SOCIETY FOR ECOSYSTEM RESTORATION IN NORTHERN BRITISH COLUMBIA

Restoring Fish Passage in the Peace Region - 2024

PEA-F24-F-3944-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

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new graph environment

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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.

Executive Summary

This report is available as a PDF and as an online interactive report at https://www.newgraphenvironment.com/fish_passage_peace_2024_reporting/. We recommend viewing online as the web-hosted HTML version contains more features and is more easily navigable. Please reference the website for the latest version stamped PDF from fish_passage_peace_2024_reporting.pdf.

Since 2019, the Society for Ecosystem Restoration in Northern BC (SERNbc) is working together with the McLeod Lake Indian Band, the Peace Region Fish and Wildlife Compensation Program (FWCP), the Provincial Fish Passage Technical Working Group (FPTWG), road/rail tenure holders and other stakeholders/partners to prioritize, plan and fund the restoration of fish passage at road crossing structure barriers within the Parsnip River, Carp River and Crooked River watershed groups.

The primary objective of this project is to identify and prioritize fish passage barriers within these study areas, develop comprehensive restoration plans to address these barriers, and foster momentum for broader ecosystem restoration initiatives. While the primary focus is on fish passage, this work also serves as a lens through which to view the broader ecosystems, leveraging efforts to build capacity for ecosystem restoration and improving our understanding of watershed health. We recognize that the health of life - such as our own - and the health of our surroundings are interconnected, with our overall well-being dependent on the health of our environment.

Although the main purpose of this report is to document 2024 field work data and results, it also builds on reporting from field activities conducted from 2020 to 2023. In addition to the numerous assessments at sites undocumented in past years of the project, field activities in 2024 were also conducted at sites where habitat confirmations were previously documented within the reports linked below.

- Parsnip River Watershed – Fish Habitat Confirmations (PEA-F20-F-2967) (Irvine 2020)
- PEA-F22-F-3577-DCA Restoring Fish Passage in the Peace Region (Irvine 2022)
- Restoring Fish Passage in the Peace Region - 2022 - PEA-F23-F-3761-DCA (Irvine and Winterscheidt 2023)
- Restoring Fish Passage in the Peace Region - 2023 (Irvine and Winterscheidt 2024)

Fish passage assessment procedures conducted through SERNbc in the Peace River Watershed since 2020 are amalgamated online within the Results and Discussion section of the report found here which includes links to project reporting for each site.

In 2024, fish passage assessments were completed at 15 sites (11 new Phase 1 sites and 4 reassessments), focusing on structures with potential barriers to upstream fish movement using standard provincial criteria.

Habitat confirmation assessments were conducted at multiple sites within the Crooked and Carp River watersheds, covering over 2 km of stream length. Detailed habitat metrics were documented alongside electrofishing surveys to evaluate habitat quality and presence of fish species.

Fish sampling occurred at 16 sites across 6 streams, yielding 319 fish captures. All fish were measured for fork length and weight, with life stages classified by size. Salmonids over 60 mm were PIT-tagged under a scientific permit to support long-term tracking of individual fish health and movement.

Monitoring was conducted at four sites, including post-remediation evaluations at PSCIS crossings 125179 and 125231. Monitoring included electrofishing, habitat observations, and UAV-based imagery. A custom effectiveness monitoring form was developed, drawing from the Forest Investment Account (2003) framework but tailored to fish passage projects. Metrics assessed included flow velocity, substrate condition, channel constriction, riparian condition, and cover availability.

A major challenge in advancing fish passage restoration is the complexity of working across jurisdictions and with multiple stakeholders—rail and highway authorities, forestry ministries, licensees, and private landowners. These partners are often being asked to accommodate priorities that originate outside their mandates and budgets. Convincing them to invest in difficult, high-cost interventions—like modifying crossings or relocating infrastructure—requires navigating uncertainty about costs and ecological outcomes, as well as a disconnect between the benefits to watershed health and the internal pressures or performance goals of these agencies. It's a tough ask: to take on massive, uncertain projects when they're already stretched thin with their own responsibilities.

Fish passage restoration across British Columbia is further complicated by the legacy of infrastructure deeply embedded in the landscape. Roads, railways, highways, community infrastructure and private assets often constrain floodplains and disrupt natural hydrological processes. While targeted repairs to individual barriers are essential, they won't resolve the broader systemic issues without rethinking and restructuring how infrastructure interacts with watershed function. Loss of riparian vegetation and intensive beaver management only add to the degradation. Addressing these challenges means making strategic, well-communicated choices—picking battles carefully, building trust, and staying committed to a longer-term transformation.

While preliminary top remediation priorities are provided by watershed group, these rankings are inherently subjective and can depend on the capacity and willingness of infrastructure owners and tenure holders to support implementation—both financially and over the often multi-year project timelines. In practice, we must often act opportunistically, pursuing simpler, lower-cost options to maintain momentum and achieve near-term progress.

To enhance fish passage restoration in the FWCP Peace Region:

- Maintain strong partnerships to support funding, site selection, remediation, and monitoring through adaptive management informed by traditional knowledge and real-time data.
- Prioritize detailed assessments in areas with blockages and high habitat potential, especially near McLeod Lake.
- Use climate modeling to prioritize crossings that enable access to cold, drought-resistant habitats.
- Secure financial commitments for Fern Creek remediation despite uncertainties in harvest planning.
- Continue effectiveness monitoring at key sites using fish sampling, eDNA, PIT tagging, temperature data, and aerial imagery.
- Continue to develop a cost-effective monitoring framework to assess productivity gains from improved passage.
- Collaborate with WLRS, UNC, local fisheries experts, FWCP, and the CEMPRA Project working group.
- Utilize environmental DNA (eDNA) to better understand bull trout and Arctic grayling habitat use at both potential and remediated sites. This will refine prioritization and assess fish passage effectiveness.

1 Introduction

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The health and viability of freshwater fish populations can depend on access to tributary and off channel areas which provide refuge during high flows, opportunities for foraging, overwintering habitat, spawning habitat and summer rearing habitat (Bramblett et al. 2002; Swales and Levings 1989; Diebel et al. 2015). Culverts can present barriers to fish migration due to low water depth, increased water velocity, turbulence, a vertical drop at the culvert outlet and/or maintenance issues (Slaney, Zaldokas, and Watershed Restoration Program (B.C.) 1997; Cote et al. 2005). As road crossing structures are commonly upgraded or removed there are numerous opportunities to restore connectivity by ensuring that fish passage considerations are incorporated into repair, replacement, relocation and deactivation designs.

The Society for Ecosystem Restoration in Northern BC (SERNbc) is working together with the McLeod Lake Indian Band, the Peace Region Fish and Wildlife Compensation Program (FWCP), the Provincial Fish Passage Technical Working Group (FPTWG), road/rail tenure holders and other stakeholders/partners to prioritize, plan and fund the restoration of fish passage at road crossing structure barriers within the Parsnip River, Carp River and Crooked River watershed groups.

This project builds on Society for Ecosystem Restoration Northern BC (SERNbc) work in:

- Parsnip River Watershed – Fish Habitat Confirmations (PEA-F20-F-2967) (Irvine 2020)
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- Restoring Fish Passage in the Peace Region - 2023 (Irvine and Winterscheidt 2024)

Through this year’s project activities (2024/2025) we engaged numerous project partners and were able to identify, complete and catalyze fish passage restoration activities at multiple priority sites.

Through the ongoing development of open source analysis, data presentation and project collaboration tools we are identifying new restoration opportunities, clarifying restoration benefits, communicating with the broader community and implementing on the ground works.

This document can be considered a living document. Version numbers are logged for each release with modifications, enhancements, and other changes tracked in the Changelog (page 79) with issues and proposed/planned enhancements tracked here.

2 Background

2.1 Project Location

The study area includes the FWCP Peace Region with a focus to date on traditional territories of the Tse'khene First Nations. In 2024, field assessments were completed with the Parsnip River, Carp River and Crooked River watershed groups (Figure 2.1).

In 2019/2020, following a literature review, analysis of fish habitat modelling data, the Provincial Stream Crossing Inventory System (PSCIS) and a community scoping exercise within the McLeod Lake Indian Band habitat confirmation assessments were conducted at 17 sites throughout the Parsnip River watershed with 10 crossings rated as high priorities for rehabilitation and three crossings rated as moderate priorities for restoration. An engineering design for site 125179 on a tributary to the Missinka River was also completed through the 2019/2020 project. In 2021/2022, project activities reconvened through FWCP directed project PEA-F22-F-3577-DCA. Partners were engaged, funding was raised, planning was conducted and reporting was completed to initiate restoration activities of high priority crossings. Materials were purchased and permitting was put in place to prep for replacement of the twin culverts on the Missinka River tributary with a clear-span bridge.

In 2024/2025, this collaborative project leveraged ongoing connectivity restoration initiatives in the province and engaged multiple partners to catalyze fish passage restoration activities at high-priority sites identified in from 2019-2023. Key accomplishments include the replacement of PSCIS crossing 125231 on a tributary to the Table River and field assessments including effectiveness monitoring at PSCIS crossing 125179 which was replaced in 2022.

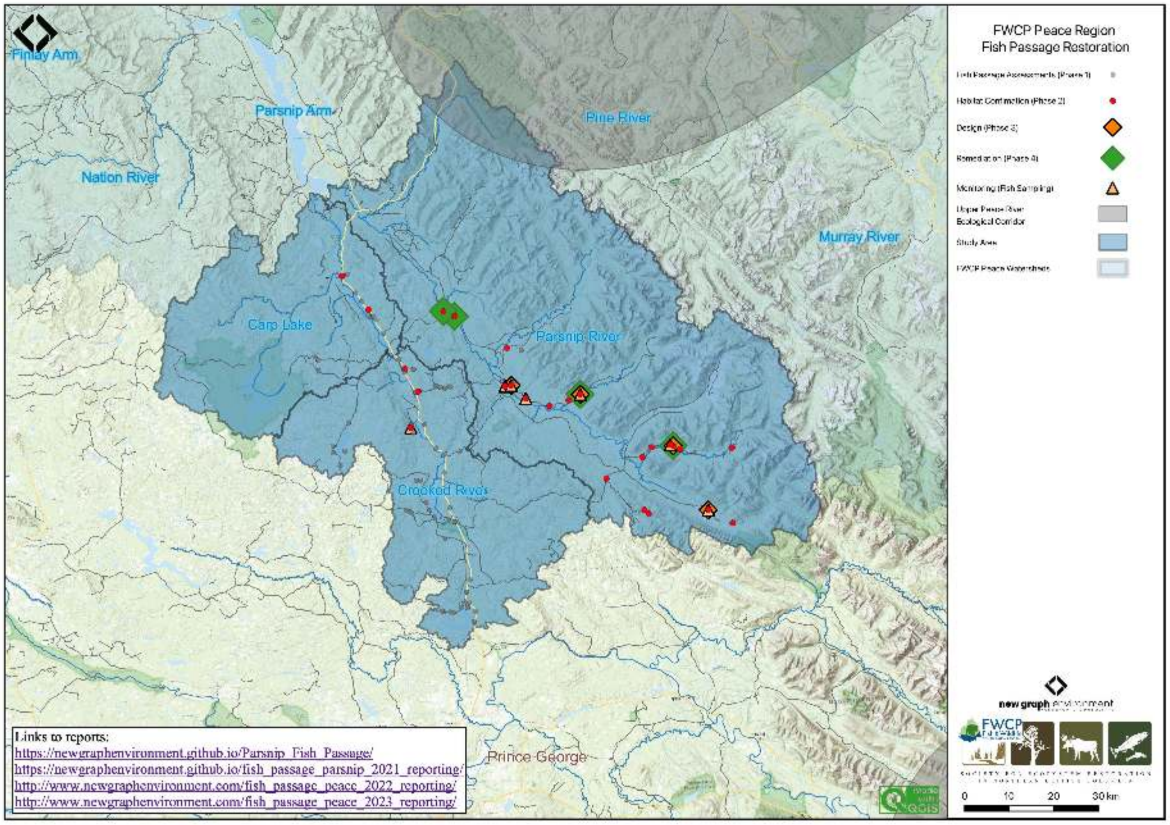

Figure 2.1: Overview map of Study Area

2.2 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 2.1). 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 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 (Figure 2.2).

Construction of the 183m high and 2134m 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 et al. 2019; Stamford, Hagen, and Williamson 2017). 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.

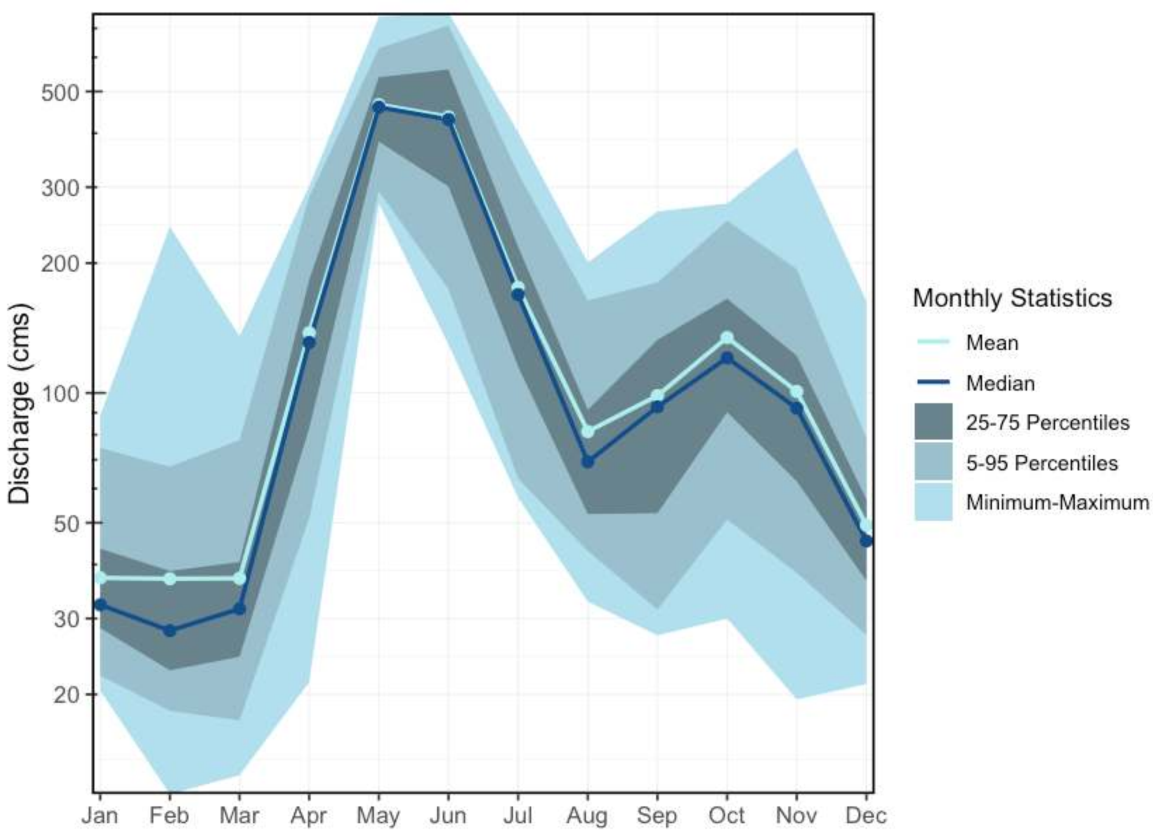

Figure 2.2: Hydrograph for Parsnip River above Misinchinka River (Station #07EE007).

2.3 Fisheries

Fish species recorded in the Parsnip River watershed are detailed in Table 2.1 (MoE 2019). 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 2017; 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 Wildlife 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 2.1: Fish species recorded in the Parsnip River, Carp Lake, and Crooked River watershed groups.

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA	Parsnip	Carp	Crooked
Catostomus catostomus	Longnose Sucker	LSU	Yellow	–	–	–	Yes	Yes	Yes
Catostomus columbianus	Bridgelip Sucker	BSU	Yellow	–	–	–	–	–	Yes
Catostomus commersonii	White Sucker	WSU	Yellow	–	–	–	Yes	Yes	Yes
Catostomus macrocheilus	Largescale Sucker	CSU	Yellow	–	–	–	Yes	Yes	Yes
Coregonus clupeaformis	Lake Whitefish	LW	Yellow	–	–	–	Yes	Yes	Yes
Cottus aleuticus	Coastrange Sculpin (formerly Aleutian Sculpin)	CAL	Yellow	–	–	–	Yes	–	–
Cottus asper	Prickly Sculpin	CAS	Yellow	–	–	–	Yes	Yes	Yes
Cottus cognatus	Slimy Sculpin	CCG	Yellow	–	–	–	Yes	Yes	–
Cottus hubbsi	Mottled Sculpin	CBA	Blue	–	SC (Nov 2010)	1-SC (Jun 2003)	Yes	–	–
Couesius plumbeus	Lake Chub	LKC	Yellow	–	DD	–	Yes	Yes	Yes
Esox lucius	Northern Pike	NP	Yellow	–	–	–	–	–	Yes
Hybognathus hankinsoni	Brassy Minnow	BMC	No Status	–	–	–	–	Yes	Yes
Lota lota	Burbot	BB	Yellow	–	–	–	Yes	Yes	Yes
Mylocheilus caurinus	Peamouth Chub	PCC	Yellow	–	–	–	Yes	Yes	Yes

2.3 Fisheries

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA	Parsnip	Carp	Crooked
Oncorhynchus nerka	Kokanee	KO	Yellow	–	–	–	Yes	–	–
Osmerus dentex	Rainbow Smelt	RSM	Unknown	–	–	–	Yes	–	–
Prosopium coulterii	Pygmy Whitefish	PW	Yellow	–	NAR (Nov 2016)	–	Yes	–	–
Prosopium cylindraceum	Round Whitefish	RW	Yellow	–	–	–	Yes	–	–
Prosopium williamsoni	Mountain Whitefish	MW	Yellow	–	–	–	Yes	Yes	Yes
Ptychocheilus oregonensis	Northern Pikeminnow	NSC	Yellow	–	–	–	Yes	Yes	Yes
Rhinichthys cataractae	Longnose Dace	LNC	Yellow	–	–	–	Yes	–	Yes
Richardsonius balteatus	Redside Shiner	RSC	Yellow	–	–	–	Yes	Yes	Yes
Salvelinus confluentus	Bull Trout	BT	Blue	Y (Jun 2006)	SC (Nov 2012)	–	Yes	Yes	Yes
Salvelinus fontinalis	Brook Trout	EB	Exotic	–	–	–	Yes	–	Yes
Salvelinus malma	Dolly Varden	DV	Yellow	–	–	–	Yes	Yes	Yes
Salvelinus namaycush	Lake Trout	LT	Yellow	–	–	–	Yes	Yes	Yes
Thymallus arcticus	Arctic Grayling	GR	Yellow	–	–	–	Yes	–	–
–	Chub (General)	CBC	–	–	–	–	Yes	Yes	Yes
–	Dace (General)	DC	–	–	–	–	Yes	–	–
–	Minnow (General)	C	–	–	–	–	Yes	Yes	Yes
–	Sculpin (General)	CC	–	–	–	–	Yes	Yes	Yes
–	Squanga	SQ	–	–	–	–	–	–	Yes
–	Sucker (General)	SU	–	–	–	–	Yes	Yes	Yes
–	Whitefish (General)	WF	–	–	–	–	Yes	Yes	Yes

* COSEWIC abbreviations :
SC - Special concern
DD - Data deficient
NAR - Not at risk

BC List definitions :
Yellow - Species that is apparently secure
Blue - Species that is of special concern
Exotic - Species that have been moved beyond their natural range as a result of human activity

Bull Trout - sa’ba

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 et al. 2019) .

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 adfluvial (large bodied) bull trout spawners. The Table River was also highlighted as an important spawning destination. 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, 2013c). 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 Range Practices Act 2018).

Arctic Grayling - dusk'ihje

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 et al. 2019).

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). Rapid increases in industrial activity and angler access in the Parsnip River watershed pose significant risks to Arctic Grayling productivity with these threats primarily linked to forestry and pipeline initiatives (Hagen and Stamford 2021).

A detailed review of dusk'ihje life history can be referenced in Stamford, Hagen, and Williamson (2017). 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 2017). 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 and 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). In 2019, preliminary telemetry results indicate that both Arctic grayling and bull trout rely on the Parsnip River mainstem for overwinter residencies. Arctic grayling move into the tributaries beginning in April, and become widespread across the watershed by June.

A 5 year study on Parsnip River watershed dusk'ihje abundance and trend are discussed in Hagen and Stamford (2023) where they report that the most productive habitats for Arctic grayling summer rearing are within the Anzac River and Table River. Although estimated abundance is lower than in the Anzac and Table, productive summer rearing habitats for adult Arctic grayling in the upper Parsnip River watershed are distributed between 36-25 km of the Missinka River and from 48-32 km of the Hominka River. Hagen and Stamford (2021) report that within the Anzac River, a 30-km stretch from a chute obstruction at 47 km to 16 km is assumed to provide productive summer rearing habitats for adults as it is characterized by a high abundance of Arctic grayling. Although the spatial distribution of high Arctic grayling abundance in the Table River has not been determined through reconnaissance surveys it has been observed to span at least a 20-km zone from the waterfall migration barrier at 37 km to 18 km.

Spatial ecology studies in the Parsnip between 2018 and 2021 has been reported on by Martins et al. (2022) with results related to:

- temperature modeling and spatio-temporal patterns in thermal habitat,
- telemetry data modeling and arctic grayling spatial ecology, and
- trophic relationships between Arctic grayling and bull trout

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 2.3 - 2.5). 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 2.2: Summary of historic fish 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

species_code	Gradient	Count	total_spp	Percent
RB	08 - 15 %	27	415	7
RB	15 - 22 %	7	415	2

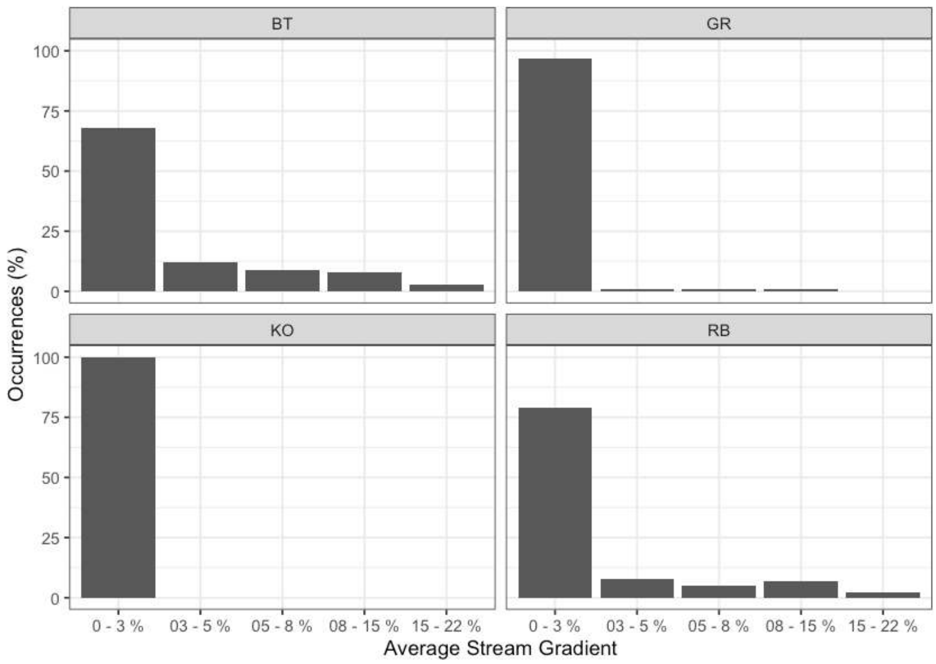

Figure 2.3: Summary of historic fish observations vs. stream gradient category for the Parsnip River watershed group.

Table 2.3: Summary of historic fish 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

species_code	Width	Count	total_spp	Percent
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
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

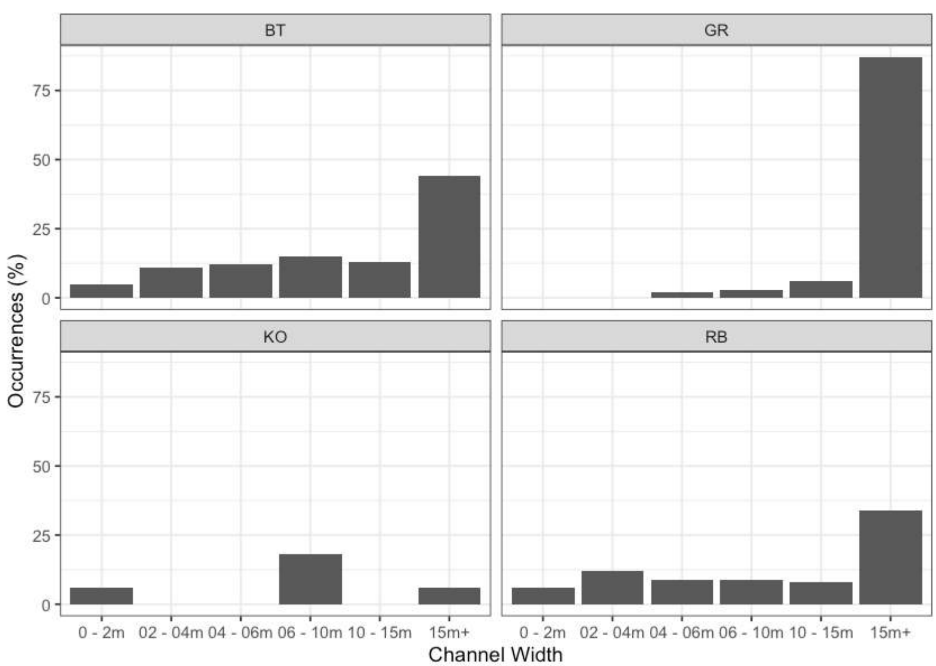

Figure 2.4: Summary of historic fish observations vs. channel width category for the Parsnip River watershed group.

Table 2.4: Summary of historic fish 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
GR	75 - 100km2	6	230	3
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

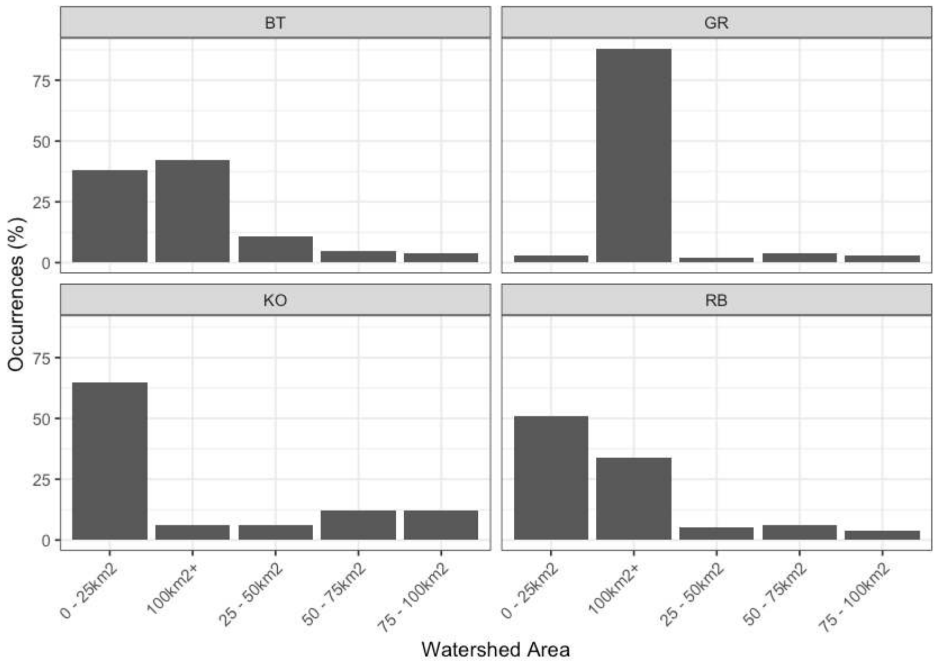

Figure 2.5: Summary of historic fish observations vs. watershed size category for the Parsnip River watershed group.

3 Methods

3.1 Collaborative GIS Environment

Geographical Information Systems are essential for developing and communicating restoration plans as well as the reasons they are required and how they are developed. Without the ability to visualize the landscape and the data that is used to make decisions, it is difficult to conduct and communicate the need for restoration, the details of past and future plans as well as and the potential results of physical works.

To facilitate the planning and implementation of restoration activities, a collaborative GIS environment has been established using QGIS and is served on the cloud using source code stored here. This environment is intended to be a space where project team members can access, view, and contribute to the amalgamation of background spatial data and the development of restoration as well as monitoring for the project. The collaborative GIS environment allows users to view, edit, and analyze shared, up to date spatial data on personal computers in an office setting as well as on phones and tablets in the field. At the time of reporting, the environment was being used to develop and share maps, conduct spatial analyses, communicate restoration plans to stakeholders as well as to provide a central place to store methodologies and tools for conducting field assessments on standardized pre-developed digital forms. The platform can also be used to track the progress of restoration activities and monitor changes in the landscape over time, helping encourage the record keeping of past and future restoration activities in a coordinated manner.

The shared QGIS project was created using scripts currently kept in `dff-2022` with the precise calls to project creation scripts tracked in the `project_creation_and_permissions.txt` document kept in the main QGIS project directory. Information about the scripts used for GIS project creation and updates can be viewed here with outcomes of their use summarized below:

- Download and clip user specified layers from the BC Data Catalogue as well as data layers stored in custom Amazon Web Services buckets for an area of interest defined by a list of watershed groups and load to a geopackage called `background_layers.gpkg` stored in the main directory of the project.
- A project directory is created to hold the spatial data and `QGIS` project information (ie. layer symbology and naming conventions, metadata, etc.).
- Metadata for individual project spatial layers is kept in the `rfp_tracking` table within the `background_layers.gpkg` along with tables related to user supplied stream width/gradient inputs to `bcfishpass` to model potentially high value habitat that is accessible to fish species of interest.

3.1.1 Mapping

The workflows to produce the georeferenced `pdf` maps include using a QGIS layer file defining and symbolizing all layers required and are continuously evolving. At the time of reporting - mapping scripts and associated layer file were kept under version control within `bcfishpass` here. Loading the QGIS layer file within a QGIS project, allows load and representation of all map component layers provided the user points to a postgresql database populated via `bcfishpass` outputs.

3.2 Planning

3.2.1 Habitat Modelling

Habitat modelling used to help guide planning for field assessments is generated by `bcfishpass` (Norris [2020] 2024) which has been designed to prioritize potential fish passage barriers for assessment or remediation by generating a simple model of aquatic habitat connectivity. We utilize the `bcfishpass` access model, linear spawning/rearing habitat model and lateral habitat connectivity for planning purposes. These models provide a valuable starting point, but their results are not definitive and should always be considered with professional judgment. Detailed information regarding model methodology, select parameters and known model limitations are detailed in Norris ([2020] 2024) with key documentation linked below:

- Access model
- Linear spawning/rearing habitat models
- Lateral habitat model

Table 3.1 documents the custom species-specific thresholds for stream gradient and channel width applied to the linear spawning and rearing habitat model for this year's project planning.

Table 3.1: Stream gradient and channel width thresholds used to model potentially highest value fish habitat.

Variable	Bull Trout	Arctic Grayling
Spawning Gradient Max (%)	5.5	2.5
Spawning Width Min (m)	2	4
Rearing Width Min (m)	1.5	1.5
Rearing Gradient Max (%)	10.5	3.5

*

3.2.1.1 Statistical Support for `bcfishpass` Fish Habitat Modelling Updates

This project provided the statistical background for updates to `bcfishpass` that facilitated incorporation of channel width (observed or predicted) into species specific linear spawning/rearing habitat models. In early 2021, Bayesian statistical methods were developed to predict channel width in all provincial freshwater atlas stream segments where width measurements had not previously been measured in the field. The model was based on the relationship between watershed area and mean annual precipitation weighted by upstream watershed area (Thorley and Irvine 2021). In December of 2021, Thorley and Irvine (2021) methods were updated using a power model derived by Finnegan et al. (2005) which relates stream discharge to watershed area and mean annual precipitation resulting in Thorley, Norris, and Irvine (2021) which was utilized for channel width estimates within `bcfishpass` modelling at the time of reporting. More detailed documentation of the methodology used to facilitate both the data collection and statistical analysis can be sourced in Irvine ([2021] 2022) and Thorley, Norris, and Irvine (2021).

In 2024, in collaboration with Poisson Consulting - stream discharge and temperature causal effects pathways were mapped with the intent of focusing aquatic restoration actions in areas of highest potential for positive impacts on fisheries values (ie. elimination of areas from intrinic models where water temperatures are likely too cold to support fish production). The project began with a custom mechanistic model (visually represented here), but the model struggled to converge. The project then shifted to the air2stream model, which offers a middle ground between fully mechanistic models—often data-intensive and reliant on quantities that are difficult to measure or estimate—and purely statistical models, which lack physical justification and perform poorly when extrapolated to new conditions (Toffolon and Piccolroaz (2015)). After several adaptations, the expected stream temperatures were best modeled using the four-parameter version of the air2stream model, with added random effects by site for each of the four parameters (Hill, Thorley, and Irvine (2024)). The data used for the model were sourced from the following locations, for years 2019-2021:

- Water temperature data collected in the Nechako Watershed were downloaded from Zenodo (Gilbert et al. 2022).
- Hourly air temperature data were obtained from the ERA-5-Land dataset via the Copernicus Climate Change Service (Muñoz Sabater (2019))
- Daily baseflow and surface runoff data were sourced from the Pacific Climate Impacts Consortium's Gridded Hydrologic Model Output using the ACCESS1-0_rcp85 scenario (Pacific Climate Impacts Consortium (n.d.)).

3.2.2 Bull Trout and Arctic Grayling Critical Habitat

We have incorporate Arctic Grayling critical habitat data related to Bottoms et al. (2023) work on grayling in the Peace region and are custodianing

3.3 Fish Passage Assessments

3.3.1 Natural Barriers to Fish Passage

Our assessments may include natural features such as waterfalls that could limit fish passage. This informs whether upstream culvert upgrades would restore access for anadromous species (e.g., salmon) or primarily benefit resident fish already upstream. We document these features by measuring height, gradient, and pool depth, recording field observations, capturing site photographs, and reviewing background sources for context.

3.3.2 Road Stream Crossings

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” (MoE 2011). The reader is referred to (MoE 2011) for detailed methodology. 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, road 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 3.2).

Table 3.2: 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).

Fish passage potential was determined for each stream crossing identified as a closed bottom structure as per MoE (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 3.3, Table 3.4). 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). For crossings determined to be potential barriers or barriers based on the data, a culvert fix and recommended diameter/span was proposed.

Table 3.3: 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 3.4: Fish Barrier Scoring Results (MoE 2011).

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

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 25% (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 3.3), a "total" value of habitat <20% output from `bcfishpass` was used to estimate the amount of habitat upstream of each crossing less than 25% 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 (10.5%) was used. To generate estimates for area of habitat upstream (m^2), 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 MoE (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..

3.3.3 Cost Estimates

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 help refine estimates which have since been adjusted for inflation in 2020 and based on past experience.

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 $30000/linear m and assumed that the road could be closed during construction and a minimum bridge span of 15m. For streams with channel widths <2m, embedded culverts were reported as an effective solution with total installation costs estimated at $100k/crossing (pers. comm. Phil MacDonald, Steve Page then adjusted for inflation in 2020). For larger streams (>6m), estimated span width increased proportionally to the size of the stream. 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 generated to estimate incremental cost increases with costs estimated for structure replacement on paved surfaces, railways and arterial/highways costing up to 15 times more than forest service roads due to expenses associate with design/engineering requirements, traffic control and paving. The cost multiplier table (Table 3.5) should be considered very approximate with refinement recommended for future projects.

Table 3.5: Cost multiplier table based on road class and surface type.

Class	Surface	Class Multiplier	Surface Multiplier	Bridge $/15m	Streambed Simulation $
FSR	Rough	1	1	450,000	100,000
FSR	Loose	1	1	450,000	100,000
Resource	Loose	1	1	450,000	100,000
Resource	Rough	1	1	450,000	100,000
Permit	Unknown	1	1	450,000	100,000
Permit	Loose	1	1	450,000	100,000
Permit	Rough	1	1	450,000	100,000
Unclassified	Loose	1	1	450,000	100,000
Unclassified	Rough	1	1	450,000	100,000
Unclassified	Paved	1	2	750,000	150,000
Unclassified	Unknown	1	2	750,000	150,000
Local	Loose	4	1	1,500,000	200,000
Local	Paved	4	2	3,000,000	400,000
Collector	Paved	4	2	3,000,000	400,000
Arterial	Paved	15	2	11,250,000	1,500,000
Highway	Paved	15	2	11,250,000	1,500,000
Rail	Rail	15	2	11,250,000	1,500,000

3.3.4 Climate Change Risk Assessment

In collaboration with the Ministry of Transportation and Infrastructure (MoTi), a new climate change replacement program aims to prioritize vulnerable culverts for replacement (pers. comm Sean Wong, 2022) based on data collected and ranked related to three categories - culvert condition, vulnerability and priority. Within the "condition" risk category - data was collected and crossings were ranked based on erosion, embankment and blockage issues. The "climate" risk category included ranked assessments of the likelihood of both a flood event affecting the culvert as well as the consequence of a flood event affecting the culvert. Within the "priority" category the following factors were ranked - traffic volume, community access, cost, constructability, fish bearing status and environmental impacts (Table 3.6). This project is still in its early stages with methodology changes going forward.

Table 3.6: Climate change data collected at MoTi culvert sites

Parameter	Description
erosion_issues	Erosion (scale 1 low - 5 high)
embankment_fill_issues	Embankment fill issues 1 (low) 2 (medium) 3 (high)
blockage_issues	Blockage Issues 1 (0-30%) 2 (>30-75%) 3 (>75%)
condition_rank	Condition Rank = embankment + blockage + erosion
condition_notes	Describe details and rational for condition rankings
likelihood_flood_event_affecting_culvert	Likelihood Flood Event Affecting Culvert (scale 1 low - 5 high)
consequence_flood_event_affecting_culvert	Consequence Flood Event Affecting Culvert (scale 1 low - 5 high)
climate_change_flood_risk	Climate Change Flood Risk (likelihood x consequence) 1-6 (low) 6-12 (medium) 10-25 (high)
vulnerability_rank	Vulnerability Rank = Condition Rank + Climate Rank
climate_notes	Describe details and rational for climate risk rankings
traffic_volume	Traffic Volume 1 (low) 5 (medium) 10 (high)
community_access	Community Access - Scale - 1 (high - multiple road access) 5 (medium - some road access) 10 (low - one road access)
cost	Cost (scale: 1 high - 10 low)
constructability	Constructibility (scale: 1 difficult -10 easy)
fish_bearing	Fish Bearing 10 (Yes) 0 (No) - see maps for fish points
environmental_impacts	Environmental Impacts (scale: 1 high -10 low)
priority_rank	Priority Rank = traffic volume + community access + cost + constructability + fish bearing + environmental impacts
overall_rank	Overall Rank = Vulnerability Rank + Priority Rank
priority_notes	Describe details and rational for priority rankings

3.4 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 3.2).

During habitat confirmations, to standardize data collected and facilitate submission of the data to provincial databases, information was collected on digital field forms adapted from provincial "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 a minimum distance 300m and upstream to a minimum distance of 500 - 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.

3.4.1 Fish Sampling

3.4.1.1 Electrofishing

Fish sampling was conducted on a subset of sites when biological data was considered to add significant value to the physical habitat assessment information. Electrofishing was utilized for fish sampling according to stream inventory standards and procedures found in the Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Manual (Resources Inventory Committee 2001). A Haltech 2000 backpack electrofisher was used within discrete site units both upstream and downstream of the subject crossing with electrofisher settings and seconds, water quality parameters (i.e. conductivity, temperature and ph), start and end locations, length of site and wetted widths (average of a minimum of three) recorded.

3.4.1.2 Fish Handling and Processing

Captured fish were held in buckets with sufficient water to minimize stress until processing, and multiple buckets were used when catch numbers were high. For each fish captured, fork length, weight and species was recorded with results documented in the fish data submission spreadsheet.

3.4.1.3 Pit Tagging

Fish with a fork length greater than 60 mm and belonging to species approved under the scientific fish collection permit PG24-879256 were tagged with Passive Integrated Transponders (PIT tags) using the [Abdominal Cavity]() method outlined by Biomark. To anesthetize fish prior to pit tagging, we used a solution of approximately 0.1 mL of clove oil per 1 L of water (1:10,000). This concentration was selected for its efficiency in providing effective sedation with minimal residual effects, making it ideal for studies in which fish are released back into their natural habitats (Fernandes et al. 2017). The clove oil solution was prepared in advance by dissolving pure clove oil in ethyl alcohol in a 1:9 ratio (clove oil: ethyl alcohol) to enhance solubility, then mixed into the water bucket (Fernandes et al. 2017). Fish were immersed in this solution until they reached an appropriate level of anesthesia for handling and then were tagged. To maintain needle sharpness and minimize injury risk, needles were replaced approximately every 10 fish. Each tagged fish was scanned with the PIT reader, and both the PIT tag ID and row ID were recorded. Once tagged, fish were placed into a bucket of fresh water and allowed to recover before being released back into the stream. Fish information and habitat data will be submitted to the province under scientific fish collection permit PG24-879256.

3.4.2 Aerial Imagery

Scripted processing and serving of UAV imagery collected during the project is available at https://github.com/NewGraphEnvironment/stac_uav_bc/ (Irvine [2025] 2025). `OpenDroneMap` was utilized to produce orthomosaics, digital surface models (DSMs), and digital terrain models (DTMs) (OpenDroneMap Authors [2014] 2025). To support efficient web-based access - imagery products were converted to cloud-optimized GeoTIFFs (COGs) using `rio-cogeo`, then collated accordiong to the SpatioTemporal Asset Catalog (STAC) specification with `pystac` and uploaded to S3 storage Amazon Web Services (2025). A `titiler` tile server was set up to facilitate interactive viewing of the orthoimagery and an Application Program Interface (API) leveraging `stac-fastapi-pgstac` is served at https://images.a11s.one to enable linking of collection images through QGIS as well as remote spatial and temporal querying using open source software such as `rstac` (Development Seed [2019] 2025; stac-utils 2025; Simoes et al. 2021).

3.5 Engineering Design

Engineering designs were signed and sealed by professional engineers. When possible - completed designs are loaded to the PSCIS data portal.

3.6 Remediations

Structure replacement was conducted by project specific contractors. If not already completed, as-built drawings will be loaded to the PSCIS data portal.

3.7 Monitoring

Monitoring of fish passage restoration sites — both proposed and completed - is essential to ensure restoration investments lead to meaningful ecological outcomes. Monitoring enables evaluation of whether remediation actions improve connectivity for fish and provides critical feedback to refine future prioritization and restoration strategies.

3.7 Monitoring

Baseline data collection, including fish sampling and aerial surveys via drone, are core components of this monitoring. While detailed methods for these activities are included in the previous habitat confirmation section, they are also fundamental to effectiveness monitoring, as they provide context to not only facilitate prioritization and communications but also for detecting change following restoration.

To support consistent and targeted assessment, a custom field form was developed for routine effectiveness monitoring based loosely on Forest Investment Account (2003) but tailored specifically for fish passage projects. Table 3.7 outlines the monitoring metrics used.

Table 3.7: Description of monitoring metrics used for effectiveness monitoring.

Parameter	Description
Dewatering	Have the remediation works led to dewatering of the channel due to substrate aggradation or other factors?
Velocity	Are flow velocities similar to those within the natural channel? Are they expected to exceed swim speeds of particular fish species/life stages of interest?
Constriction	Have the remediation works led to constriction of the channel. Compare channel width underneath structure and within construction footprint to average channel widths upstream and downstream?
Substrate	Is the substrate within/under and adjacent to the remediated structure generally equivalent to that found upstream and downstream where natural channel conditions exist?
Riparian	What is the condition of the riparian area within the construction footprint?
UAV Flight	Was a flight conducted with unmmanned aerial vehicle to document conditions at time of monitoring?
Flow_depth	What are the flow depths at the time of assessment within project footprint. Are depths expected to be sufficient to facilitat upstream passage for specific species/life stages of interest?
Stability	Does the structure appear to be stable or is there evidence of erosion/shifting?
Revegetation	How were riparian areas rehabillitated and are they improving fish habitat value?
Cover	Is cover available for fish within the construction footprint in the form of overhanging vegetation, large/small woody debris, boulders, undercut banks, etc?
Maintenance	If required, provide maintenance recommendations.
Recommendations	General recommendations for follow up. Could include revegetation, addition of substrate, fish sampling, etc.

4 Results and Discussion

4.1 Site Assessment Data Since 2019

Fish passage assessment procedures conducted through FWCP in the Peace River Region since 2019 are amalgamated online within the Results and Discussion section of the report found here

Since 2019, orthoimagery and elevation model rasters have been generated and stored as Cloud Optimized Geotiffs on a cloud service provider (AWS) with select imagery linked to in the collaborative GIS project. Additionally - a tile service has been set up to facilitate viewing and downloading of individual images, provided athttps://www.newgraphenvironment.com/fish_passage_peace_2024_reporting//results-and-discussion.html.

4.2 Collaborative GIS Environment

In addition to numerous layers documenting fieldwork activities since 2019, a summary of background information spatial layers and tables loaded to the collaborative GIS project (sern_peace_fwcp_2023) at the time of writing (2025-04-16) are included online here

4.3 Planning

4.3.1 Habitat Modelling

Habitat modelling from `bcfishpass` including access model, linear spawning/rearing habitat model and lateral habitat connectivity models for watershed groups within our study area were updated for the spring of 2025 and are included spatially in the collaborative GIS project. A snapshot of these outputs related to each modeled and PSCIS stream crossing structure are also included within an `sqlite` database within this year's project reporting/code repository here.

4.3.1.1 Statistical Support for `bcfishpass` Fish Habitat Modelling Updates

Initial mapping of stream discharge and temperature causal effects pathways for the future purpose of focusing aquatic restoration actions in areas of highest potential for positive impacts on fisheries values (ie. elimination of areas from intrinsic models where water temperatures are likely too cold to support fish production) are detailed in Hill, Thorley, and Irvine (2024) which is included as Attachment - Water Temperature Modelling (page 97).

4.4 Fish Passage Assessemnts

Field assessments were conducted between September 04, 2024 and September 11, 2024 by Allan Irvine, R.P.Bio. and Lucy Schick, B.Sc., Bianca Prince, and Jillian Isadore. A total of 15 Fish Passage Assessments were completed, including 11 Phase 1 assessments and 4 reassessments. In 2024, field efforts prioritized revisiting previously assessed sites for monitoring rather than evaluating new Fish Passage Assessment locations.

Of the 15 sites where fish passage assessments were completed, 11 were not yet inventoried in the PSCIS system. This included 8 crossings considered “passable”, 0 crossings considered a “potential” barrier, and 3 crossings were considered “barriers” according to threshold values based on culvert embedment, outlet drop, slope, diameter (relative to channel size) and length (MoE 2011).

Reassessments were completed at 4 sites where PSICS data required updating.

A summary of crossings assessed, a rough cost estimate for remediation, and a priority ranking for follow-up for Phase 1 sites is presented in Table 4.1. Detailed data with photos are presented in Attachment - Phase 1 Data and Photos (page 93).

The “Barrier” and “Potential Barrier” rankings used in this project followed MoE (2011) and represent an assessment of passability for juvenile salmon or small resident rainbow trout under any flow conditions that may occur throughout the year (Clarkin et al. 2005; Bell 1991; Thompson 2013). As noted in Bourne et al. (2011), with a detailed review of different criteria in Kemp and O’Hanley (2010), passability of barriers can be quantified in many different ways. Fish physiology (i.e. species, length, swim speeds) can make defining passability complex but with important implications for evaluating connectivity and prioritizing remediation candidates (Bourne et al. 2011; Shaw et al. 2016; Mahlum et al. 2014; Kemp and O’Hanley 2010). Washington Department of Fish & Wildlife (2009) present criteria for assigning passability scores to culverts that have already been assessed as barriers in coarser level assessments. These passability scores provide additional information to feed into decision making processes related to the prioritization of remediation site candidates and have potential for application in British Columbia.

Table 4.1: Upstream habitat estimates and cost benefit analysis for Phase 1 assessments ranked as a ‘barrier’ or ‘potential’ barrier. Bull trout network model used for habitat estimates (total length of stream network

PSCIS ID	External ID	Stream	Road	Barrier Result	Habitat value	Habitat Upstream (km)	Stream Width (m)	Priority	Fix	Cost Est ($K)
125180	–	Tributary to Missinka River	Chuchinka-Missinka FSR	Potential	Medium	3.80	4.1	low	OBS	450
125186	–	Tributary to Missinka River	Chuchinka-Missinka FSR	Barrier	Medium	1.86	2.8	mod	OBS	450
125261	–	Fern Creek	Chuchinka-Table FSR	Barrier	High	48.27	5.0	high	OBS	450
199662	24755467	Tributary to Colbourne Creek	Chuchinka-Colbourne FSR	Barrier	Low	0.20	1.0	low	SS-CBS	100
199663	16602610	Tributary to Colbourne Creek	Chco 11000 FSR	Barrier	Medium	4.12	2.5	mod	OBS	–
199664	2201350	Tributary to McLeod Lake	Unnamed	Barrier	Medium	9.04	2.3	mod	OBS	585

4.5 Habitat Confirmation Assessments

During the 2024 field assessments, habitat confirmation assessments were conducted at two sites within the Carp River and Crooked River watershed groups. A total of approximately 2 km of stream was assessed. Electrofishing surveys were conducted at both habitat confirmation sites. Georeferenced field maps are provided in Attachment - Maps (page 91).

As collaborative decision-making was ongoing at the time of reporting, site prioritization can be considered preliminary. Results are summarized in Tables 4.2 - 4.2 with raw habitat and fish sampling data included in Attachment - Data (page 95). A summary of preliminary modelling results illustrating quantities of bull trout spawning and rearing habitat potentially available upstream of each crossing as estimated by measured/modelled channel width and upstream accessible stream length are presented in Figure 4.1. Detailed information for each site assessed with Phase 2 assessments (including maps) are presented within site-specific appendices to this document.

Table 4.2: Overview of habitat confirmation sites. Bull trout rearing model used for habitat estimates (total length of stream network

PSCIS ID	Stream	Road	Tenure	UTM	UTM zone	Fish Species	Habitat Gain (km)	Habitat Value	Priority	Comments
198692	Tributary To Kerry Lake	Kerry Lake FSR	MoF	511736 6059308	10	–	2.3	Medium	High	Significant flow for this time of year. Patches of gravel were present suitable for spawning resident rainbow trout and bull trout. Rainbow trout were captured during sampling. Healthy riparian of mixed forest and shrub. The stream narrowed into a canyon roughly 150m upstream of Kerry FSR. Surveyed to approximately 300 m upstream of the Kerry FSR. 11:43:48
198669	Tributary To Mcleod Lake	Hart Highway	MoTi	503347 6085960	10	RB	4.9	Medium	Moderate	Stream was surveyed for 550m upstream of the crossing. Abundant gravels throughout. Channel turns to predominantly fine substrates at the powerline corridor. Then there is a beaver dam (1.2 m high) backwater area approximately 100 m upstream of the transmission line. Numerous fish between 40 mm and 120 mm were observed up to the beaver dam and RB are documented upstream in FISS. Upstream of the dam impounded area the stream returns to predominantly gravel with frequent pools to 40 cm deep. 15:22:55

Table 4.3: Summary of Phase 2 fish passage reassessments.

PSCIS ID	Embedded	Outlet Drop (m)	Diameter (m)	SWR	Slope (%)	Length (m)	Final score	Barrier Result
198669	No	0.36	0.9	3.89	2	42	37	Barrier
198692	No	0.34	1.2	3.33	4	19	39	Barrier

Table 4.4: Cost benefit analysis for Phase 2 assessments. Bull trout rearing model used for habitat estimates (total length of stream network

PSCIS ID	Stream	Road	Barrier Result	Habitat value	Stream Width (m)	Fix	Cost Est ($K)	Habitat Upstream (m)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
198669	Tributary to McLeod Lake	Hart Highway	Barrier	Medium	3.7	SS-CBS	1500	4892	3261.3	5707.3
198692	Tributary to Kerry Lake	Kerry Lake FSR	Barrier	Medium	4.0	OBS	450	2273	5051.1	10102.2

Table 4.5: Summary of Phase 2 habitat confirmation details.

PSCIS ID	Length surveyed upstream (m)	Average Channel Width (m)	Average Wetted Width (m)	Average Pool Depth (m)	Average Gradient (%)	Total Cover	Habitat Value
198669	550	3.7	2.4	0.4	2.5	moderate	medium
198692	500	4.0	1.5	0.2	5.0	abundant	medium

Table 4.6: Summary of watershed area statistics upstream of Phase 2 crossings.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
125179	4.3	–	799	1876	1306	1213	SSW
125231	4.0	755	754	1605	1183	1115	SSE
198669	6.8	682	682	1004	867	843	SSW
198692	5.1	725	760	1148	973	955	SE

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

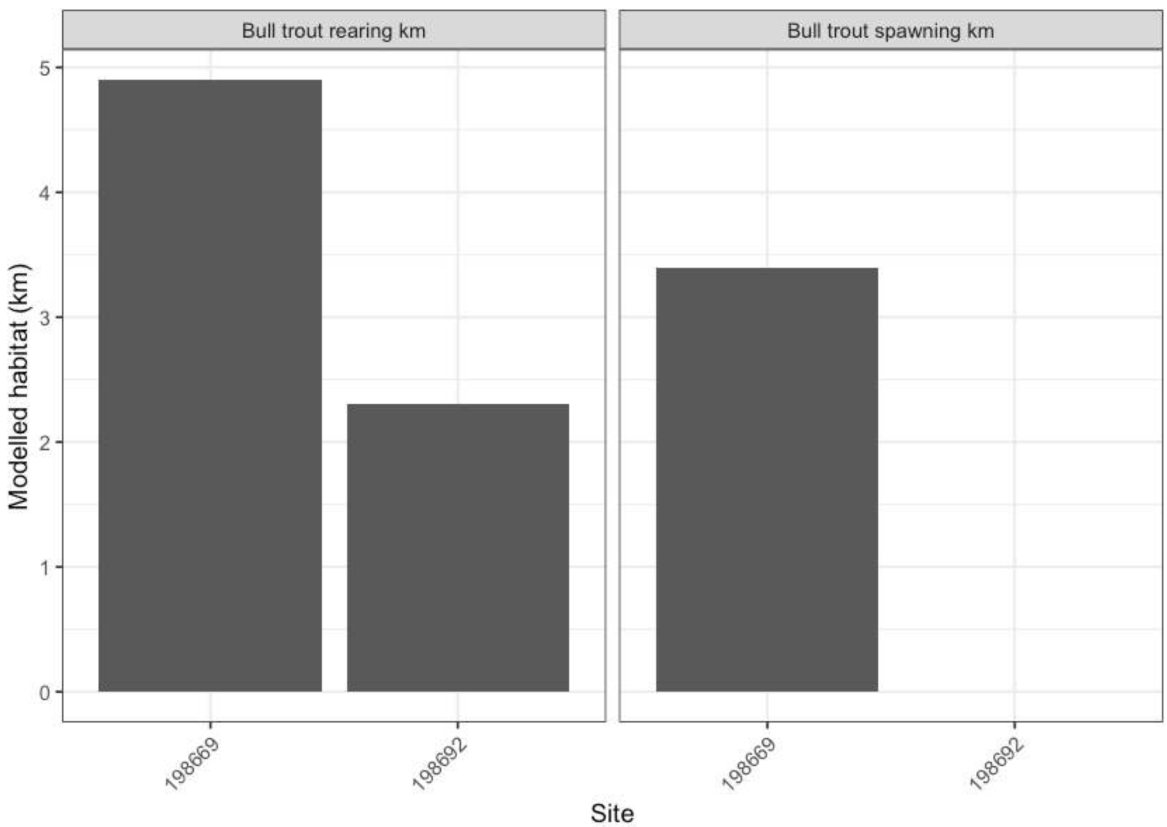

Figure 4.1: Summary of potential rearing and spawning habitat upstream of habitat confirmation assessment sites. Bull trout rearing and spawning models used for habitat estimates (total length of stream network <10.5% and <5.5% gradient, respectively).

4.5.1 Fish Sampling

Fish sampling was conducted at 16 sites within 6 streams, with a total of 319 fish captured. Fork length, weight, and species were documented for each fish. Salmonids with fork lengths >60mm were PIT-tagged to facilitate long-term tracking of health and movement. Fork length data was used to delineate salmonids based on life stages: fry (0 to 65mm), parr (>65 to 110mm), juvenile (>110mm to 140mm), and adult (>140mm) by visually assessing the histograms presented in Figure 4.3. A summary of sites assessed is included in Table 4.7, and raw data is provided in Attachment - Data (page 95). A summary of density results is also presented in Figure 4.2.

Results are presented in detail within the individual appendices in this report with the 2023 report updated with fish sampling data for PSCIS crossing 125131 on Chuchinka-Table FSR. Documentation for each site can be accessed online within the Results and Discussion section of the report found here.

Table 4.7: Summary of electrofishing sites.

site	stream	passes	ef_length_m	ef_width_m	area_m2	enclosure
125180_us_ef1	Tributary To Missinka River	1	35	2.3	80.5	partial enclosure
125180_ds_ef1	Tributary To Missinka River	1	30	3.3	99.0	partial enclosure
125194_ds_ef1	Tributary To Missinka River	1	115	1.7	195.5	open
125179_ds_ef1	Tributary To Missinka River	1	35	3.7	129.5	partial enclosure
125179_us_ef1	Tributary To Missinka River	1	40	2.4	96.0	partial enclosure
125180_ds_ef2	Tributary To Missinka River	1	30	3.3	99.0	partial enclosure
125231_ds_ef1	Tributary To Table River	1	40	2.1	84.0	closed
125231_us_ef1	Tributary To Table River	1	70	3.0	210.0	partial enclosure
125231_ds_ef2	Tributary To Table River	1	30	2.2	66.0	partial enclosure
125261_ds_ef1	Fern Creek	1	21	3.8	79.8	partial enclosure
125261_ds_ef2	Fern Creek	1	21	3.2	67.2	partial enclosure
125261_us_ef1	Fern Creek	1	29	3.4	98.6	partial enclosure
125261_us_ef2	Fern Creek	1	22	4.2	92.4	partial enclosure
198692_ds_ef1	Tributary To Kerry Lake	1	20	1.9	38.0	partial enclosure
198692_ds_ef2	Tributary To Kerry Lake	1	4	5.0	20.0	open
198692_us_ef1	Tributary To Kerry Lake	1	27	1.4	37.8	partial enclosure

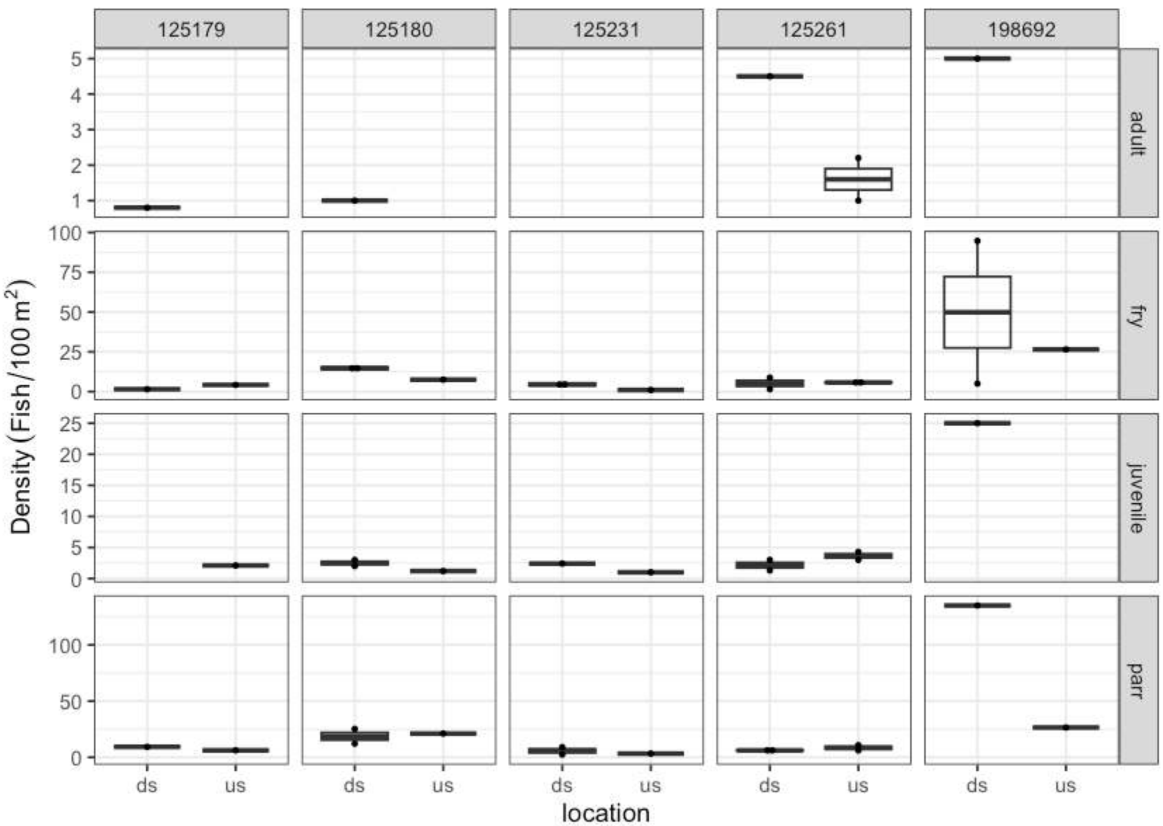

Figure 4.2: Boxplots of densities (fish/100m2) of rainbow trout captured downstream (ds) and upstream (us) by electrofishing.

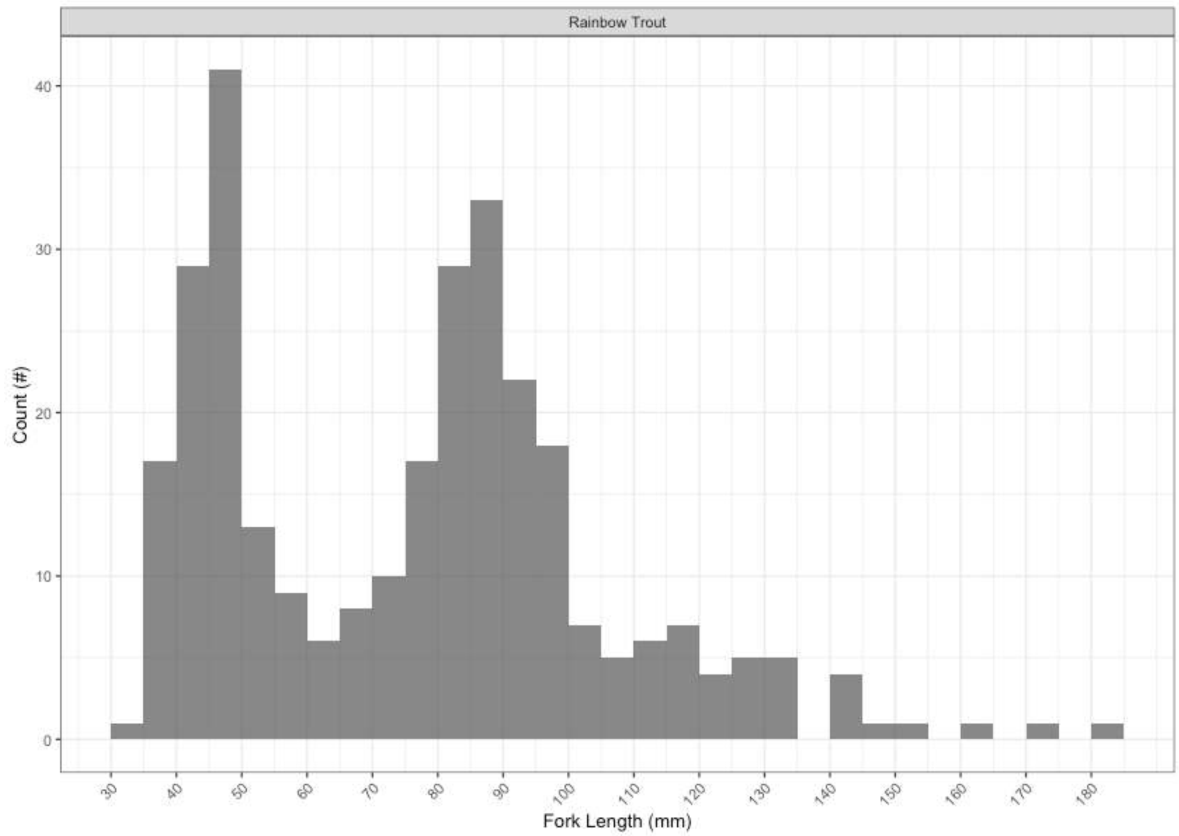

Figure 4.3: Histograms of fish lengths by species. Fish captured by electrofishing during habitat confirmation assessments.

4.6 Engineering Design

No new designs were commissioned in 2024 due to uncertainty related to forest harvesting activities and lack of funding for the 50% costs of replacing structures. All sites with a design for remediation of fish passage can be found online within the Results and Discussion section of the report found here.

4.7 Remediations

In 2024, remediation of fish passage was completed at PSCIS crossing 125231, located on Tributary to Table River at km 21 on the Chuchinka-Table FSR. The crossing was replaced with a clear-span bridge by Canfor with environmental oversight and engineering from DWB Consulting Services Ltd. Half the total funding for the project was provided by FWCP through coordination from SERNbc. More information regarding the crossing can be found within this report here.

All sites where remediation of fish passage has been completed can be found online within the Results and Discussion section of the report found here.

4.8 Monitoring

In 2024, baseline or follow up monitoring data was gathered through completion of an effectivness montoring form (sites where remediation has been completed) and/or through baseline fish sampling and aquistion of aerial imagery at four sites:

- Effectiveness monitoring was conducted on a Tributary to Missinka (PSCIS crossing 125179) on Chuchinka-Missinka FSR which was replaced in 2022. Background can be reviewed here with results of the monitoring presented within this report in Tributary to Missinka River - 125179 - Appendix (page 45).

- In the summer of 2024, Tributary to Table crossing (PSCIS crossing 125131) on Chuchinka-Table FSR was replaced, with effectiveness monitoring conducted in the fall. The initial habitat confirmation for the site is documented in Irvine (2020) here. Baseline monitoring in 2023 along with the results of 2024 effectiveness monitoring (updated reporting) can be reviewed in here.

- Baseline fish sampling was conducted at PSCIS crossing 125261 located on Fern Creek near the 2.1km mark of the Chuchinka-Table FSR. Although restoration of this site (in collaboration with Canfor) had been planned for 2025 - remediation has been delayed due to uncertainty regarding forest harvest activities within the greater Table River watershed. Fish sampling activities including PIT tagging were conducted in 2024 to compliment fish data aquired in 2023. Documentation is provided in Irvine and Winterscheidt (2024) here.

- Baseline fish sampling and acquisition of aerial imagery was conducted at PSCIS crossings 198692 is located on Tributary to Kerry Lake, at kilometer 7 of Kerry Lake FSR. Documentation is provided within this report Tributary to Kerry Lake - 198692 - Appendix (page 63).

5 Recommendations

A major challenge in advancing fish passage restoration is the complexity of working across jurisdictions and with multiple stakeholders—rail and highway authorities, forestry ministries, licensees, and private landowners. These partners are often being asked to accommodate priorities that originate outside their mandates and budgets. Convincing them to invest in difficult, high-cost interventions—like modifying crossings or relocating infrastructure—requires navigating uncertainty about costs and ecological outcomes, as well as a disconnect between the benefits to watershed health and the internal pressures or performance goals of these agencies. It's a tough ask: to take on massive, uncertain projects when they're already stretched thin with their own responsibilities.

Fish passage restoration across British Columbia is further complicated by the legacy of infrastructure deeply embedded in the landscape. Roads, railways, highways, community infrastructure and private assets often constrain floodplains and disrupt natural hydrological processes. While targeted repairs to individual barriers are essential, they won't resolve the broader systemic issues without rethinking and restructuring how infrastructure interacts with watershed function. Loss of riparian vegetation and intensive beaver management only add to the degradation. Addressing these challenges means making strategic, well-communicated choices—picking battles carefully, building trust, and staying committed to a longer-term transformation.

While preliminary top remediation priorities are provided by watershed group, these rankings are inherently subjective and can depend on the capacity and willingness of infrastructure owners and tenure holders to support implementation—both financially and over the often multi-year project timelines. In practice, we must often act opportunistically, pursuing simpler, lower-cost options to maintain momentum and achieve near-term progress.

Government, community groups, landowners, non-profits, industry and other stakeholders should work collaboratively to address high and moderate priority barriers identified online within the Results and Discussion section of the report found here. Although the table presents many options - currently - linked reports specify whether each site is a low, moderate, or high priority. Progress on any front is meaningful, and aiming to remediate at least one high-priority site per year per watershed group—regardless of its overall rank—is a practical and effective approach.

To enhance fish passage restoration in the FWCP Peace Region:

- Maintain strong partnerships to support funding, site selection, remediation, and monitoring through adaptive management informed by traditional knowledge and real-time data.
- Prioritize detailed assessments in areas with blockages and high habitat potential, especially near McLeod Lake.
- Use climate modeling to prioritize crossings that enable access to cold, drought-resistant habitats.
- Secure financial commitments for Fern Creek remediation despite uncertainties in harvest planning.

- Continue effectiveness monitoring at key sites using fish sampling, eDNA, PIT tagging, temperature data, and aerial imagery.
- Continue to develop a cost-effective monitoring framework to assess productivity gains from improved passage.
- Collaborate with WLRS, UNC, local fisheries experts, FWCP, and the CEMPRA Project working group.
- Utilize environmental DNA (eDNA) to better understand bull trout and Arctic grayling habitat use at both potential and remediated sites. This will refine prioritization and assess fish passage effectiveness.

Tributary to Missinka River - 125179 - Appendix

Site Location

PSCIS crossing 125179 is located on a Tributary to Missinka River , between kilometer 3 and 4 of Chuchinka-Missinka FSR. The crossing is located approximately 660m east of PSCIS crossing 125180 and joins this adjacent stream just before emptying into the Missinka River, approximately 1km downstream. At the crossing location, the road is the responsibility of Sinclar Forest Group R01821 51A. The crossing is within the Parsnip River watershed group.

Background

At the crossing location, Tributary to Missinka River is a second order stream and drains a watershed of approximately 4.3km^2. The watershed ranges in elevation from a maximum of 1876m to 799m near the crossing (Table 5.1).

In 2018, the Missinka River watershed was designated as a fisheries sensitive watershed under the authority of the Forest and Range Practices Act due to significant downstream fisheries values and watershed sensitivity (Beaudry 2013b). Special management is required in the crossing's watershed to protect habitat for bull trout and arctic grayling and includes measures (among others) to limit equivalent clearcut area, reduce impacts to natural stream channel morphology, retain old growth attributes and maintain fish habitat/movement.

The site was originally prioritized for replacement in 2019 by Irvine (2020), following a habitat confirmation assessment which can be found here. In the summer of 2022, Sinclar Forest Group replaced the crossing with a 15m steel girder permanent bridge with modular timber decks (Irvine and Winterscheidt 2023). In addition to Irvine (2020) - post-replacement documentation regarding this crossing can also be found in the 2022 report here. A map of the watershed is provided in map attachment 093I.116.

Table 5.1: Summary of derived upstream watershed statistics for PSCIS crossing 125179.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
125179	4.3	–	799	1876	1306	1213	SSW

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

Monitoring

5.0.1 Effectiveness Monitoring Checklist

Monitoring results gathered on a effectiveness monitoring checklist are summarised in Table 5.2. In general - the structure appeared stable with no maintenance required at the time of reporting. Lessons learned from the work - to be leveraged towards future projects - include reducing the amount of riprap material placed within the bankfull channel width and replanting of areas where riparian vegetation is removed during construction. Photos showing a comparison of the culvert assessment conducted in 2019 versus the completed bridge construction in 2024 are presented in Figure 5.2.

Table 5.2: Summary of monitoring metric results for site 125179.

variable	value
Pscis Crossing Id	125179
Stream Name	Tributary to Missinka River
Road Name	Chuchinka-Missinka FSR
Crossing Subtype	BRIDGE
Span	15
Width	4.8
Assessment Comment	Monitoring visit conducted. Electrofishing was performed upstream and downstream, with all fish >60mm tagged. See camera roll for additional photos. Recommend bringing old photos as a reference to recreate photo angles and shutter length.
Dewatering Notes	No dewatering
Velocity Notes	Velocity was higher under the bridge than both upstream and downstream due to channel constriction from riprap.
Constriction Notes	Channel width measurements beneath the structure within the road right-of-way were 2.9m, 3.5m, and 2.5m, which were narrower than the typical channel width observed both upstream and downstream, as noted on the fish site cards.
Substrate Notes	A significant amount of riprap material was present within the channel in the road right-of-way. Occasional pieces of riprap were functioning to create step-pool habitat downstream. Overall, the substrate under the structure was slightly larger than that observed both upstream and downstream.
Riparian Notes	There did not appear to have been any riparian planting conducted during construction, with only herbaceous regrowth observed, including grasses and fireweed. The site could have been planted with willow whips to provide cover and food.
Flow Depth Notes	Flow depth was comparable to sections downstream, with measured depths ranging from 5–20cm. At the observed flow levels during the survey, migration was not likely hindered.
Stability Notes	The structure and extensive rock riprap appeared fully stable, with no evidence of slumping or instability.
Revegetation Notes	As noted in the riparian section, the construction footprint was vegetated primarily with herbaceous plants where rock was not present.

variable	value
Cover Notes	Due to the extensive rock placement within the construction footprint, there was no overhanging vegetation cover. However, occasional pieces of riprap and boulder lines within the channel provided some boulder and step-pool habitat. The larger substrate was providing fish habitat, as observed during electrofishing.
Maintenance Notes	It appears that no maintenance is required at this time.

Fish Sampling

As per recommendations in Irvine (2020) and Irvine and Winterscheidt (2023) - to provide reference site data for comparison, electrofishing was conducted not only at the site of the remediation - but also at PSCIS crossing 125180, a similarly sized culverted stream - located approximately 660m east of the subject crossing (Irvine and Winterscheidt 2023; Irvine 2020). Another site (PSCIS crossing 125186) was also scoped for potential as as reference site - however the stream was almost completely dry in 2024 (with the exception of the outlet pool and intermittent shallow pool sections).

Upstream on the reference site (`125180_us_ef1`) - fish lengths and weights were recorded, and all fish with a fork length greater than 60mm were tagged with Passive Integrated Transponders (PIT tags - data stored here. On the first sampling event downstream (`125180_ds_ef1`) - only species and length data was collected. However, the same site was revisited a few days later (`125180_ds_ef2`) with length/weight collected and PIT tagging conducted. Results are summarised in Tables 5.3 - 5.4 and Figure 5.1.

A total of 15 rainbow trout were captured downstream and 12 rainbow trout were captured upstream of crossing 125179 (Figures 5.3).

A total of 44 rainbow trout were captured downstream during the first sampling event (`125180_ds_ef1`), and 24 rainbow trout were captured upstream (Figures 5.4). During the second downstream sampling event (when PIT tagging was conducted - `125180_ds_ef2`), a total of 28 rainbow trout were captured. The lower density of rainbow trout parr captured on the second round of sampling within the same section of stream is not surprising since disturbance of the site and handling of fish a few days earlier likely impacted the recapture rate.

Conclusion

Fish passage at crossing 125179 was restored in the summer of 2022 with a 15m steel girder permanent bridge with modular timber decks. Partial funding for the project was provided by FWCP through coordination from SERNbc. Effectiveness monitoring at the site was conducted in 2024 with the structure in stable condition with no maintenance required at the time of reporting. Lessons learned from the work - to be leveraged towards future projects - include reducing the amount of riprap material placed within the bankfull channel width and replanting of areas where riparian vegetation is removed during construction.

Resampling of fish at the restoration and reference sites in future years is recommended to build our understanding of fish use, movement and health in the subject streams. Acquisition of additional aerial imagery in the future is also recommended so that imagery and elevation models can be compared with data collected immediately following replacement (2022) to evaluate stream morphology changes and riparian recovery since construction.

Table 5.3: Fish sampling site summary for 125179.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
125179_ds_ef1	1	35	3.7	129.5	partial enclosure
125179_us_ef1	1	40	2.4	96.0	partial enclosure

Table 5.4: Fish sampling density results summary for 125179.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
125179_ds_ef1	Rainbow Trout	adult	1	0.8	FALSE
125179_ds_ef1	Rainbow Trout	fry	2	1.5	FALSE
125179_ds_ef1	Rainbow Trout	parr	12	9.3	FALSE
125179_us_ef1	Rainbow Trout	fry	4	4.2	FALSE
125179_us_ef1	Rainbow Trout	juvenile	2	2.1	FALSE
125179_us_ef1	Rainbow Trout	parr	6	6.2	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.

Table 5.5: Fish sampling site summary for 125180.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
125180_us_ef1	1	35	2.3	80.5	partial enclosure
125180_ds_ef1	1	30	3.3	99.0	partial enclosure
125180_ds_ef2	1	30	3.3	99.0	partial enclosure

Table 5.6: Fish sampling density results summary for 125180.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
125180_ds_ef1	Rainbow Trout	fry	16	16.2	FALSE
125180_ds_ef1	Rainbow Trout	juvenile	3	3.0	FALSE
125180_ds_ef1	Rainbow Trout	parr	25	25.3	FALSE
125180_ds_ef2	Rainbow Trout	adult	1	1.0	FALSE
125180_ds_ef2	Rainbow Trout	fry	13	13.1	FALSE
125180_ds_ef2	Rainbow Trout	juvenile	2	2.0	FALSE
125180_ds_ef2	Rainbow Trout	parr	12	12.1	FALSE
125180_us_ef1	Rainbow Trout	fry	6	7.5	FALSE
125180_us_ef1	Rainbow Trout	juvenile	1	1.2	FALSE
125180_us_ef1	Rainbow Trout	parr	17	21.1	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.

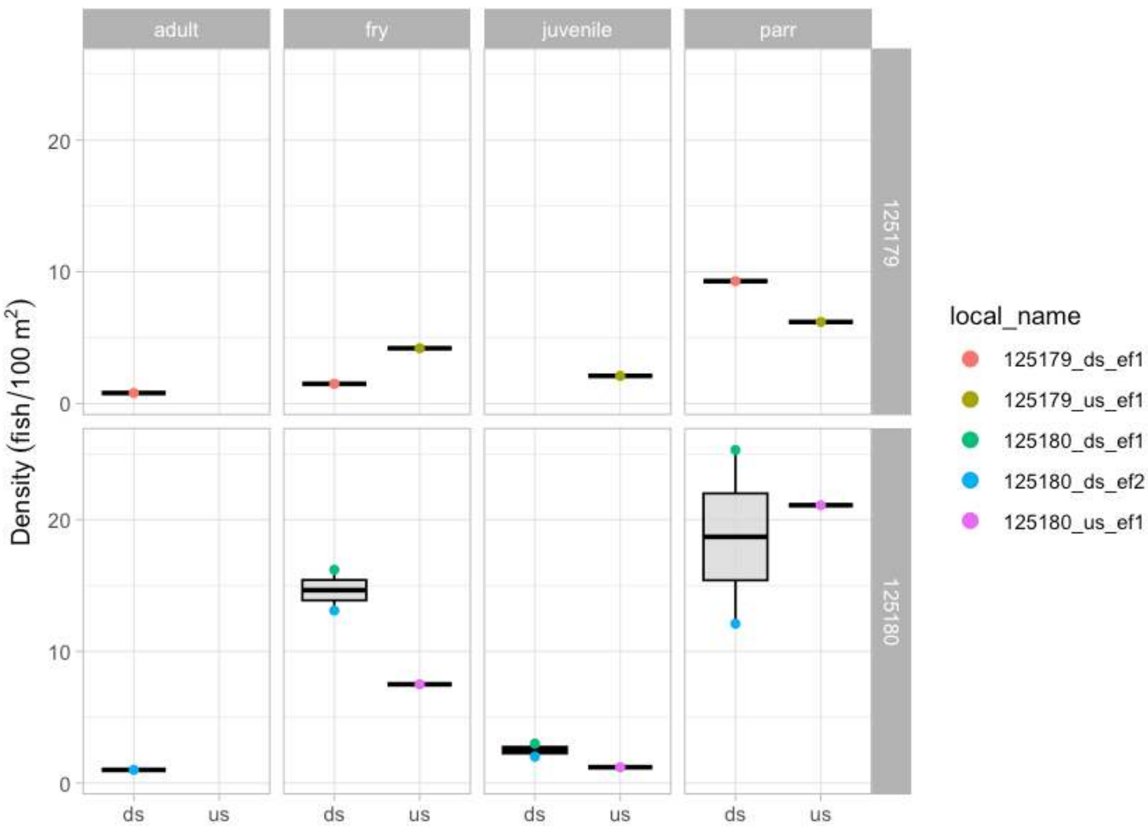

Figure 5.1: Densites of rainbow trout (fish/100m2) captured upstream and downstream of PSCIS crossings 125179 and 125180. Note that two sampling events were conducted within the same sampling site on different days - downstream of site 125180

Figure 5.2: Left: Photos of crossing 125179 in 2019. Right: Photos of crossing 125179 in 2024.

Figure 5.3: Left: Typical habitat electrofished upstream of PSCIS crossing 125179. Right: Rainbow trout captured upstream of PSCIS crossing 125179.

Figure 5.4: Left: Typical habitat electrofished upstream of PSCIS crossing 125180. Right: Rainbow trout captured upstream of PSCIS crossing 125180.

Tributary to McLeod Lake - 198669 - Appendix

Site Location

PSCIS crossings 198669 is located on Tributary to McLeod Lake, approximately 13km south of the community of McLeod Lake, BC. The crossing is located 250m upstream of McLeod Lake, on the Hart Highway, and is within the Carp River watershed group. Crossing 198669 is the responsibility of the Ministry of Transportation and Infrastructure (chris_culvert_id: 1996861).

Background

At this location, Tributary to McLeod Lake is a third order stream and drains a watershed of approximately 6.8km^2. The watershed ranges in elevation from a maximum of 1004m to 682m near the crossing (Table 5.7).

In 2023, crossing 198669 was assessed with a fish passage assessment and was prioritized for follow-up with a habitat confirmation assessment due to the extremely poor condition and size of the culvert, and the presence of quality habitat observed upstream (Irvine and Winterscheidt 2024). Upstream of the highway, rainbow trout have previously been recorded (Norris [2018] 2024; MoE 2024).

Table 5.7: Summary of derived upstream watershed statistics for PSCIS crossing 198669.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
198669	6.8	682	682	1004	867	843	SSW

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

A summary of habitat modelling outputs for the crossing are presented in Table 5.8. A map of the watershed is provided in map attachment 093J.123.

Table 5.8: Summary of fish habitat modelling for PSCIS crossing 198669.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	4.9	2.1	43
BT Spawning (km)	3.4	2.1	62

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Stream (km)	13.3	3.9	29
BT Lake Reservoir (ha)	2.3	0.0	0
BT Wetland (ha)	4.2	0.0	0
BT Slopeclass03 (km)	1.8	0.5	28
BT Slopeclass05 (km)	4.7	2.1	45
BT Slopeclass08 (km)	3.8	1.2	32
BT Slopeclass15 (km)	3.2	0.1	3

* Model data is preliminary and subject to adjustments.

Stream Characteristics at Crossing 198669

At the time of the 2024 assessment, PSCIS crossing 198669 on the Hart Highway was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocols (MoE 2011) (Table 5.9). The culvert had a 0.36m outlet drop, a 1m deep outlet pool, and was in extremely poor condition with approximately 2m of the culvert unraveling at the outlet. There were signs of significant erosion around the pipe inlet, suggesting the culvert is undersized for the stream.

The water temperature was 11°C, pH was 8.3 and conductivity was 430 uS/cm.

Table 5.9: Summary of fish passage assessment for PSCIS crossing 198669.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2024-09-05	Crossing Sub Type	Round Culvert
PSCIS ID	198669	Diameter (m)	0.9
External ID	–	Length (m)	42
Crew	LS AI	Embedded	No
UTM Zone	10	Depth Embedded (m)	–
Easting	503347	Resemble Channel	No
Northing	6085960	Backwatered	No
Stream	Tributary to McLeod Lake	Percent Backwatered	–
Road	Hart Highway	Fill Depth (m)	8
Road Tenure	MoTi	Outlet Drop (m)	0.36
Channel Width (m)	3.5	Outlet Pool Depth (m)	1
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 Structure with Streambed Simulation CBS	Fix Span / Diameter	4.5

Location and Stream Data	Crossing Characteristics	–

Comments: The culvert is completely broken in half at the outlet. Fish were observed downstream, and rainbow trout are documented upstream in FISS. Good habitat consisting of pools and gravels were observed downstream. A substantial amount of road fill is present. The inlet was blocked by a log and debris creating an inlet drop. There were signs of significant erosion around the pipe inlet, suggesting the culvert is undersized for the stream. MoTi chris_culvert_id: 1996861. 17:51:46

Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.

Stream Characteristics Downstream of Crossing 198669

The stream was surveyed downstream from crossing 198669 for 250m , to the confluence with McLeod Lake. The stream had frequent pools, good cover, and abundant gravels, providing medium value habitat for overwintering and spawning fish. Beaver activity was visible and fish were observed the entire length of the survey (Figure 5.5). The dominant substrate was cobbles with gravels sub-dominant.The average channel width was 3.4m, the average wetted width was 1.5m, and the average gradient was 1.6%.Total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, deep pools, and overhanging vegetation.

Stream Characteristics Upstream of Crossing 198669

The stream was surveyed upstream from crossing 198669 for 550m (Figure 5.5). Abundant gravels were present throughout the lower section, providing suitable spawning habitat. Near the powerline corridor, substrate composition transitioned to predominantly fines. Approximately 100m upstream of the transmission line, a 1.2m high beaver dam created a backwatered area. Numerous fish, ranging from 40-120mm, were observed throughout the surveyed section up to the beaver dam. Upstream of the impounded area, the stream returned to predominantly gravel substrates with frequent pools up to 40cm deep. 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.The average channel width was 3.7m, the average wetted width was 2.4m, and the average gradient was 2.5%. The habitat was rated as medium value for salmonid spawning and rearing.

Structure Remediation and Cost Estimate

Should restoration/maintenance activities proceed, replacement of the Hart Highway crossing with a bridge (4.5 m span) is recommended. At the time of reporting in 2025, the cost of the work is estimated at $ 1,500,000.

Conclusion

Approximately 5km of bull trout rearing habitat is modelled upstream, and the habitat was rated as medium value for anadromous spawning and rearing. The culvert was in extremely poor condition, with a deep outlet pool and significant erosion around the pipe inlet, indicating that the culvert is severely undersized for the stream. The 0.36m outlet drop likely inhibits juvenile fish passage. The crossing is a moderate priority for replacement. Due to this crossing being situated on the Hart Highway, construction would be complex and costly.

Table 5.10: Summary of habitat details for PSCIS crossings 198669.

Site	Location	Length Surveyed (m)	Average Channel Width (m)	Average Wetted Width (m)	Average Pool Depth (m)	Average Gradient (%)	Total Cover	Habitat Value
198669	Downstream	250	3.4	1.5	0.3	1.6	abundant	medium
198669	Upstream	550	3.7	2.4	0.4	2.5	moderate	medium

Figure 5.5: Left: Typical habitat downstream of PSCIS crossing 198669. Right: Typical habitat upstream of PSCIS crossing 198669.

Tributary to Kerry Lake - 198692 - Appendix

Site Location

PSCIS crossings 198692 is located on Tributary to Kerry Lake, at kilometer 7 of Kerry Lake FSR, approximately 25km north of the community of Bear Lake, BC. The crossing is located 750m upstream of the streams confluence with Kerry Lake, on the northwestern side of the lake. Located. At this location, the road is the responsibility of the Ministry of Forests. The crossing is within the Crooked River watershed group.

Background

At this location, Tributary to Kerry Lake is a third order stream and drains a watershed of approximately 5.1km^2. The watershed ranges in elevation from a maximum of 1148m to 725m near the crossing (Table 5.11).

In 2023, crossing 198692 was assessed with a fish passage assessment and prioritized for follow-up with a habitat confirmation assessment due to the presence of quality habitat observed upstream and its proximity to fish-bearing Kerry Lake (Irvine and Winterscheidt 2024). No fisheries data are available for this stream; however, longnose sucker, lake chub, peamouth chub, northern pikeminnow, longnose dace, redside shiner, rainbow trout, mountain whitefish, dolly varden, and prickly sculpin have been documented in Kerry Lake, located just downstream (Norris [2018] 2024; MoE 2024).

Table 5.11: Summary of derived upstream watershed statistics for PSCIS crossing 198692.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
198692	5.1	725	760	1148	973	955	SE

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

A summary of habitat modelling outputs for the crossing are presented in Table 5.12. A map of the watershed is provided in map attachment 093J.118.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
BT Rearing (km)	2.3	2.3	100
BT Spawning (km)	0.0	0.0	–
BT Network (km)	12.4	6.8	55
BT Stream (km)	12.2	6.7	55
BT Lake Reservoir (ha)	0.0	0.0	–
BT Wetland (ha)	1.1	0.5	45
BT Slopeclass03 (km)	0.8	0.1	12
BT Slopeclass05 (km)	0.0	0.0	–
BT Slopeclass08 (km)	4.1	2.1	51
BT Slopeclass15 (km)	4.4	3.5	80

* Model data is preliminary and subject to adjustments.

Stream Characteristics at Crossing 198692

At the time of the 2024 assessment, the crossing on Kerry Lake FSR was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocols (MoE 2011) (Table 5.13). The culvert had a 0.34m outlet drop and a 0.8m deep outlet pool.

The water temperature was 7.4°C, pH was 8.2 and conductivity was 99 uS/cm.

Stream Characteristics at Crossing 19…

Table 5.13: Summary of fish passage assessment for PSCIS crossing 198692.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2024-09-05	Crossing Sub Type	Round Culvert
PSCIS ID	198692	Diameter (m)	1.2
External ID	–	Length (m)	19
Crew	LS AI	Embedded	No
UTM Zone	10	Depth Embedded (m)	–
Easting	511736	Resemble Channel	No
Northing	6059308	Backwatered	No
Stream	Tributary to Kerry Lake	Percent Backwatered	–
Road	Kerry Lake FSR	Fill Depth (m)	2.5
Road Tenure	MoF	Outlet Drop (m)	0.34
Channel Width (m)	4	Outlet Pool Depth (m)	0.82
Stream Slope (%)	5	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	4
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	39	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	15

Location and Stream Data	Crossing Characteristics

Comments: Rainbow trout juveniles and adults (40-120mm in fork length) were captured with electrofishing within sites located 50m upstream and downstream of the Kerry Lake FSR. Fish were also observed in the outlet pool and upstream of the FSR crossing. There was beaver activity near the inlet and a large outlet drop. Upstream gravels provide suitable spawning habitat for resident fish, with good riparian vegetation supporting overall habitat quality.. 11:12:52

Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.

Stream Characteristics Downstream of Crossing 198692

The stream was surveyed downstream from crossing 198692 for 230m . Frequent deep pools provided cover for resident fish and gravels were present for spawning. The habitat was rated as medium value for anandromous spawning and rearing (Figure 5.7). The stream frequently flowed subsurface beginning around 200m downstream of the crossing. Total cover amount was rated as abundant with large woody debris dominant. Cover was also present as small woody debris, undercut banks, deep pools, and overhanging vegetation.The average channel width was 3.0m, the average wetted width was 1.4m, and the average gradient was 2.5%.The dominant substrate was cobbles with gravels sub-dominant.

Stream Characteristics Upstream of Crossing 198692

The stream was surveyed upstream from crossing 198692 for 500m . The stream was noted as having significant flow for the time of year. The habitat was rated as medium value, with patches of gravel suitable for spawning resident rainbow trout and bull trout present (Figure 5.7). The stream narrowed into a canyon approximately 150m upstream of Kerry FSR (Figure 5.8). The dominant substrate was cobbles with gravels sub-dominant.The average channel width was 4m, the average wetted width was 1.5m, and the average gradient was 5%.Total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, deep pools, and overhanging vegetation.

Fish Sampling

Electrofishing was conducted downstream and upstream of the Kerry Lake FSR crossing with results summarised in Tables 5.15 - 5.16 and Figure 5.6. A total of 70 fish were captured downstream and 20 fish were captured upstream, all of which were rainbow trout (Figures 5.8).

Aerial Imagery

An aerial survey was conducted with a remotely piloted aircraft and the resulting imagery was processed into an orthomosaic available to view and download here.

Structure Remediation and Cost Estimate

If there are no plans for further logging in the area, removing the crossing and deactivating the road should be considered as a fish passage remediation option. If logging activities are planned to continue and restoration/maintenance activities proceed, replacement of the Kerry Lake FSR crossing with a bridge (15 m span) is recommended. At the time of reporting in 2025, the cost of the work is estimated at $ 450,000.

Conclusion

Approximately 2.3km of bull trout rearing habitat is modelled upstream, and the habitat was rated as medium value for anandromous spawning and rearing. The 0.34m outlet drop at PSCIS crossing 198692 likely inhibits juvenile anandromous fish passage and the crossing is rated as a high priority for replacement.

Located on a low-traffic forest service road, remediation of this crossing would not require significant involvement. The road falls under the tenure of the Ministry of Forests, and if there are no plans for further logging in the area, removing the crossing and deactivating the road could be considered as a fish passage remediation option. If logging activities are planned to continue, opportunities should be explored to collaborate with road tenure holders to replace the crossing.

Table 5.14: Summary of habitat details for PSCIS crossings 198692.

Site	Location	Length Surveyed (m)	Average Channel Width (m)	Average Wetted Width (m)	Average Pool Depth (m)	Average Gradient (%)	Total Cover	Habitat Value
198692	Downstream	230	3	1.4	0.4	2.5	abundant	medium
198692	Upstream	500	4	1.5	0.2	5.0	abundant	medium

Table 5.15: Fish sampling site summary for 198692.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
198692_ds_ef1	1	20	1.9	38.0	partial enclosure
198692_ds_ef2	1	4	5.0	20.0	open
198692_us_ef1	1	27	1.4	37.8	partial enclosure

Table 5.16: Fish sampling density results summary for 198692.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
198692_ds_ef1	Rainbow Trout	fry	36	94.7	FALSE
198692_ds_ef2	Rainbow Trout	adult	1	5.0	FALSE
198692_ds_ef2	Rainbow Trout	fry	1	5.0	FALSE
198692_ds_ef2	Rainbow Trout	juvenile	5	25.0	FALSE
198692_ds_ef2	Rainbow Trout	parr	27	135.0	FALSE
198692_us_ef1	Rainbow Trout	fry	10	26.5	FALSE
198692_us_ef1	Rainbow Trout	parr	10	26.5	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.

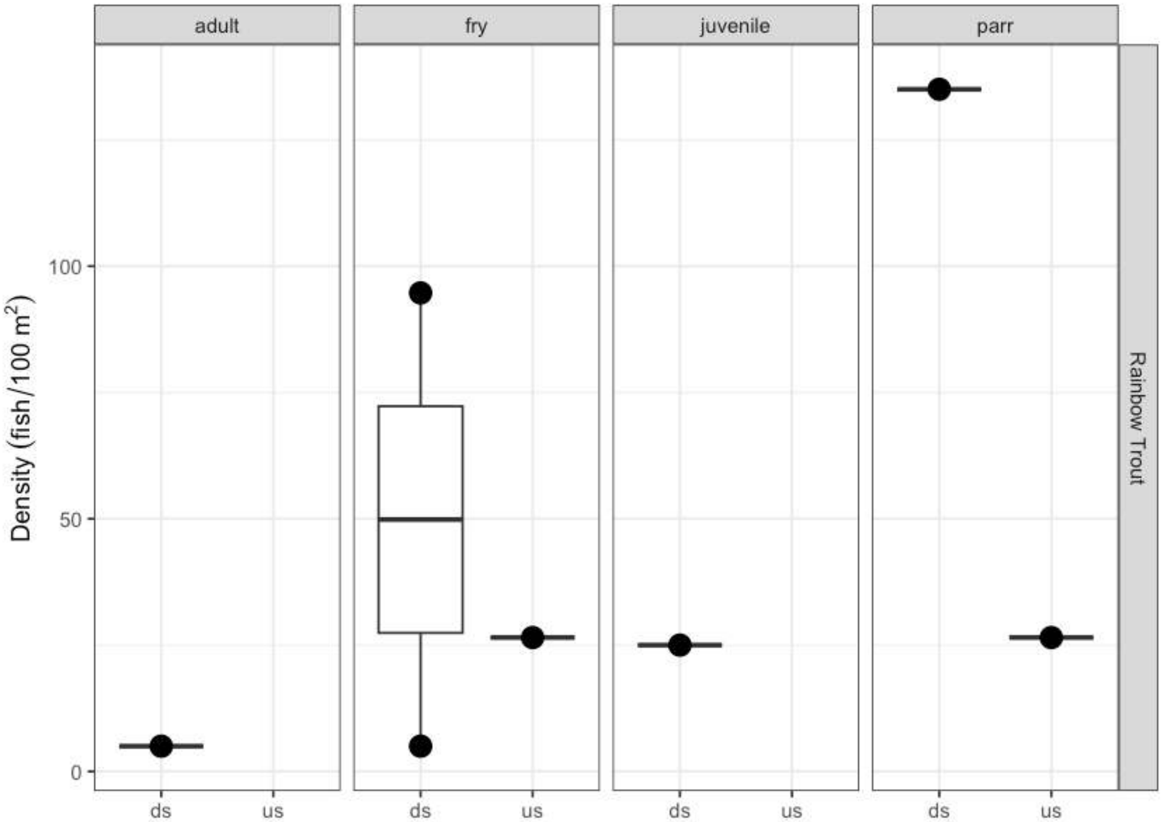

Figure 5.6: Densites of fish (fish/100m2) captured upstream and downstream of PSCIS crossing 198692.

Figure 5.7: Left: Typical habitat downstream of PSCIS crossing 198692. Right: Typical habitat upstream of PSCIS crossing 198692.

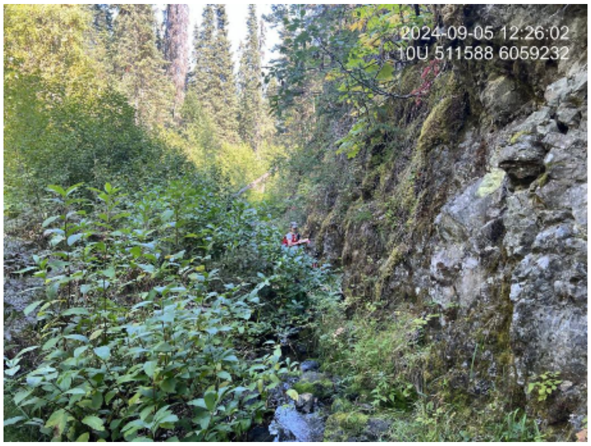

Figure 5.8: Left: Canyon located approximately 150m upstream of PSCIS crossing 198692. Right: Rainbow trout captured upstream of PSCIS crossing 198692.

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Note that this reference was not actually cited in the body of the report but rather in the `index.Rmd` file `yaml` headerj under the `no_cite` key.

Changelog

fish_passage_peace_2024_reporting 0.1.0 (2025-03-31)

- add Exec summary
- add recommendations
- rework methods and results

fish_passage_peace_2024_reporting 0.0.2 (2025-01-09)

- initial DRAFT release with progress map and Results summary tables

Session Info

Information about the computing environment is important for reproducibility. A summary of the computing environment is saved to `session_info.csv`, which can be viewed and downloaded from here.

```
## — Session info
```

```
## setting  value
## version  R version 4.4.0 (2024-04-24)
## os       macOS 15.3.2
## system   aarch64, darwin20
## ui       RStudio
## language (EN)
## collate  en_US.UTF-8
## ctype    en_US.UTF-8
## tz       America/Vancouver
## date     2025-04-16
## rstudio  2024.12.1+563 Kousa Dogwood (desktop)
## pandoc   3.2 @
/Applications/RStudio.app/Contents/Resources/app/quarto/bin/tools/aarch6-
```

```
4/ (via rmarkdown)
##
## ─ Packages
```

```
## package        * version   date (UTC) lib source
## archive          1.1.9     2024-09-12 [2] CRAN (R 4.4.1)
## bit              4.5.0.1   2024-12-03 [1] CRAN (R 4.4.1)
## bit64            4.6.0-1   2025-01-16 [1] CRAN (R 4.4.1)
## blob             1.2.4     2023-03-17 [1] CRAN (R 4.4.0)
## bookdown       * 0.42      2025-01-07 [1] CRAN (R 4.4.1)
## bslib            0.9.0     2025-01-30 [1] CRAN (R 4.4.1)
## cachem           1.1.0     2024-05-16 [1] CRAN (R 4.4.1)
## cellranger       1.1.0     2016-07-27 [1] CRAN (R 4.4.0)
## chk              0.10.0    2025-01-24 [1] CRAN (R 4.4.1)
## chromote         0.4.0     2025-01-25 [1] CRAN (R 4.4.1)
## class            7.3-22    2023-05-03 [2] CRAN (R 4.4.0)
## classInt         0.4-11    2025-01-08 [1] CRAN (R 4.4.1)
## cli              3.6.3     2024-06-21 [1] CRAN (R 4.4.1)
## codetools        0.2-20    2024-03-31 [2] CRAN (R 4.4.0)
## colorspace       2.1-1     2024-07-26 [1] CRAN (R 4.4.1)
## crayon           1.5.3     2024-06-20 [1] CRAN (R 4.4.1)
## curl             6.2.0     2025-01-23 [1] CRAN (R 4.4.1)
## DBI              1.2.3     2024-06-02 [1] CRAN (R 4.4.1)
## dbplyr           2.5.0     2024-03-19 [1] CRAN (R 4.4.0)
## devtools         2.4.5     2022-10-11 [2] CRAN (R 4.4.0)
## digest           0.6.37    2024-08-19 [1] CRAN (R 4.4.1)
## dplyr          * 1.1.4     2023-11-17 [1] CRAN (R 4.4.0)
## e1071            1.7-16    2024-09-16 [1] CRAN (R 4.4.1)
## ellipsis         0.3.2     2021-04-29 [2] CRAN (R 4.4.0)
## english          1.2-6     2021-08-21 [2] CRAN (R 4.4.0)
## evaluate         1.0.3     2025-01-10 [1] CRAN (R 4.4.1)
## farver           2.1.2     2024-05-13 [1] CRAN (R 4.4.1)
## fasstr           0.5.3     2024-09-27 [1] CRAN (R 4.4.1)
## fastmap          1.2.0     2024-05-15 [1] CRAN (R 4.4.1)
## fishbc           0.2.1     2021-05-12 [1] CRAN (R 4.4.0)
## forcats        * 1.0.0     2023-01-29 [1] CRAN (R 4.4.0)
## fpr            * 1.2.0     2025-04-11 [1] local
## fs               1.6.5     2024-10-30 [1] CRAN (R 4.4.1)
## generics         0.1.3     2022-07-05 [1] CRAN (R 4.4.1)
## ggdark         * 0.2.1     2019-01-11 [1] CRAN (R 4.4.0)
## ggplot2        * 3.5.1     2024-04-23 [1] CRAN (R 4.4.0)
## glue             1.8.0     2024-09-30 [1] CRAN (R 4.4.1)
## gtable           0.3.6     2024-10-25 [1] CRAN (R 4.4.1)
## here             1.0.1     2020-12-13 [1] CRAN (R 4.4.1)
## hms              1.1.3     2023-03-21 [1] CRAN (R 4.4.0)
## htmltools        0.5.8.1   2024-04-04 [1] CRAN (R 4.4.1)
## htmlwidgets      1.6.4     2023-12-06 [1] CRAN (R 4.4.0)
## httpuv           1.6.15    2024-03-26 [1] CRAN (R 4.4.0)
## httr             1.4.7     2023-08-15 [1] CRAN (R 4.4.0)
## janitor          2.2.1     2024-12-22 [1] CRAN (R 4.4.1)
```

```
##  jquerylib          0.1.4      2021-04-26 [1] CRAN (R 4.4.0)
##  jsonlite           1.8.9      2024-09-20 [1] CRAN (R 4.4.1)
##  kableExtra       * 1.4.0.3    2025-03-03 [1] Github
(haozhu233/kableExtra@a9c509a)
##  KernSmooth         2.23-22    2023-07-10 [2] CRAN (R 4.4.0)
##  knitr            * 1.49       2024-11-08 [1] CRAN (R 4.4.1)
##  labeling           0.4.3      2023-08-29 [1] CRAN (R 4.4.1)
##  later              1.4.1      2024-11-27 [1] CRAN (R 4.4.1)
##  lifecycle          1.0.4      2023-11-07 [1] CRAN (R 4.4.1)
##  lubridate        * 1.9.4      2024-12-08 [1] CRAN (R 4.4.1)
##  magick             2.8.5      2024-09-20 [1] CRAN (R 4.4.1)
##  magrittr           2.0.3      2022-03-30 [1] CRAN (R 4.4.1)
##  memoise            2.0.1      2021-11-26 [1] CRAN (R 4.4.0)
##  mime               0.12       2021-09-28 [1] CRAN (R 4.4.1)
##  miniUI             0.1.1.1    2018-05-18 [2] CRAN (R 4.4.0)
##  munsell            0.5.1      2024-04-01 [1] CRAN (R 4.4.1)
##  ngr              * 0.0.0.9002 2025-03-03 [1] Github
(newgraphenvironment/ngr@b888f82)
##  pagedown         * 0.22       2025-01-07 [1] CRAN (R 4.4.1)
##  pak                0.8.0.2    2025-04-08 [1] CRAN (R 4.4.1)
##  pillar             1.10.1     2025-01-07 [1] CRAN (R 4.4.1)
##  pkgbuild           1.4.6      2025-01-16 [1] CRAN (R 4.4.1)
##  pkgconfig          2.0.3      2019-09-22 [1] CRAN (R 4.4.1)
##  pkgload            1.4.0      2024-06-28 [1] CRAN (R 4.4.0)
##  poisutils          0.0.0.9010 2024-05-14 [2] Github
(poissonconsulting/poisutils@8310dc4)
##  processx           3.8.5      2025-01-08 [1] CRAN (R 4.4.1)
##  profvis            0.3.8      2023-05-02 [2] CRAN (R 4.4.0)
##  promises           1.3.2      2024-11-28 [1] CRAN (R 4.4.1)
##  proxy              0.4-27     2022-06-09 [1] CRAN (R 4.4.1)
##  ps                 1.8.1      2024-10-28 [1] CRAN (R 4.4.1)
##  purrr            * 1.0.4      2025-02-05 [1] CRAN (R 4.4.1)
##  R6                 2.6.0      2025-02-12 [1] CRAN (R 4.4.1)
##  rappdirs           0.3.3      2021-01-31 [1] CRAN (R 4.4.1)
##  rbbt             * 0.0.0.9000 2025-02-13 [1] Github
(NewGraphEnvironment/rbbt@f14a53c)
##  Rcpp               1.0.14     2025-01-12 [1] CRAN (R 4.4.1)
##  RcppRoll           0.3.1      2024-07-07 [1] CRAN (R 4.4.1)
##  readr            * 2.1.5      2024-01-10 [1] CRAN (R 4.4.0)
##  readwritesqlite  * 0.2.0      2022-10-16 [2] CRAN (R 4.4.0)
##  readxl             1.4.3      2023-07-06 [1] CRAN (R 4.4.0)
##  remotes            2.5.0      2024-03-17 [2] CRAN (R 4.4.0)
##  rlang              1.1.5      2025-01-17 [1] CRAN (R 4.4.1)
##  rmarkdown        * 2.29       2024-11-04 [1] CRAN (R 4.4.1)
##  roxygen2           7.3.1      2024-01-22 [2] CRAN (R 4.4.0)
##  RPostgres        * 1.4.8      2025-02-25 [1] CRAN (R 4.4.1)
##  rprojroot          2.0.4      2023-11-05 [1] CRAN (R 4.4.1)
```

```
##  RSQLite          2.3.9      2024-12-03 [1] CRAN (R 4.4.1)
##  rstudioapi       0.17.1     2024-10-22 [1] CRAN (R 4.4.1)
##  rvest            1.0.4      2024-02-12 [1] CRAN (R 4.4.0)
##  s2               1.1.7      2024-07-17 [1] CRAN (R 4.4.0)
##  sass             0.4.9      2024-03-15 [1] CRAN (R 4.4.0)
##  scales           1.3.0      2023-11-28 [1] CRAN (R 4.4.0)
##  servr            0.32       2024-10-04 [1] CRAN (R 4.4.1)
##  sessioninfo      1.2.2      2021-12-06 [2] CRAN (R 4.4.0)
##  sf             * 1.0-19     2024-11-05 [1] CRAN (R 4.4.1)
##  shiny            1.10.0     2024-12-14 [2] CRAN (R 4.4.1)
##  shrtcts          0.1.2      2024-05-14 [2] Github
(gadenbuie/shrtcts@41051cf)
##  snakecase        0.11.1     2023-08-27 [1] CRAN (R 4.4.0)
##  staticimports  * 0.0.0.9001 2025-04-11 [1] local
##  stringi          1.8.4      2024-05-06 [1] CRAN (R 4.4.1)
##  stringr        * 1.5.1      2023-11-14 [1] CRAN (R 4.4.0)
##  svglite          2.1.3      2023-12-08 [1] CRAN (R 4.4.0)
##  systemfonts      1.2.1      2025-01-20 [1] CRAN (R 4.4.1)
##  terra            1.8-29     2025-02-26 [1] CRAN (R 4.4.1)
##  tibble         * 3.2.1      2023-03-20 [1] CRAN (R 4.4.0)
##  tidyhydat        0.7.0      2024-10-04 [1] CRAN (R 4.4.1)
##  tidyr          * 1.3.1      2024-01-24 [1] CRAN (R 4.4.1)
##  tidyselect       1.2.1      2024-03-11 [1] CRAN (R 4.4.0)
##  tidyverse      * 2.0.0      2023-02-22 [1] CRAN (R 4.4.0)
##  tidyxl           1.0.10     2025-03-03 [1] Github
(nacnudus/tidyxl@7e2fbe7)
##  timechange       0.3.0      2024-01-18 [1] CRAN (R 4.4.1)
##  tzdb             0.4.0      2023-05-12 [1] CRAN (R 4.4.0)
##  units            0.8-5      2023-11-28 [1] CRAN (R 4.4.1)
##  urlchecker       1.0.1      2021-11-30 [2] CRAN (R 4.4.0)
##  usethis          2.2.3      2024-02-19 [2] CRAN (R 4.4.0)
##  vctrs            0.6.5      2023-12-01 [1] CRAN (R 4.4.0)
##  viridisLite      0.4.2      2023-05-02 [1] CRAN (R 4.4.1)
##  vroom            1.6.5      2023-12-05 [1] CRAN (R 4.4.0)
##  websocket        1.4.2      2024-07-22 [1] CRAN (R 4.4.1)
##  withr            3.0.2      2024-10-28 [1] CRAN (R 4.4.1)
##  wk               0.9.4      2024-10-11 [1] CRAN (R 4.4.1)
##  xfun             0.50       2025-01-07 [1] CRAN (R 4.4.1)
##  xml2             1.3.6      2023-12-04 [1] CRAN (R 4.4.1)
##  xtable           1.8-4      2019-04-21 [2] CRAN (R 4.4.0)
##  yaml             2.3.10     2024-07-26 [1] CRAN (R 4.4.1)
##  yesno            0.1.2      2020-07-10 [2] CRAN (R 4.4.0)
##
##  [1] /Users/lucy/Library/R/arm64/4.4/library
##  [2] /Library/Frameworks/R.framework/Versions/4.4-
arm64/Resources/library
##
```

Attachment - Maps

All georeferenced field maps are presented at:

- https://hillcrestgeo.ca/outgoing/fishpassage/projects/parsnip/archive/2022-05-27/

Maps are also available zipped for bulk download at:

- https://hillcrestgeo.ca/outgoing/fishpassage/projects/parsnip/archive/2022-05-27/2022-05-27.zip

Attachment - Phase 1 Data and Photos

Data and photos for all Phase 1 - fish passage assessments are provided online at https://www.newgraphenvironment.com/fish_passage_peace_2024_reporting/appendix---phase-1-fish-passage-assessment-data-and-photos.html - with a pdf version available at https://github.com/NewGraphEnvironment/fish_passage_peace_2024_reporting/raw/main/docs/Appendix_1.pdf

Attachment - Habitat Assessment and Fish Sampling Data

All field data collected is available here.

Habitat assessment data (including fish sampling and PIT tagging information) is available for download here https://github.com/NewGraphEnvironment/fish_passage_peace_2024_reporting/blob/main/data/habitat_confirmations.xls.

Raw fish data is available for download here https://github.com/NewGraphEnvironment/fish_passage_peace_2024_reporting/blob/main/data/fish_data_tags_joined.csv.

Attachment - Bayesian analysis to map stream discharge and temperature causal effects pathways

Details of this analysis and subsequent outputs can be reviewed in the report Spatial Stream Network Analysis of Nechako Watershed Stream Temperatures 2022b (Hill, Thorley, and Irvine 2024). At the time of reporting, ongoing work regarding the project was tracked https://github.com/poissonconsulting/fish-passage-22/issues and https://github.com/poissonconsulting/fish-passage-22b/issues.