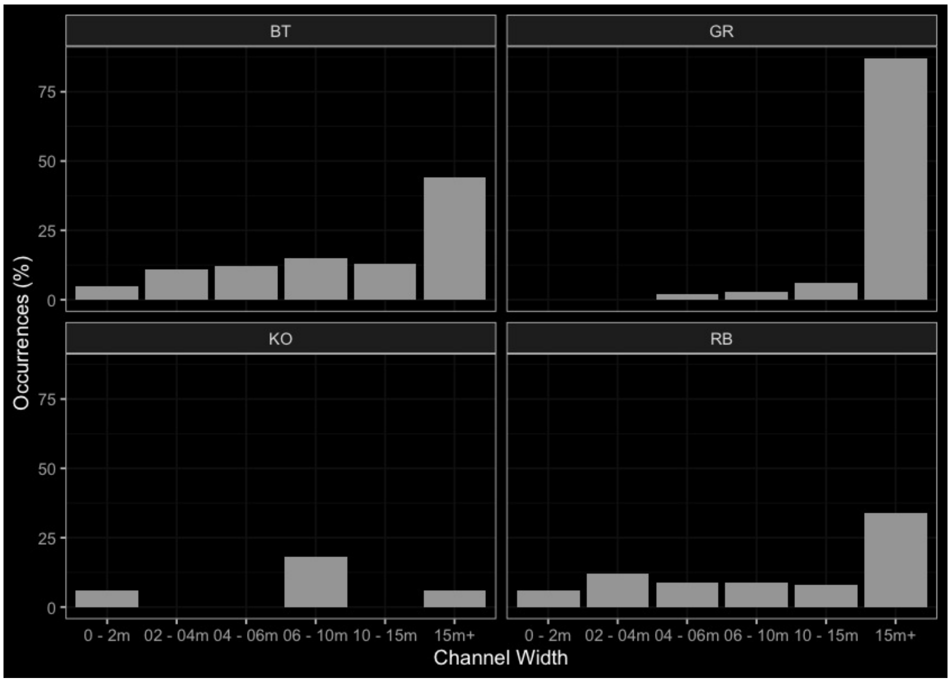

Figure 1.5: Summary of historic salmonid observations vs. channel width category for the Parsnip River watershed group.

Table 1.4: Summary of historic salmonid observations vs. watershed size category for the Parsnip River watershed group.

species_code	Watershed	count_wshd	total_spp	Percent
BT	0 - 25km2	89	236	38
BT	25 - 50km2	27	236	11
BT	50 - 75km2	12	236	5
BT	75 - 100km2	9	236	4
BT	100km2+	99	236	42
GR	0 - 25km2	7	230	3
GR	25 - 50km2	5	230	2
GR	50 - 75km2	9	230	4

species_code	Watershed	count_wshd	total_spp	Percent
GR	100km2+	203	230	88
KO	0 - 25km2	11	17	65
KO	25 - 50km2	1	17	6
KO	50 - 75km2	2	17	12
KO	75 - 100km2	2	17	12
KO	100km2+	1	17	6
RB	0 - 25km2	210	415	51
RB	25 - 50km2	22	415	5
RB	50 - 75km2	26	415	6
RB	75 - 100km2	17	415	4
RB	100km2+	140	415	34

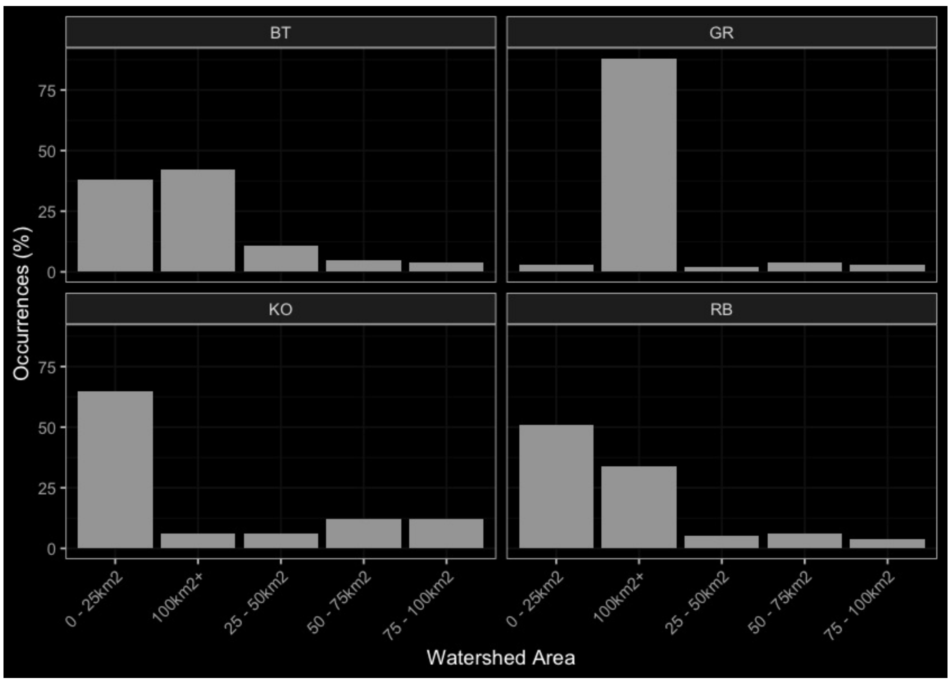

Figure 1.6: Summary of historic salmonid observations vs. watershed size category for the Parsnip River watershed group.

2 Methods

Workflows for the project have been classified into planning, fish passage assessments, habitat confirmation assessments, reporting and mapping. All components leveraged `R`, `SQL` or `Python` programming languages to facilitate workflow tracking, collaboration, transparency and continually improving research. Project workflows utilized local and remote `postgreSQL` databases as well as a "snapshot" of select datasets contained within a local `sqlite` database. A data and script repository to facilitate this reporting is located on [Github]().

2.1 Planning

To identify priorities for crossing structure rehabilitation, background literature, fisheries information, PSCIS, and `bcfishpass` (Norris [2020] 2021) outputs were reviewed. `bcfishpass` is an updated open-source code repository comprised of tools ported over from the `Fish Habitat Model` (Norris and Mount 2016) developed by the BC Ministry of Environment along with a number of significant upgrades and new features. Scripts within `bcfishpass` also pull and analyze data using other open-source tools such as `bcdata` (Norris [2016] 2021), `bcfishobs` (Norris [2018] 2022), and `fwapg` (Norris [2019] 2021) which serve numerous functions related to open-data access as well as the analysis of the BC Freshwater Atlas, roads, fish and fish habitat in British Columbia.

2.1.1 Habitat Modelling

`bcfishpass` calculates the average gradient of BC Freshwater Atlas stream network lines at minimum 100m long intervals starting from the downstream end of the streamline segment and working upstream. The network lines are broken into max gradient categories with new segments created if and when the average slope of the stream line segment exceeds user provided thresholds. For this project, the user provided gradient thresholds used to delineate "potentially accessible habitat" were based on estimated max gradients that salmon (15% - coho and chinook) and steelhead (20%) are likely to be capable of ascending.

Through this initiative and other SERN/New Graph led initiatives, and other connectivity restoration planning by the Provincial Fish Passage Remediation Program, the Pacific Salmon Foundation and the Canadian Wildlife Federation, `bcfishpass` has been designed to prioritize potential fish passage barriers for assessment or remediation. The software is under continual development and has been designed and constructed by Norris ([2020] 2021) using sql and python based shell script libraries to generate a simple model of aquatic habitat connectivity. The model identifies natural barriers (ex. steep gradients for extended distances) and hydroelectric dams to classifying the accessibility upstream by fish (Norris [2020] 2021). On potentially accessible streams, scripts identify known barriers (ex. waterfalls >5m high) and additional anthropogenic features which are primarily road/railway stream crossings (i.e. culverts) that are potentially barriers. To prioritize these features for assessment or remediation, scripts report on how much modelled potentially accessible aquatic habitat the barriers may obstruct. The model can be refined with known fish observations upstream of identified barriers and for each crossing location, the area of lake and wetland habitat upstream, species documented upstream/downstream, an estimate of watershed area (on 2nd order and higher streams), mean annual precipitation weighted to upstream watershed area and channel width can be collated using `bcfishpass`, `fwapg` and `bcfishobs`. This, information, can be used to provides an indication of the potential quantity and quality of habitat potentially gained should fish passage be restored by comparing to user defined thresholds for the aforementioned parameters. A discussion of the methodology to derive channel width is below.

Gradient, channel size and stream discharge are key determinants of channel morphology and subsequently fish distribution. High value rearing, overwintering and spawning habitat preferred by numerous species/life stages of fish are often located within channel types that have relatively low gradients and large channel widths (also quantified by the amount of flow in the stream). Following delineation of “potentially accessible habitat”, the average gradient of each stream segment within habitat classified as below the 15% and 20% thresholds was calculated and summed within species and life stage specific gradient categories. Average gradient of stream line segments can be calculated from elevations contained in the provincial freshwater atlas streamline dataset. To obtain estimates of channel width upstream of crossing locations, Where available, `bcfishpass` was utilized to pull average channel gradients from Fisheries Information Summary System (FISS) site assessment data (MoE 2019b) or PSCIS assessment data (MoE 2021) and associate with stream segment lines. When both FISS and PSCIS values were associated with a particular stream segment, FISS channel width was used. When multiple FISS sites were associated with a particular stream segment a mean of the average channel widths was taken. To model channel width for 2nd order and above stream segments without associated FISS or PSCIS sites, first `fwapg` was used to estimate the drainage area upstream of the segment. Then, rasters from ClimateBC (Wang et al. 2012) were sampled for each stream segments and a mean annual precipitation weighted by upstream watershed area was calculated. Mean annual precipitation was then combined with the channel widths and BEC zone information (gathered through a spatial query tied to the bottom of the stream segment) into a dataset (n = 22990) for analysis fo the relationship between these variables. The details of this analysis and resulting formula used to estimate channel width on stream segments in the Parsnip Watershed is included as a technical appendix at https://www.poissonconsulting.ca/f/859859031.

`bcfishpass` and associated tools have been designed to be flexible in analysis, accepting user defined gradient, channel width and stream discharge categories (MoE 2019b). Although currently in draft form, and subject to development revisions, gradient and channel width thresholds for habitat with the highest intrinsic value for a number of fish species in the Parsnip River watershed group have been specified and applied to model habitat upstream of stream crossing locations with the highest intrinsic value (Table 2.1). Definitions of modelling outputs for bull trout are presented in Table 2.3. Modelling of habitat for Arctic grayling, kokannee and rainbow trout in the Peace region are planned for 2022/2023 wtih the work leveraging multiple other initiatives underway by SERNbc and others throughout British Columbia.

Table 2.1: Stream gradient and channel width thresholds used to model potentially highest value fish habitat.

Variable	Bull Trout	Rainbow Trout	Arctic Grayling	Kokanee
Spawning Gradient Max (%)	5	5	2	2
Spawning Width Min (m)	2	2	4	2
Rearing Gradient Max (%)	7.4	7.4	3.4	–
Rearing Width Min (m)	1.5	1.5	1.5	1.5

Table 2.2: References for stream gradient and channel width thresholds used to model potentially highest value fish habitat. Preliminary and subject to revisions.

Variable	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon
Spawning Gradient Max (%)	0.03 (Kirsch et al. 2004, Busch et al. 2011, Cooney and Holzer 2006)	0.05 (Roberge et al. 2002, Sloat et al. 2017)	0.04 (Scheer and Steel 2006, Cooney and Holzer 2006)	0.02 (Lake 1999, Hoopes 1972)
Spawning Width Min (m)	3.7 (Busch et al. 2011, Cooney and Holzer 2006)	2 (Sloat et. al 2017)	3.8 (Cooney and Holzer 2006)	2 (Woll et al. 2017)
Rearing Gradient Max (%)	0.05 (Woll et al. 2017, Porter et al. 2008)	0.05 (Kirsch et al. 2004, Porter et al. 2008, Rosenfeld et al. 2000)	0.074 (Porter et al. 2008)	–

Table 2.3: bcfishpass outputs and associated definitions

Attribute	Definition
BT Rearing Below Barriers (km)	Length of stream upstream of point and below any additional upstream barriers, modelled as potential Bull Trout rearing habitat
BT Rearing (km)	Length of stream upstream of point modelled as potential Bull Trout rearing habitat
BT Spawning Below Barriers (km)	Length of stream upstream of point and below any additional upstream barriers, modelled as potential Bull Trout spawning habitat
BT Spawning (km)	Length of stream upstream of point modelled as potential Bull Trout spawning habitat
BT Below Barriers Network (km)	Bull Trout model, total length of stream network potentially accessible upstream of point and below any additional upstream barriers
BT Network (km)	Bull Trout model, total length of stream network potentially accessible upstream of point
BT Below Barriers Stream (km)	Bull Trout model, total length of streams and rivers potentially accessible upstream of point and below any additional upstream barriers (does not include network connectors in lakes etc)
BT Stream (km)	Bull Trout model, total length of streams and rivers potentially accessible upstream of point (does not include network connectors in lakes etc)
BT Below Barriers Lake Reservoir (ha)	Bull Trout model, total area lakes and reservoirs potentially accessible upstream of point and below any additional upstream barriers
BT Lake Reservoir (ha)	Bull Trout model, total area lakes and reservoirs potentially accessible upstream of point
BT Below Barriers Wetland (ha)	Bull Trout model, total area wetlands potentially accessible upstream of point and below any additional upstream barriers
BT Wetland (ha)	Bull Trout model, total area wetlands potentially accessible upstream of point
BT Below Barriers Slopeclass03 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 0-3%
BT Slopeclass03 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 0-3%
BT Below Barriers Slopeclass05 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 3-5%
BT Slopeclass05 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 3-5%
BT Below Barriers Slopeclass08 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 5-8%
BT Slopeclass08 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 5-8%

Attribute	Definition
Slopeclass15 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 8-15%
BT Slopeclass15 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 8-15%
Barriers BT Dnstr	–
BT Below Barriers Slopeclass03 Waterbodies (km)	Bull Trout model, length of stream connectors (in waterbodies) potentially accessible upstream of point and below any additional upstream barriers, with slope 0-3%
BT Below Barriers Slopeclass22 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 15-22%
BT Below Barriers Slopeclass30 (km)	Bull Trout model, length of stream potentially accessible upstream of point and below any additional upstream barriers, with slope 22-30%
BT Slopeclass03 Waterbodies (km)	Bull Trout model, length of stream connectors (in waterbodies) potentially accessible upstream of point with slope 0-3%
BT Slopeclass22 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 15-22%
BT Slopeclass30 (km)	Bull Trout model, length of stream potentially accessible upstream of point with slope 22-30%

* Bull trout model uses a gradient threshold of maximum 25% to determine if access if likely possible

2.2 Fish Passage Assessments

In the field, crossings prioritized for follow-up were first assessed for fish passage following the procedures outlined in “Field Assessment for Determining Fish Passage Status of Closed Bottomed Structures” (BC Ministry of Environment 2011). Crossings surveyed included closed bottom structures (CBS), open bottom structures (OBS) and crossings considered “other” (i.e. fords). Photos were taken at surveyed crossings and when possible included images of the road, crossing inlet, crossing outlet, crossing barrel, channel downstream and channel upstream of the crossing and any other relevant features. The following information was recorded for all surveyed crossings: date of inspection, crossing reference, crew member initials, Universal Transverse Mercator (UTM) coordinates, stream name, road name and kilometer, road tenure information, crossing type, crossing subtype, culvert diameter or span for OBS, culvert length or width for OBS. A more detailed “full assessment” was completed for all closed bottom structures and included the following parameters: presence/absence of continuous culvert embedment (yes/no), average depth of embedment, whether or not the culvert bed resembled the native stream bed, presence of and percentage backwatering, fill depth, outlet drop, outlet pool depth, inlet drop, culvert slope, average downstream channel width, stream slope, presence/absence of beaver activity, presence/absence of fish at time of survey, type of valley fill, and a habitat value rating. Habitat value ratings were based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), fish migration patterns, the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation (Table 2.4). For crossings determined to be potential barriers or barriers based on the data (see Barrier Scoring (page 16)), a culvert fix and recommended diameter/span was proposed.

Table 2.4: Habitat value criteria (Fish Passage Technical Working Group, 2011).

Habitat Value	Fish Habitat Criteria
High	The presence of high value spawning or rearing habitat (e.g., locations with abundance of suitably sized gravels, deep pools, undercut banks, or stable debris) which are critical to the fish population.
Medium	Important migration corridor. Presence of suitable spawning habitat. Habitat with moderate rearing potential for the fish species present.
Low	No suitable spawning habitat, and habitat with low rearing potential (e.g., locations without deep pools, undercut banks, or stable debris, and with little or no suitably sized spawning gravels for the fish species present).

2.2.1 Barrier Scoring

Fish passage potential was determined for each stream crossing identified as a closed bottom structure as per BC Ministry of Environment (2011). The combined scores from five criteria: depth and degree to which the structure is embedded, outlet drop, stream width ratio, culvert slope, and culvert length were used to screen whether each culvert was a likely barrier to some fish species and life stages (Table 2.5, Table 2.6. These criteria were developed based on data obtained from various studies and reflect an estimation for the passage of a juvenile salmon or small resident rainbow trout (Clarkin et al. 2005 ; Bell 1991; Thompson 2013).

Table 2.5: Fish Barrier Risk Assessment (MoE 2011).

Risk	LOW	MOD	HIGH
Embedded	>30cm or >20% of diameter and continuous	<30cm or 20% of diameter but continuous	No embedment or discontinuous
Value	0	5	10
Outlet Drop (cm)	<15	15-30	>30
Value	0	5	10
SWR	<1.0	1.0-1.3	>1.3
Value	0	3	6
Slope (%)	<1	1-3	>3
Value	0	5	10
Length (m)	<15	15-30	>30
Value	0	3	6

Table 2.6: Fish Barrier Scoring Results (MoE 2011).

Cumlative Score	Result
0-14	passable
15-19	potential barrier
>20	barrier

2.2.2 Cost Benefit Analysis

A cost benefit analysis was conducted for each crossing determined to be a barrier based on an estimate of cost associated with remediation or replacement of the crossing with a structure that facilitates fish passage and the amount of potential habitat that would be made available by remediating fish passage at the site (habitat gain index).

2.2.2.1 Habitat Gain Index

The habitat gain index is the quantity of modelled habitat upstream of the subject crossing and represents an estimate of habitat gained with remediation of fish passage at the crossing. For this project, a gradient threshold between accessible and non-accessible habitat was set at 20% (for a minimimum length of 100m) intended to represent the maximum gradient of which the strongest swimmers of anadromous species (bull trout) are likely to be able to migrate upstream.

For reporting of Phase 1 - fish passage assessments within the body of this report (Table 2.5), a "total" value of habitat <20% output from `bcfishpass` was used to estimate the amount of habitat upstream of each crossing less than 20% gradient before a falls of height >5m - as recorded in MoE (2020) or documented in other `bcfishpass` online documentation. For Phase 2 - habitat confirmation sites, conservative estimates of the linear quantity of habitat to be potentially gained by fish passage restoration, bull trout rearing maximum gradient threshold (7.4%) was used. To generate areas of habitat upstream, the estimated linear length was multiplied by half the downstream channel width measured (overall triangular channel shape) as part of the fish passage assessment protocol. Although these estimates are not generally conservative, have low accuracy and do not account for upstream stream crossing structures they allow a rough idea of the best candidates for follow up.

Potential options to remediate fish passage were selected from BC Ministry of Environment (2011) and included:

- Removal (RM) - Complete removal of the structure and deactivation of the road.
- Open Bottom Structure (OBS) - Replacement of the culvert with a bridge or other open bottom structure. Based on consultation with FLNR road crossing engineering experts, for this project we considered bridges as the only viable option for OBS type .
- Streambed Simulation (SS) - Replacement of the structure with a streambed simulation design culvert. Often achieved by embedding the culvert by 40% or more. Based on consultation with FLNR engineering experts, we considered crossings on streams with a channel width of <2m and a stream gradient of <8% as candidates for replacement with streambed simulations.
- Additional Substrate Material (EM) - Add additional substrate to the culvert and/or downstream weir to embed culvert and reduce overall velocity/turbulence. This option was considered only when outlet drop = 0, culvert slope <1.0% and stream width ratio < 1.0.
- Backwater (BW) - Backwatering of the structure to reduce velocity and turbulence. This option was considered only when outlet drop < 0.3m, culvert slope <2.0%, stream width ratio < 1.2 and stream profiling indicates it would be effective..

Cost estimates for structure replacement with bridges and embedded culverts were generated based on the channel width, slope of the culvert, depth of fill, road class and road surface type.

Road details were sourced from FLNRORD (2020b) and FLNRORD (2020a) through `bcfishpass`. Interviews with Phil MacDonald, Engineering Specialist FLNR - Kootenay, Steve Page, Area Engineer - FLNR - Northern Engineering Group and Matt Hawkins - MoTi - Design Supervisor for Highway Design and Survey - Nelson were utilized to helped refine estimates.

Base costs for installation of bridges on forest service roads and permit roads with surfaces specified in provincial GIS road layers as rough and loose was estimated at $12500/linear m and assumed that the road could be closed during construction and a minimum bridge span of 10m. For streams with channel widths <2m, embedded culverts were reported as an effective solution with total installation costs estimated at $25k/crossing (pers. comm. Phil MacDonald, Steve Page). For larger streams (>6m), span width increased proportionally to the size of the stream (ex. for an 8m wide stream a 12m wide span was prescribed). For crossings with large amounts of fill (>3m), the replacement bridge span was increased by an additional 3m for each 1m of fill >3m to account for cutslopes to the stream at a 1.5:1 ratio. To account for road type, a multiplier table was also generated to estimate incremental cost increases with costs estimated for structure replacement on paved surfaces, railways and arterial/highways costing up to 20 times more than forest service roads due to expenses associate with design/engineering requirements, traffic control and paving. The cost multiplier table (Table 2.7) should be considered very approximate with refinement recommended for future projects.

Table 2.7: Cost multiplier table based on road class and surface type.

Class	Surface	Class Multiplier	Surface Multiplier	Bridge $K/10m	Streambed Simulation $K
FSR	Loose	1	1	250	50
Resource	Loose	1	1	250	50
Permit	Loose	1	1	250	50
Unclassified	Loose	1	1	250	50
Unclassified	Rough	1	1	250	50
Unclassified	Paved	1	2	500	100
Unclassified	Unknown	1	2	500	100
Local	Loose	4	1	1000	200
Local	Paved	4	2	2000	400
Arterial	Paved	15	2	7500	1500
Highway	Paved	15	2	7500	1500
Rail	Rail	15	2	7500	1500

2.3 Habitat Confirmation Assessments

Following fish passage assessments, habitat confirmations were completed in accordance with procedures outlined in the document "A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation of a Stream Crossing" (Fish Passage Technical Working Group 2011). The main objective of the field surveys was to document upstream habitat quantity and quality and to determine if any other obstructions exist above or below the crossing. Habitat value was assessed based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation. Criteria used to rank habitat value was based on guidelines in Fish Passage Technical Working Group (2011) (Table 2.4).

During habitat confirmations, to standardize data collected and facilitate submission of the data to provincial databases, information was collected on "Site Cards". Habitat characteristics recorded included channel widths, wetted widths, residual pool depths, gradients, bankfull depths, stage, temperature, conductivity, pH, cover by type, substrate and channel morphology (among others). When possible, the crew surveyed downstream of the crossing to the point where fish presence had been previously confirmed and upstream to a minimum distance of 600m. Any potential obstacles to fish passage were inventoried with photos, physical descriptions and locations recorded on site cards. Surveyed routes were recorded with time-signatures on handheld GPS units.

Fish sampling was conducted on a subset of sites when biological data was considered to add significant value to the physical habitat assessment information. When possible, electrofishing was utilized within discrete site units both upstream and downstream of the subject crossing with electrofisher settings, water quality parameters (i.e. conductivity, temperature and ph), start location, length of site and wetted widths (average of a minimum of three) recorded. For each fish captured, fork length and species was recorded, with results included within the fish data submission spreadsheet. Fish information and habitat data will be submitted to the province under scientific fish collection permit CB20-611971.

2.4 Reporting

Reporting was generated with bookdown (Xie 2016) from Rmarkdown (Allaire et al. 2022) with primarily R (R Core Team 2022) and SQL scripts. The R package fpr contains many specialized custom functions related to the work (Allan Irvine [2022] 2022). In addition to numerous spatial layers sourced through the BC Data Catalogue then stored and queried in a local postgresql and sqlite databases data inputs for this project include:

- Populated Fish Data Submission Spreadsheet Template - V 2.0, January 20, 2020
- Populated pscis_assessment_template_v24.xls
- bcfishpass outputs.
- Custom CSV file detailing Phase 2 site:
  - priority level for proceeding to design for replacement
  - length of survey upstream and downstream
  - a conservative estimate of the linear length of mainstem habitat potentially available upstream of the crossing
  - fish species confirmed as present upstream of the crossing
- GPS tracks from field surveys.
- Photos and photo metadata

Version changes are tracked here and issues/planned enhancements tracked here.

2.5 Mapping

Mapping was completed by Hillcrest Geographics. pdf maps were generated using QGIS with data supplied via a postgreSQL database. A QGIS layer file defining and symbolizing all layers required for general fish passage mapping was developed and at the time of reporting was kept under version control within bcfishpass.

3 Results and Discussion

3.1 Potential Remediations

3.1.1 Tributary to Anzac River - PSCIS crossing 6745

PSCIS crossing 6745 is located on a tributary to Parsnip River, on Chuchinka-Crocker FSR. This site is located approximately 0.9km upstream from the confluence with the Anzac River. At crossing 6745, tributary to Parsnip River is a third order stream with a watershed area upstream of the crossing of approximately 2.1km^2. The elevation of the watershed ranges from a maximum of 869m to 745m near the crossing (Table 3.1). At the time of reporting, there was no fisheries information available within provincial databases for the area upstream of crossing 6745.

Table 3.1: Summary of derived upstream watershed statistics for PSCIS crossing 6745.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
6745	2.1	764	745	869	835	831	WSW

* Elev P60 = Elevation at which 60% of the watershed area is above

A summary of habitat modelling outputs is presented in Table 3.2 and a map of the watershed is provided in map attachment 093J.124.

Table 3.2: Summary of fish habitat modelling for PSCIS crossing 6745.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	0.0	0.0	–
BT Spawning (km)	0.0	0.0	–
BT Network (km)	6.1	6.1	100
BT Stream (km)	3.7	3.7	100
BT Lake Reservoir (ha)	0.0	0.0	–
BT Wetland (ha)	0.0	0.0	–
BT Slopeclass03 (km)	2.7	2.7	100
BT Slopeclass05 (km)	1.0	1.0	100
BT Slopeclass08 (km)	0.0	0.0	–
BT Slopeclass15 (km)	0.1	0.1	100

* Model data is preliminary and subject to adjustments.

Stream Characteristics at Crossing

At the time of the survey, PSCIS crossing 6745 was un-embedded, non-backwatered and ranked as potential to upstream fish passage according to the provincial protocol (MoE 2011) (Table 3.3). Water temperature was 11°C, pH was 7.9 and conductivity was 102uS/cm.

Table 3.3: Summary of fish passage assessment for PSCIS crossing 6745.

Location and Stream Data	•	Crossing Characteristics	–
Date	2022-08-14	Crossing Sub Type	Round Culvert
PSCIS ID	6745	Diameter (m)	1.6
External ID	–	Length (m)	14
Crew	MW AI	Embedded	No
UTM Zone	10	Depth Embedded (m)	–
Easting	533992	Resemble Channel	No
Northing	6076165	Backwatered	No
Stream	tributary to Parsnip River	Percent Backwatered	–
Road	Chuchinka-Crocker FSR	Fill Depth (m)	0.6
Road Tenure	Resource Demographic	Outlet Drop (m)	0
Channel Width (m)	1.5	Outlet Pool Depth (m)	0
Stream Slope (%)	2	Inlet Drop	No
Beaver Activity	No	Slope (%)	1
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	15	Barrier Result	Potential
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	3

Location and Stream Data	•	Crossing Characteristics	–
Comments: Damaged near outlet. Small stream but flowing. Middle of pipe filled with fines. Nearly embedded throughout most pipe except top end. 11:18			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Stream Characteristics Downstream

The stream was surveyed downstream from crossing 6745 for 200m (Figure 3.1). Total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation.The dominant substrate was gravels with fines sub-dominant.The average channel width was 1.2m, the average wetted width was 1m, and the average gradient was 0.5%. There were abundant undercut banks suitable for juvenile rearing. The stream channel is smaller and narrower than upstream. There were small gravels suitable for smaller fish. The habitat was rated as medium value for salmonid rearing and spawning due to low flow volumes and a lack of deep pools.

Stream Characteristics Upstream

The stream was surveyed upstream from crossing 6745 for 550m (Figure 3.2). The average channel width was 1.5m, the average wetted width was 1m, and the average gradient was 1.7%.The dominant substrate was gravels with fines sub-dominant.Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, deep pools, and overhanging vegetation. This is a small, perennial stream. There were abundant gravels present, suitable for resident rainbow. Some deep pools up to 45cm in depth were present that would be suitable for rearing. There was an abundance of undercut banks and larger gravels about 30 cm in size. Overall, the habitat surveyed upstream of the crossing was rated as medium value as an important migration corridor containing habitat suitable for spawning with moderate rearing potential.

Conclusion

Modelling indicates there is 1.2km of habitat upstream of crossing 6745 suitable for bull trout rearing with areas surveyed rated as medium value for rearing and spawning. Crossing 6745 was ranked as a low priority for proceeding to design for replacement. The culvert is considered passable and not a fish passage issue at this time. There were abundant gravels present upstream of the crossing, but no fish were spotted. Due to the lack of historic fisheries information upstream, fish sampling is recommended to determine if fish are utilising this tributary as a spawning and rearing location.

Table 3.4: Summary of habitat details for PSCIS crossing 6745.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
6745	Downstream	200	1.2	1	–	0.5	abundant	medium
6745	Upstream	550	1.5	1	0.3	1.7	moderate	medium

Figure 3.1: Left: Typical habitat downstream of PSCIS crossing 6745. Right: Typical habitat downstream of PSCIS crossing 6745.

Figure 3.2: Left: Typical habitat upstream of PSCIS crossing 6745. Right: Typical habitat upstream of PSCIS crossing 6745.

Figure 3.3: Left: Typical habitat upstream of PSCIS crossing 6745. Right: Typical habitat upstream of PSCIS crossing 6745.

3.1.2 Tributary to Missinka River - PSCIS crossing 125194

PSCIS crossing 125194 is located on a tributary to Missinka River, on Chuchinka-Missinka FSR. The site is located approximately 0.6km upstream from the confluence with the Missinka River. At crossing 125194, tributary to Missinka River is a second order stream with a watershed area upstream of the crossing of approximately 2.7km^2. The elevation of the watershed ranges from a maximum of 1432m to 740m near the crossing (Table 3.5). At the time of reporting, there was no fisheries information available for the area upstream of crossing 125194.

Table 3.5: Summary of derived upstream watershed statistics for PSCIS crossing 125194.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
125194	2.7	828	740	1432	936	914	S

* Elev P60 = Elevation at which 60% of the watershed area is above

A summary of habitat modelling outputs is presented in Table 3.6 and a map of the watershed is provided in map attachment 093J.115.

Table 3.6: Summary of fish habitat modelling for PSCIS crossing 125194.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	0.0	0.0	–
BT Spawning (km)	0.0	0.0	–
BT Network (km)	4.5	4.5	100
BT Stream (km)	4.5	4.5	100
BT Lake Reservoir (ha)	0.0	0.0	–
BT Wetland (ha)	0.0	0.0	–
BT Slopeclass03 (km)	2.8	2.8	100
BT Slopeclass05 (km)	0.8	0.8	100
BT Slopeclass08 (km)	0.0	0.0	–
BT Slopeclass15 (km)	0.7	0.7	100

* Model data is preliminary and subject to adjustments.

Stream Characteristics at Crossing

At the time of survey, PSCIS crossing 125194 was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011) (Table 3.7). Water temperature was 10°C, pH was 8 and conductivity was 180uS/cm.

Table 3.7: Summary of fish passage assessment for PSCIS crossing 125194.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2022-08-17	Crossing Sub Type	Round Culvert
PSCIS ID	125194	Diameter (m)	1.8
External ID	–	Length (m)	30
Crew	MW AI	Embedded	No
UTM Zone	10	Depth Embedded (m)	–
Easting	563293	Resemble Channel	No
Northing	6050578	Backwatered	No
Stream	tributary to Missinka River	Percent Backwatered	–
Road	Chuchinka-Missinka FSR	Fill Depth (m)	4
Road Tenure	Resource Demographic	Outlet Drop (m)	1.1
Channel Width (m)	2.4	Outlet Pool Depth (m)	0.3
Stream Slope (%)	2	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	2
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	37	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	13

Location and Stream Data	•	Crossing Characteristics	–
Comments: Very narrow cascade at outlet, big outlet drop. Good size pools downstream. Upstream has evenly distributed shale. Lots of functional woody debris. 11:09			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Stream Characteristics Downstream

The stream was surveyed downstream from crossing 125194 for 250m (Figure 3.4). The average channel width was 2.8m, the average wetted width was 2.5m, and the average gradient was 2.8%.Total cover amount was rated as moderate with small woody debris dominant. Cover was also present as large woody debris and overhanging vegetation.The dominant substrate was gravels with fines sub-dominant. There were trace amounts of undercut banks and pools that were suitable for rearing. Abundant gravels were present that would be suitable for resident rainbow spawning. There was abundant woody debris that added complexity to the stream habitat and provided cover for resident fish. The habitat was rated as medium value for salmonid rearing and spawning.

Stream Characteristics Upstream

The stream was surveyed upstream from crossing 125194 for 500m (Figure 3.5). Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation.The dominant substrate was cobbles with fines sub-dominant.The average channel width was 3.4m, the average wetted width was 2.5m, and the average gradient was 6.2%. The water was tinged brown at the time of survey; likely from beaver activity upstream. No gravels were present suitable for spawning and the substrate was composed primarily of angular rock. Several rock steps 50-60cm high were present in the first 300m of survey that would prevent upstream juvenile salmonid migration. There was a crossing modelled upstream (ID 16601526) that was accessed to check for a structure and assess habitat. There was a large beaver dam approximately 1.6m in height at this location at the time of survey. Overall, the habitat surveyed upstream of the crossing was rated as medium value as an important migration corridor containing habitat suitable for spawning with moderate rearing potential.

Conclusion

Crossing 125194 was ranked as a low priority for proceeding to design for replacement. Modelling indicates 2km of habitat upstream of crossing 125194 suitable for bull trout rearing with areas surveyed rated as medium value for rearing and spawning. However, there is a beaver dam 1.6m in height located approximately 800m upstream of this crossing. This would likely block the upstream migration of all fish species and life stages. In order to open up habitat in this system, it is recommended that beaver management methods be pursued at this location.

Table 3.8: Summary of habitat details for PSCIS crossing 125194.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
125194	Downstream	250	2.8	2.5	0.3	2.8	moderate	medium
125194	Upstream	500	3.4	2.5	0.4	6.2	moderate	medium

Figure 3.4: Left: Typical habitat downstream of PSCIS crossing 125194. Right: Example of typical stream substrate downstream of PSCIS crossing 125194.

Figure 3.5: Left: Typical habitat upstream of PSCIS crossing 125194. Right: Small rock step approximately 0.6m in height, upstream of PSCIS crossing 125194.

Figure 3.6: Left: Typical habitat upstream of PSCIS crossing 125194. Right: Beaver dam 1.6m high at modelled crossing 16601526, upstream of PSCIS crossing 125194.

3.1.3 Fern Creek - PSCIS crossing 125261

PSCIS crossing 125261 is located on Fern Creek, approximately 0.3km upstream from the confluence with the Parsnip River, at km 2.1 on the Chuchinka-Table FSR. Canfor Corporation are the road tenure holders at this site.

At crossing 125261, Fern Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 23.5km^2. The elevation of the watershed ranges from a maximum of 1137m to 730m near the crossing (Table 3.9). Fish species confirmed upstream of the FSR include burbot, rainbow trout, bull trout, sucker, reside shiner, dace and chub. A total of 148ha of lake and 37ha of wetland are modelled upstream. This includes Fern Lakes, a collection of three lakes that have a combined area of approximately 138ha. The outlet of the first lake in the chain is 3.3km upstream of the FSR.

PSCIS crossing 198321 was modelled as located on Fern Creek approximately 700m upstream of crossing 125261. However, upon visiting this location, this site was located at the end of an ATV trail and there was no structure or ford location. Additionally, the ATV trail did not continue beyond this point as the historic road was completely overgrown. There area a number of crossings modelled on the mainstem of Fern Creek upstream of the FSR however review of aerial imagery and deactivation of the road closer to that FSR provide significant weight of evidence that noe are likely to exist.

A summary of habitat modelling outputs is presented in Table 3.10 and a map of the watershed is provided in map attachment 093J.119.

Table 3.9: Summary of derived upstream watershed statistics for PSCIS crossing 125261.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
125261	23.5	730	723	1137	844	835	SSW

* Elev P60 = Elevation at which 60% of the watershed area is above

Table 3.10: Summary of fish habitat modelling for PSCIS crossing 125261.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	0.0	0.0	–
BT Spawning (km)	0.0	0.0	–
BT Network (km)	48.3	48.3	100
BT Stream (km)	38.4	38.4	100
BT Lake Reservoir (ha)	0.0	0.0	–
BT Wetland (ha)	0.0	0.0	–
BT Slopeclass03 (km)	7.2	7.2	100
BT Slopeclass05 (km)	14.9	14.9	100
BT Slopeclass08 (km)	3.9	3.9	100
BT Slopeclass15 (km)	11.5	11.5	100

* Model data is preliminary and subject to adjustments.

Stream Characteristics at Crossing

At the time of survey, PSCIS crossing 125261 was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011) (Table 3.11). The culvert has baffles in it to assist upstream fish passage. However, at the time of survey, the baffles were not functioning properly as they were not effectively holding back substrate. Rip rap at the outlet was creating a cascade approximately 0.5m in height that could block the migration of younger resident fish, depending on flow velocities. Water temperature was 17°C, pH was 8.4 and conductivity was 235uS/cm.

Table 3.11: Summary of fish passage assessment for PSCIS crossing 125261.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2022-08-15	Crossing Sub Type	Round Culvert
PSCIS ID	125261	Diameter (m)	2.1
External ID	–	Length (m)	5
Crew	MW AI	Embedded	No
UTM Zone	10	Depth Embedded (m)	–
Easting	534600	Resemble Channel	No
Northing	6067770	Backwatered	No
Stream	Fern Creek	Percent Backwatered	–
Road	Chuchinka-Table FSR	Fill Depth (m)	0.8
Road Tenure	Resource Demographic	Outlet Drop (m)	0.4
Channel Width (m)	5.1	Outlet Pool Depth (m)	0.4
Stream Slope (%)	2	Inlet Drop	No
Beaver Activity	No	Slope (%)	1.5
Habitat Value	High	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10

Location and Stream Data	•	Crossing Characteristics	–
Comments: Culvert has baffles in it but has significant riprap at the outlet that creates cascade approximately 0.5 m high. 14:36			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Stream Characteristics Downstream

The stream was surveyed downstream from crossing 125261 for 150m (Figure 3.7). The average channel width was 5.6m, the average wetted width was 4.1m, and the average gradient was 1%.The dominant substrate was gravels with fines sub-dominant.Total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, overhanging vegetation, and instream vegetation. Extensive gravels were found in the first 150 m surveyed downstream. The habitat then transitions to a wetland type, with depths of up to 1m on the floodplain. The habitat was rated as high value for salmonid rearing and spawning.

Stream Characteristics Upstream

The stream was surveyed upstream from crossing 125261 for 700m (Figure 3.8). The dominant substrate was gravels with cobbles sub-dominant.Total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, undercut banks, and overhanging vegetation.The average channel width was 6.2m, the average wetted width was 2.4m, and the average gradient was 2.3%. This is a large stream with abundant gravel suitable for spawning and deep pools for overwintering. Numerous fish were observed, the habitat was stable with large woody debris found throughout, and there were abundant undercut banks. At the end of the survey, a stream crossing was listed in the PSCIS database (ID 198321). Upon investigation, it was concluded that this crossing was deavticated (Figure 3.10). Overall, the habitat surveyed upstream of crossing 125261 was rated as high value as an important migration corridor containing habitat suitable for spawning with moderate rearing potential.

Conclusion

Modelling indicates that there is 14.4km of habitat upstream of crossing 125261 suitable for bull trout rearing with areas surveyed rated as high value for rearing and spawning. Crossing 125261 was ranked as a high priority for proceeding to design for replacement. Due to the lack of historic fisheries information upstream of the crossing, it is recommended that electrofishing be conducted in this area. Fish were spotted on the habitat survey upstream in 2022. Future fish sampling would help confirm migration patterns of resident populations. Additionally, it is recommended that Fern Creek be surveyed further upstream to confirm the presence (or absence) of barriers between crossing 125261 and Fern Lakes.

Table 3.12: Summary of habitat details for PSCIS crossing 125261.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
125261	Downstream	150	5.6	4.1	0.3	1.0	moderate	high
125261	Upstream	700	6.2	2.4	0.5	2.3	moderate	high

Figure 3.7: Left: Habitat downstream of PSCIS crossing 125261. Right: Transition to wetland type habitat, downstream of PSCIS crossing 125261.

Figure 3.8: Left: Habitat upstream of PSCIS crossing 125261. Right: Habitat upstream of PSCIS crossing 125261.

Figure 3.9: Left: Deep pool and functional woody debris upstream of PSCIS crossing 125261. Right: Habitat upstream of PSCIS crossing 125261.

Figure 3.10: Left: Downstream view at end of survey, at location of PSCIC crossing 198321. Right: Upstream view at end of survey, at location of PSCIS crossing 198321.

3.2 Planned Remediations

3.2.1 Tributary to Parsnip River - PSCIS crossing 125000

PSCIS crossing 125000 is located on a tributary to Parsnip River, approximately 2km upstream of the confluence with the Parsnip River, on the Chuchinka-Arctic FSR. This site is situated approximately 9km north-west of the outlet of Arctic Lake. Arctic Lake is located within Arctic Pacific Lakes Provincial Park and has an area of 112ha. The park has significant historical and recreational values and is located on Mcleod Lake indian band reservation lands. The lake supports a diverse population of fish, including lake trout, bull trout, rainbow trout, kokanee, dolly varden, mountain whitefish, redside shiner, lake char, and chinook salmon, and arctic grayling (BC Parks 2020). At crossing 125000, this tributary to Parsnip River is a third order stream with a watershed area upstream of the crossing of approximately 0.2km^2. The elevation of the watershed ranges from a maximum of 862m to 771m near the crossing (Table 3.13). There are no other stream crossings on the mainstem of this stream that block fish passage. Rainbow trout and sculpin have been captured in the past both upstream and downstream of the crossing. A map of the watershed is provided in map attachment 93I.111.

PSCIS crossing 125000 was ranked as a high priority for remediation following habitat confirmations done by A. Irvine (2020) in 2019. At that time, there was an estimated 3.5km of habitat with a gradient less than 5% available upstream of the crossing. Habitat was rated as high value for salmonid rearing and spawning. Fish sampling done in 2019 confirmed that rainbow trout and sculpin were found downstream of the crossing. There were no fish captured upstream of the crossing. At the time of survey in 2019, the culvert was a complete barrier to upstream fish passage, having an outlet drop of 0.4m and a outlet pool depth of 1.5m. A detailed overview of stream characteristics and habitat details can be found in the 2019 report.

This site was reassessed in 2021, with drone survey and fish sampling conducted. At the time of survey in 2021, PSCIS crossing 125000 was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage. This culvert is very undersized which is evidenced by the large outlet drop of 0.6m and outlet pool depth of 2m.

Table 3.13: Summary of derived upstream watershed statistics for PSCIS crossing 125000.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
125000	0.2	773	771	862	834	825	ENE

* Elev P60 = Elevation at which 60% of the watershed area is above

Table 3.14: Summary of fish habitat modelling for PSCIS crossing 125000.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	0.0	0.0	–
BT Spawning (km)	0.0	0.0	–
BT Network (km)	13.4	13.4	100
BT Stream (km)	12.7	12.7	100
BT Lake Reservoir (ha)	0.0	0.0	–
BT Wetland (ha)	0.0	0.0	–
BT Slopeclass03 (km)	2.0	2.0	100
BT Slopeclass05 (km)	1.9	1.9	100
BT Slopeclass08 (km)	4.7	4.7	100
BT Slopeclass15 (km)	2.8	2.8	100

* Model data is preliminary and subject to adjustments.

Aerial Imagery

In 2019 a video survey was conducted by drone and can be viewed here. In the summer of 2022, additional surveys were conducted with a remotely piloted aircraft at the crossing with resulting images stitched into an orthomosaic and 3-dimensional model presented here and here.

Fish Sampling

Electrofishing was conducted with results summarised in Tables 3.15 - 3.16 and Figure 3.11. Rainbow trout and sculpin were captured both upstream and downstream of the crossing. There was only one adult fish caught (rainbow), with the rest of the fish captured being parr, fry or juveniles. The majority of fish caught were tagged using Passive Integrated Transponders (PIT), with the exception of smaller fish for risk of causing harm.

Table 3.15: Fish sampling site summary for 125000.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
125000_ds_ef1	1	28	3.2	89.6	Open
125000_ds_ef2	1	7	3.0	21.0	Open
125000_ds_ef3	1	5	2.9	14.5	Open
125000_us_ef1	1	8	2.0	16.0	Open
125000_us_ef2	1	23	3.3	75.9	Open
125000_us_ef3	1	21	2.9	60.9	Open

Table 3.16: Fish sampling density results summary for 125000.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
125000_ds_ef1	CC	fry	3	3.3	FALSE
125000_ds_ef1	CC	parr	1	1.1	FALSE
125000_ds_ef1	RB	fry	20	22.3	FALSE
125000_ds_ef1	RB	parr	13	14.5	FALSE
125000_ds_ef1	RB	juvenile	3	3.3	FALSE
125000_ds_ef2	CC	fry	2	9.5	FALSE
125000_ds_ef2	RB	fry	3	14.3	FALSE
125000_ds_ef2	RB	parr	5	23.8	FALSE
125000_ds_ef3	RB	fry	1	6.9	FALSE
125000_ds_ef3	RB	parr	7	48.3	FALSE
125000_ds_ef3	RB	juvenile	1	6.9	FALSE
125000_us_ef1	RB	fry	2	12.5	FALSE
125000_us_ef1	RB	parr	1	6.2	FALSE
125000_us_ef1	RB	adult	1	6.2	FALSE
125000_us_ef2	CC	parr	1	1.3	FALSE
125000_us_ef2	RB	fry	2	2.6	FALSE
125000_us_ef2	RB	parr	1	1.3	FALSE
125000_us_ef2	RB	juvenile	5	6.6	FALSE
125000_us_ef3	CC	fry	1	1.6	FALSE
125000_us_ef3	RB	fry	1	1.6	FALSE
125000_us_ef3	RB	parr	4	6.6	FALSE

* nfc_pass FALSE means fish were captured in final pass indicating more fish of this species/lifestage may have remained in site. Mark-recaptured required to reduce uncertainties.

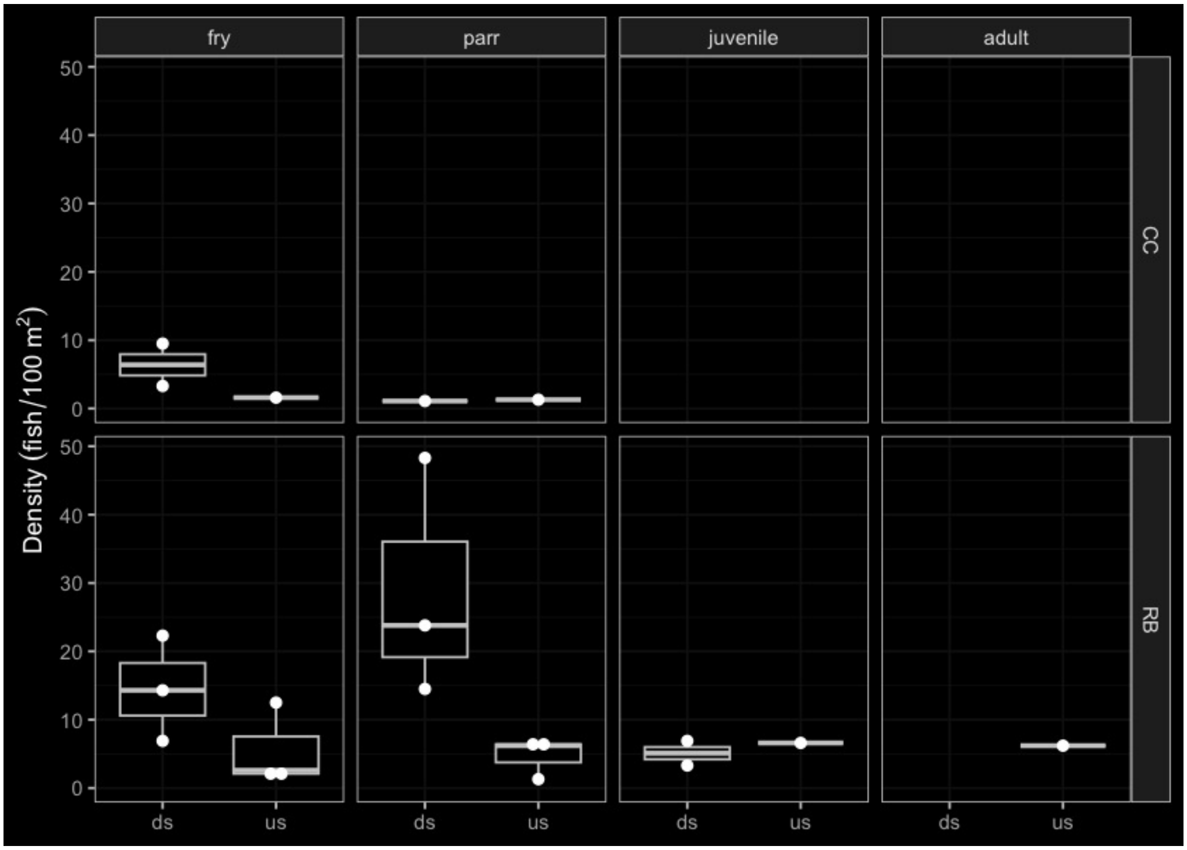

Figure 3.11: Densites of fish (fish/100m2) captured upstream of PSCIS crossing 125000.

3.3 Completed Remediations

3.3.1 Tributary to Missinka River - PSCIS crossing 125179

PSCIS crossing 125179 is located on a tributary to Missinka River, 1km upstream of the confluence, on the Chuchinka-Missinka FSR. The road tenure holder is the Ministry of Forests. This crossing is located approximately 660m east of PSCIS crossing 125180 and joins this adjacent stream just before emptying into the Missinka River. A map of the watershed is provided in map attachment 93I.117. This crossing has been remediated, with a bridge installed in the summer of 2022.

This site was first assessed by A. Irvine (2020) in 2019. At that time, there were two culverts side by side. The crossing was ranked as a high priority for follow up due to the 2km of suitable upstream high value habitat, where the presence of bull trout and rainbow trout had been previously confirmed. This watershed was classified as fisheries sensitive under the Forest Practices and Range Act (FRPA) regulations due to downstream bull trout and arctic grayling. As stated in A. Irvine (2022), further reasons for restoration at this site include the fact that “the Missinka River watershed is utilized by a possibly genetically distinct, self-sustaining dusk’ihje (Arctic grayling) population with the mainstem of the river providing critical habitat for fry and adult fish." Additionally, regions accessed by the Chuchinka-Missinka FSR provided major harvesting and silviculture obligations. Site plan designs were developed thanks to the ongoing communication and collaboration between SERNBC, Mcleod Lake Indian Band, Sinclair Group, and FLNR. Photos showing a comparison of the culvert assessment conducted in 2019 versus the completed bridge construction in 2022 are presented in Figure 3.8.

Figure 3.12: Left: Photos of crossing 125179 in 2019. Right: Photos of crossing 125179 in 2022.

In the summer of 2022, a monitoring survey was conducted with a remotely piloted aircraft at crossing 125179, with resulting images stitched into an orthomosaic and 3-dimensional model presented here and here.

Recommendations

Following the remediation of crossing 125179, it is recommended that future monitoring be conducted at this location. This would help track the stream's morphological changes over time, as well as provide insight into the fish migration patterns in this system. Electrofishing and tagging target species in this stream would aid in gaining a higher understanding into fish movements.

Additionally, fishing and monitoring in the adjacent stream (at PSCIS crossing 125180) would also be key in providing a reference site.

Appendix - Phase 1 Fish Passage Assessment Data and Photos

Location and Stream Data	•	Crossing Characteristics	–
Date	2022-08-14	Crossing Sub Type	Bridge
PSCIS ID	198320	Diameter (m)	15.3
External ID	16603769	Length (m)	5
Crew	AI MW	Embedded	–
UTM Zone	10	Depth Embedded (m)	–
Easting	537168	Resemble Channel	–
Northing	6075496	Backwatered	–
Stream	tributary to Anzac River	Percent Backwatered	–
Road	Fern Valley	Fill Depth (m)	–
Road Tenure	–	Outlet Drop (m)	–
Channel Width (m)	–	Outlet Pool Depth (m)	–
Stream Slope (%)	–	Inlet Drop	–
Beaver Activity	No	Slope (%)	–
Habitat Value	–	Valley Fill	–
Final score	0	Barrier Result	Passable
Fix type	–	Fix Span / Diameter	–

Location and Stream Data	•	Crossing Characteristics	–
Comments: Bridge, overgrown vegetation at inlet and outlet. 16:35:00			
Photos: PSCIS ID 198320. From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–
Date	2022-08-15	Crossing Sub Type	Ford
PSCIS ID	198321	Diameter (m)	–
External ID	16601271	Length (m)	–
Crew	AI	Embedded	–
UTM Zone	10	Depth Embedded (m)	–
Easting	535101	Resemble Channel	–
Northing	6068381	Backwatered	–
Stream	Fern Creek	Percent Backwatered	–
Road	Spur	Fill Depth (m)	–
Road Tenure	Unclassified	Outlet Drop (m)	–
Channel Width (m)	–	Outlet Pool Depth (m)	–
Stream Slope (%)	–	Inlet Drop	–
Beaver Activity	No	Slope (%)	–
Habitat Value	–	Valley Fill	–
Final score	0	Barrier Result	Unknown
Fix type	–	Fix Span / Diameter	–

Location and Stream Data	•	**Crossing Characteristics**	–
Comments: No ford or crossing. This appears to be the end of the accessible remnants of this rough ATV road. 17:06			
Photos: PSCIS ID 198321. From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2022-08-17	Crossing Sub Type	Ford
PSCIS ID	198322	Diameter (m)	–
External ID	2022081750	Length (m)	–
Crew	MW AI	Embedded	–
UTM Zone	10	Depth Embedded (m)	–
Easting	575104	Resemble Channel	–
Northing	6051021	Backwatered	–
Stream	tributary to Missinka River	Percent Backwatered	–
Road	Chuchinka-missinka FSR	Fill Depth (m)	–
Road Tenure	Unclassified	Outlet Drop (m)	–
Channel Width (m)	–	Outlet Pool Depth (m)	–
Stream Slope (%)	–	Inlet Drop	–
Beaver Activity	Yes	Slope (%)	–
Habitat Value	–	Valley Fill	–
Final score	0	Barrier Result	Unknown
Fix type	–	Fix Span / Diameter	–

Location and Stream Data	•	**Crossing Characteristics**	–
Comments: Located at a quad trail. 13:53			
Photos: PSCIS ID 198322. From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

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Session Info

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Running under: , RStudio 2023.3.0.386

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en_US.UTF-8

Package version:
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backports_1.4.1
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