Elk River Watershed Group Fish Passage Restoration Planning 2022

Prepared for
Nupqu Resource Limited Partnership

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Version 0.0.1
2023-02-24

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Acknowledgement

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

1 Introduction

Nupqu Resource Limited Partnership (Nupqu) was retained by the Canadian Wildlife Federation in the summer of 2022 to conduct fish habitat and fish sampling assessments at sites related to road-stream crossings within the Elk River watershed group as part of connectivity restoration planning targeting westslope cutthrout trout. New Graph Environment Ltd. was sub-contracted by Nupqu to assist with project delivery. The assessments conducted in 2022 complement work completed in 2020 (72 fish passage assessments and 15 habitat confirmation assessments) and 2021 (92 fish passage assessments and 15 habitat confirmation assessments) which can be viewed interactively online at https://newgraphenvironment.github.io/fish_passage_elk_2020_reporting_cwf/ (Irvine 2021) and https://newgraphenvironment.github.io/fish_passage_elk_2021_reporting/ (Irvine 2022). This report is available as pdf and as an online interactive report at https://newgraphenvironment.github.io/fish_passage_elk_2022_reporting/. Viewing online is recommended as the web-hosted version contains more features and is more easily navigable.

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). Also of relevance to aquatic connectivity, there are a multitude of dam structures historically installed throughout the province for numerous purposes such as water extraction and hydropower generation. There are numerous opportunities to restore connectivity by ensuring that fish passage considerations are incorporated into repair, replacement, relocation and deactivation designs for both stream crossing barrier and dam barrier structures.

2 Background

As a result of high-level direction from the provincial government, a Fish Passage Strategic Approach protocol has been developed for British Columbia to ensure that the greatest opportunities for restoration of fish passage are pursued. A Fish Passage Technical Working Group has been formed to coordinate the protocol and data is continuously amalgamated within the Provincial Steam Crossing Inventory System (PSCIS). The strategic approach protocol involves a four-phase process as described in Fish Passage Technical Working Group (2014) :

- Phase 1: Fish Passage Assessment – Fish stream crossings within watersheds with high fish values are assessed to determine barrier status of structures and document a general assessment of adjacent habitat quality and quantity.
- Phase 2: Habitat Confirmation – Assessments of crossings prioritized for follow up in Phase 1 studies are conducted to confirm quality and quantity of habitat upstream and down as well as to scope for other potential nearby barriers that could affect the practicality of remediation.
- Phase 3: Design – Site plans and designs are drawn for priority crossings where high value fish habitat has been confirmed.
- Phase 4: Remediation – Reconnecting of isolated habitats through replacement, rehabilitation or removal of prioritized crossing structure barriers.

The Canadian Wildlife Federation has been working on a watershed connectivity remediation plan for the Elk River watershed that incorporates the provincial Strategic Approach, evolution of the `bcfishpass` analysis tools and local knowledge of the watershed to prioritize barriers and restore connectivity for westslope cutthroat trout and other species in a strategic manner. Nupqu Resource Limited Partnership was retained to conduct fish passage assessments and habitat confirmations to fill data gaps in support of this work.

2.1 Project Location

To focus the project within habitat considered high value for conservation of westslope cutthrout trout, the study area included the Elk River watershed group with a focus on basins that flow into the Elk River (Figure 2.1). The Elk River has a mean annual discharge of 26 m^3/s at station 08NK016 near Sparwood and 47.3 m^3/s at station 08NK016 near Fernie with flow patterns typical of high elevation watersheds on the west side of the Rocky Mountains which receive large amounts of precipitation as snow leading to peak levels of discharge during snowmelt, typically from May to July (Figures 2.2 - 2.4) (Environment and Canada 2020).

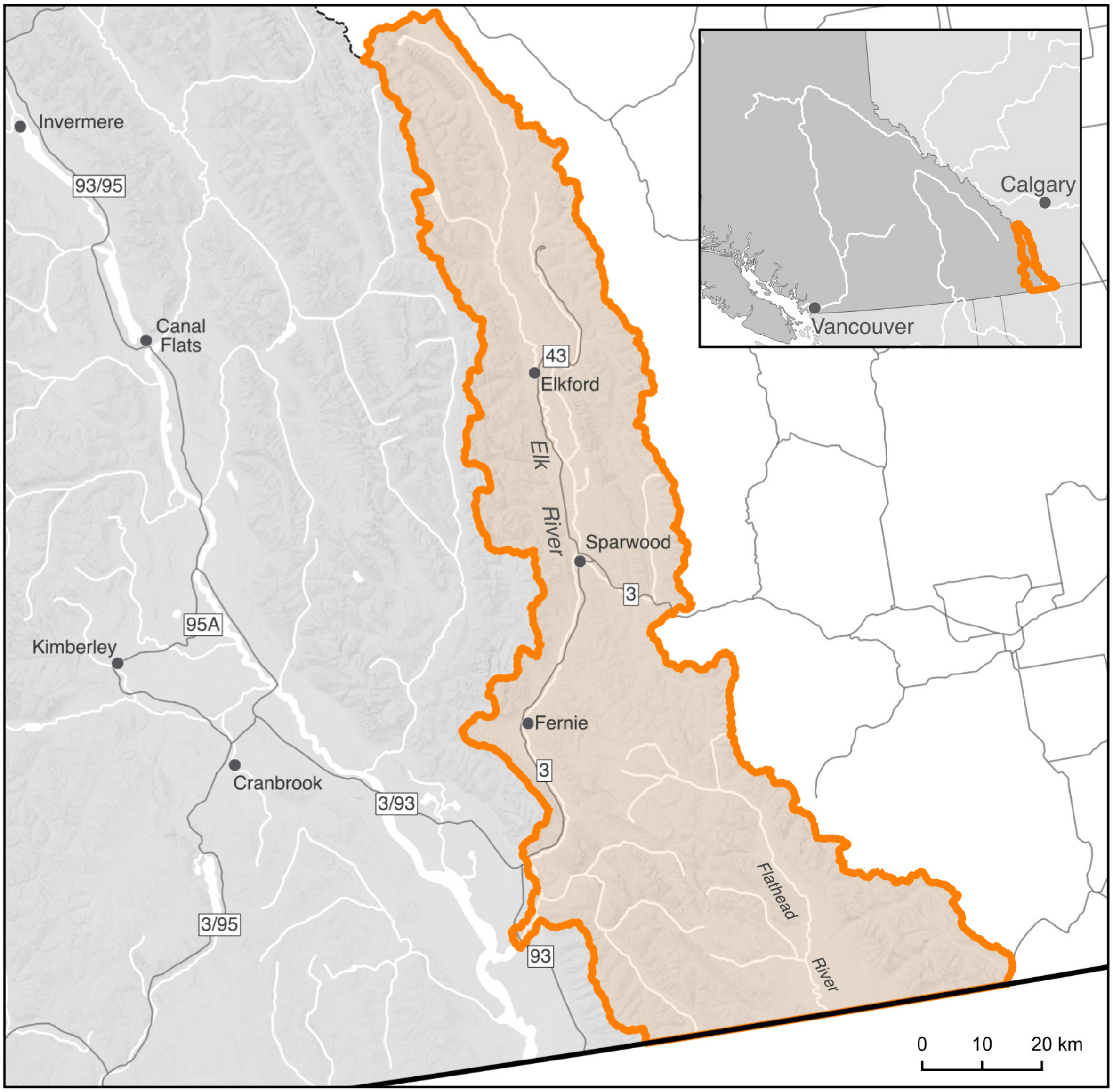

Figure 2.1: Overview map of Study Area

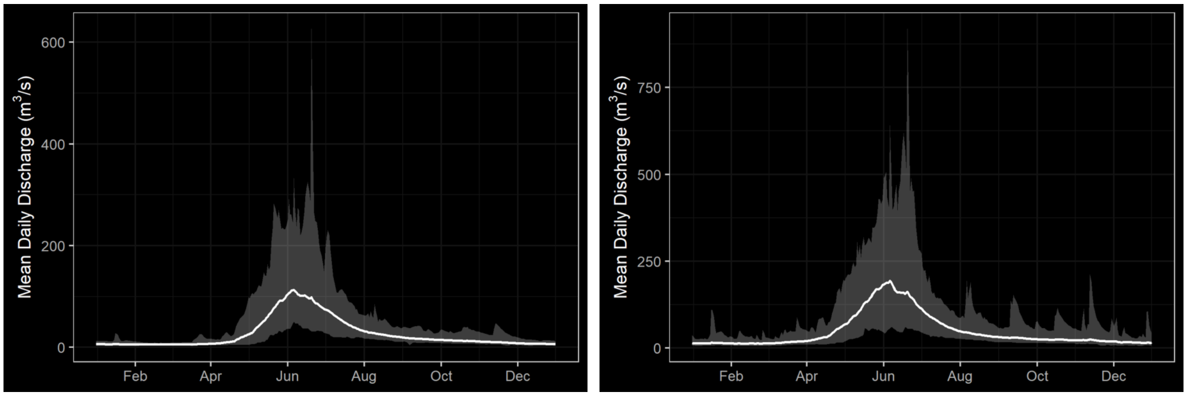

Figure 2.2: Hydrograph for Elk River near Sparwood (Station #08NK016) and near Fernie (Station #08NK002).

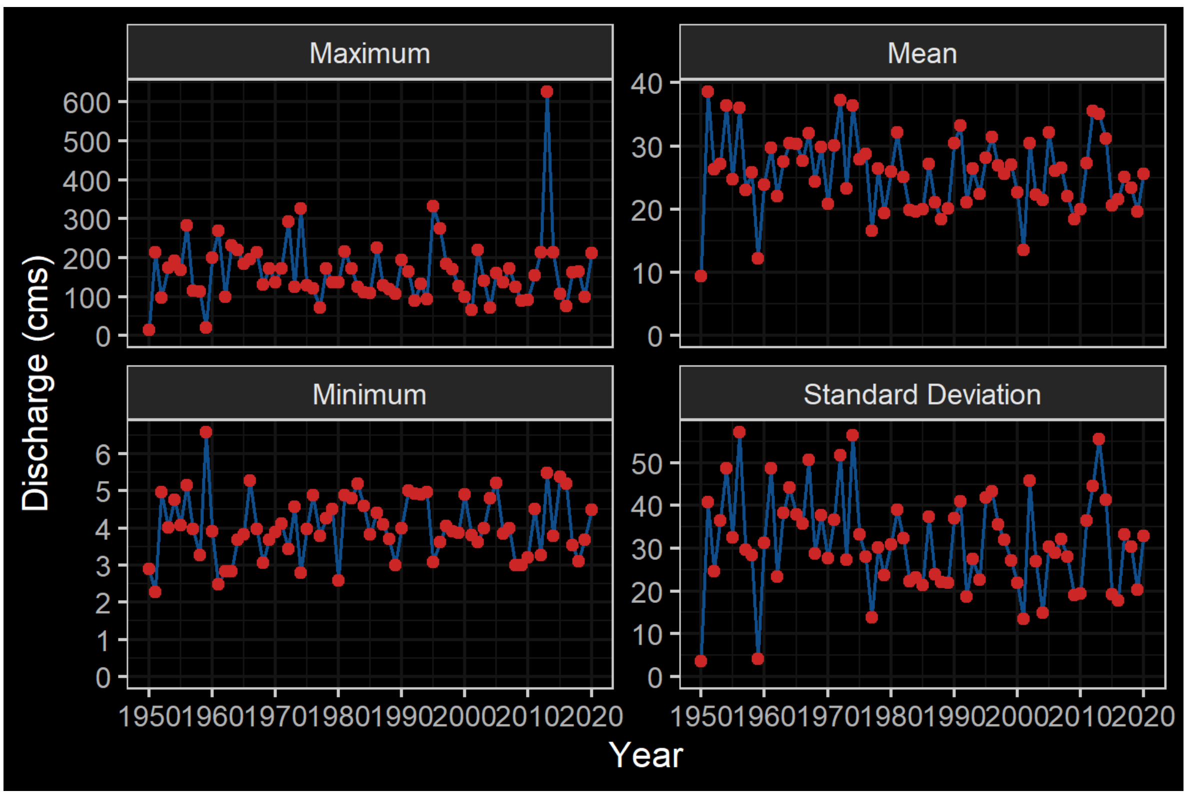

Figure 2.3: Elk River Near Sparwood (Station #08NK016 - Lat 49.86562 Lon -114.86868). Available daily discharge data from 1950 to 2020.

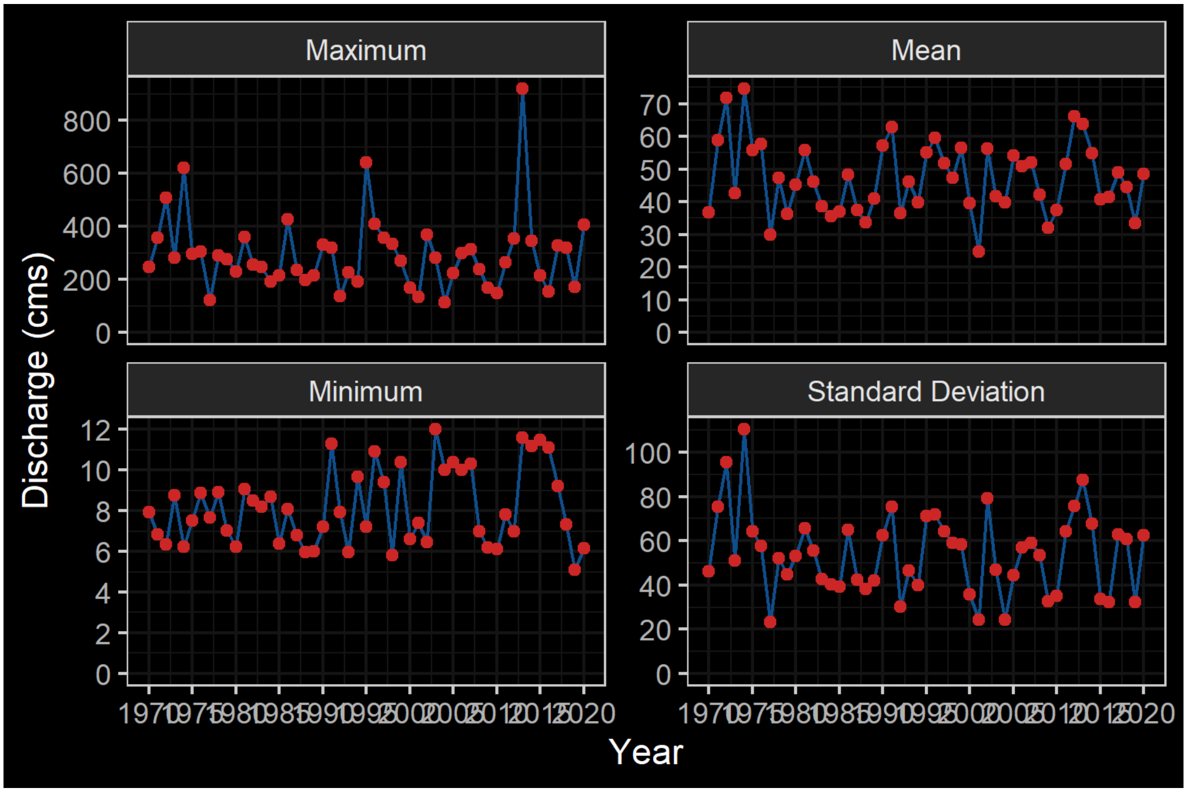

Figure 2.4: Elk River At Fernie (Station #08NK002 - Lat 49.50347 Lon -115.07013). Available daily discharge data from 1970 to 2020.

2.1.1 Ktunaxa Nation

The project location is within the traditional territory of the Ktunaxa Nation ("Ktunaxa Nation" 2020) with Elk River components within an area known as Qukin ʔamakʔis, or Raven's Land (Ministry of Forests 2020). When Europeans settled in the Kootenay Region around 200 hundred years ago, the Indian Reserves were created which lead to the seven Indian Bands:

- ʔakisq̓nuk- Columbia Lake Band (Windermere, BC);
- ʔaq̓am- St. Mary's Band (Cranbrook, BC);
- ʔakink̓umǂasnuqǂiʔit- Tobacco Plains Band (Grasmere, BC);
- yaqan nuʔkiy- Lower Kootenay Band (Creston, BC);
- kyaknuqǂiʔit- Shuswap Band (Invermere, BC);
- ʔaq̓anqmi- Kootenai Tribe of Idaho (Bonners Ferry, Idaho);
- k̓upawi¢q̓nuk- Ksanka Band (Elmo, Montana)

"Ktunaxa Nation" (2020) report the vision statement of the Ktunaxa as:

"K¢mak̓qa ksukɫuɫa·k kuk̓qani ¢ k̓itqakiɫ haqa ksiʔɫ ¢xa ʔa·kɫukqaʔis ksukiɫq̓ukaʔmi·k kiʔin Ktunaxa naʔs ʔamak̓ʔis. Qus pik̓aks¢ naʔs ¢xaɫ yaqanakiɫ haqaʔki. K̓itqawi¢mu kakiɫwi¢kiɫ ʔamakʔis k̓isnik¢ik k¢xaɫ qa kiɫk̓k̓axuxami·k k̓itqakiɫ haqa ¢ k̓isʔin ʔaknumu¢tiɫʔis."

The vision statement has been translated to english as:

"Strong, healthy citizens and communities, speaking our languages and celebrating who we are and our history in our ancestral homelands, working together, managing our lands and resources, within a self-sufficient, self-governing Nation."

2.1.2 Elk Valley Cumulative Effects Management Framework

First Nations, stakeholders, proponents and provincial and municipal governments have recognized that the region has been impacted by historic and current coal operations as well as other stresses such as forestry operations, wildfire, residential development, recreational activities and transportation. To assess the historic, current and potential future conditions of valued ecosystem components and to support resource management decisions within the region, the Provincial Cumulative Effects Framework and the Elk Valley Cumulative Effects Management Framework (EV-CEMF) have been formed under joint management between the Ktunaxa Nation Council and the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). A working group consisting of the Ktunaxa Nation Council, industry, community, organizations, and provincial government ministries has been formed to provide guidance and oversight for EV-CEMF activities. Valued component technical reports for Grizzly Bear, Riparian and westslope cutthroat trout (Davidson et al. 2018), bighorn sheep, and old and mature forest have been drafted, integrated into an overarching Cumulative Effects Assessment and Management Report (Elk Valley Cumulative Effects Management Framework Working Group 2018) and endorsed by the Working Group. These reports describe the historical, current, and future assessment of cumulative effects in the Elk Valley and provide management and mitigation recommendations. Next steps for the framework include the development of an Implementation Plan to identify priority actions and spatial locations to focus management and mitigation of cumulative effects in the valley which may include actions to address aquatic habitat connectivity issues (Ministry of Forests 2020).

2.2 Fisheries

Fish species recorded in the Elk River watershed group are detailed in Table 2.1 (MoE 2020a). Bull trout and westslope cutthrout trout are considered of special concern (blue-listed) provincially and westslope cutthrout trout (Pacific populations) are are listed under the *Species at Risk Act* by the

Committee on the Status of Endangered Wildlife in Canada as a species of special concern (BC Species & Ecosystem Explorer 2020b, 2020a; Schweigert et al. 2017). The focus of 2020 field work was to assess potential impacts of road-stream crossings on habitat connectivity for westslope cutthrout trout.

Table 2.1: Fish species recorded in the study area (FISS 2020).

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA	Elk	Flathead
Catostomus catostomus	Longnose Sucker	LSU	Yellow	–	–	–	Yes	Yes
Catostomus columbianus	Bridgelip Sucker	BSU	Yellow	–	–	–	Yes	–
Catostomus commersonii	White Sucker	WSU	Yellow	–	–	–	Yes	–
Catostomus macrocheilus	Largescale Sucker	CSU	Yellow	–	–	–	–	Yes
Cottus cognatus	Slimy Sculpin	CCG	Yellow	–	–	–	–	Yes
Cottus confusus	Shorthead Sculpin	CCN	Blue	–	SC (Nov 2010)	1-SC	–	Yes
Cottus hubbsi	Mottled Sculpin	CBA	Blue	–	SC (Nov 2010)	1-SC (Jun 2003)	–	Yes
Cottus sp. 9	Rocky Mountain Sculpin	CRM	Red	–	SC (Apr 2010)	1-SC (May 2017)	–	Yes
Oncorhynchus clarkii	Cutthroat Trout	CT	No Status	–	–	–	Yes	Yes
Oncorhynchus clarkii lewisi	Westslope Cutthroat Trout	WCT	Blue	Y (Jun 2006)	SC (Nov 2016)	1-SC (Feb 2010)	Yes	Yes
Oncorhynchus mykiss	Rainbow Trout	RB	Yellow	–	–	–	Yes	Yes
Oncorhynchus nerka	Kokanee	KO	Yellow	–	–	–	Yes	Yes
Prosopium williamsoni	Mountain Whitefish	MW	Yellow	–	–	–	Yes	Yes
Rhinichthys cataractae	Longnose Dace	LNC	Yellow	–	–	–	Yes	Yes
Richardsonius balteatus	Redside Shiner	RSC	Yellow	–	–	–	Yes	–
Salvelinus confluentus pop. 26	Bull Trout	BT	Blue	–	–	–	Yes	Yes
Salvelinus fontinalis	Brook Trout	EB	Exotic	–	–	–	Yes	–
–	Cutthroat/Rainbow cross	CRS	–	–	–	–	Yes	–
–	Sculpin (General)	CC	–	–	–	–	–	Yes
–	Sucker (General)	SU	–	–	–	–	Yes	Yes

2.2.1 Westslope Cutthrout Trout

There are multiple life history strategies for westslope cutthrout trout including stream-resident, fluvial and adfluvial. All have habitat requirements during life history stages that include cold clean water and varied forms of cover (undercut banks, pool-riffle habitat and riparian vegetation). Stream-resident fish inhabitat headwater streams above barriers, complete their life cycle within a relatively small range and typically remain relatively small (i.e. <200mm in length). Fluvial fish are migratory subpopulations that migrate between small spawning/rearing tributaries and larger adult rearing rivers. Lengths of fluvial fish generally reach more than 400mm. Finally, adfluvial subpopulations rear in lakes and migrate to spawning/rearing tributaries with lengths often exceeding 500mm (Schweigert et al. 2017).

Spawning habitat for resident and fluvial subpopulations are documented as within the tailouts of deep pools at moderate to high-flow events within small, low-gradient streams with cold well-oxygenated water and clean unsilted gravels (Schmetterling 2001). Proximity to large woody debris, boulder or bedrock cover is important for spawning fish while residing in spawning tributaries as high mortality may result when suitable cover is lacking. The dominant substrate used for spawning is gravel (1.8 - 3.3cm diameter) with spawning occurring in late May and June towards the end of the spring freshet with rising water temperatures between 7-11°C. Nine of 11 westslope cutthrout trout radio-tagged in the Blackfoot River drainage, Montana by Schmetterling (2001) made movements to tributaries presumable for spawning. While in tributaries, fish movements to spawning sites averaged 12.5km where they stayed within an approximately 100m reach during the spawning period for between 15 and 63 days.

Small perennial streams with a diversity of cover are important for juvenile rearing with young-of-year fish inhabiting low energy lateral habitats (i.e. shallow riffle or backwatered areas) with cover available. Larger juveniles move into pools with social dominance behaviors prevalent and based on fish size. Availability of pool habitat is important and limiting for parr which have large territories (Schweigert et al. 2017; Schmetterling 2001). The suitability of overwintering habitat is determined by groundwater influx and the absence of anchor ice with fluvial adults congregating in slow deep pools in the winter. Boulders and other large in-stream structures or off-channel habitat (beaver bonds and sloughs) provide cover for juveniles with adfluvial fish overwintering in lakes (Schweigert et al. 2017; Brown and Mackay 1995; S. Cope, Schwarz, and Prince 2017).

In a swimming performance study conducted in an open-channel flume Blank et al. (2020) estimated the overall average swim speeds of westlope cutthrout trout (150mm - 290mm in length) at 0.84m/s with a maximum observed swim speed of 3.55m/s.

The greatest threats to westslope cutthrout trout are hybridization with non-native rainbow trout and degradation of the environment due to forestry, hydroelectric development, mining, urbanization and agriculture (Schweigert et al. 2017). Lamson (2020) sampled over 2000 trout in the Upper Kootenay watershed from 2014 to 2019 with results of genotyping indicating consistently high levels of westslope cutthrout trout allele purity (i.e. very low levels of rainbow trout, yellowstone cutthrout trout or coastal cutthrout trout genetic introgression) throughout the Elk River watershed areas upstream of the Elko Dam. Boyer, Muhlfeld, and Allendorf (2008) sampled 31 sites in the upper Flathead River system within the United States (27 sites) and Canada (4 sites). Genetic introgression declined with latitude with no evidence of rainbow trout allelles within any westslope cutthrout trout sampled within the Canadian portion of the upper Flathead River.

Gradient of streams is an important determinant of habitat suitability for salmonids with lower gradient habitats often providing the most productive environments for both rearing and spawning while high gradient sections typically present upstream migration barriers and less available habitat. A summary of historic westslope cutthrout trout observations in the Elk River watershed group delineated by average gradient category of associated stream segments where they were captured is provided in Figure 2.5. Of 4003 observations, 93% were within stream segments with average gradients ranging from 0 - 8%. A total of 73% of historic observations were within stream segments with gradients between 0 - 3%, 12% were within stream segments with gradients ranging from 3 - 5% and 8% were within stream segments with gradients between 5 - 8% (MoE 2020a; Norris 2020).

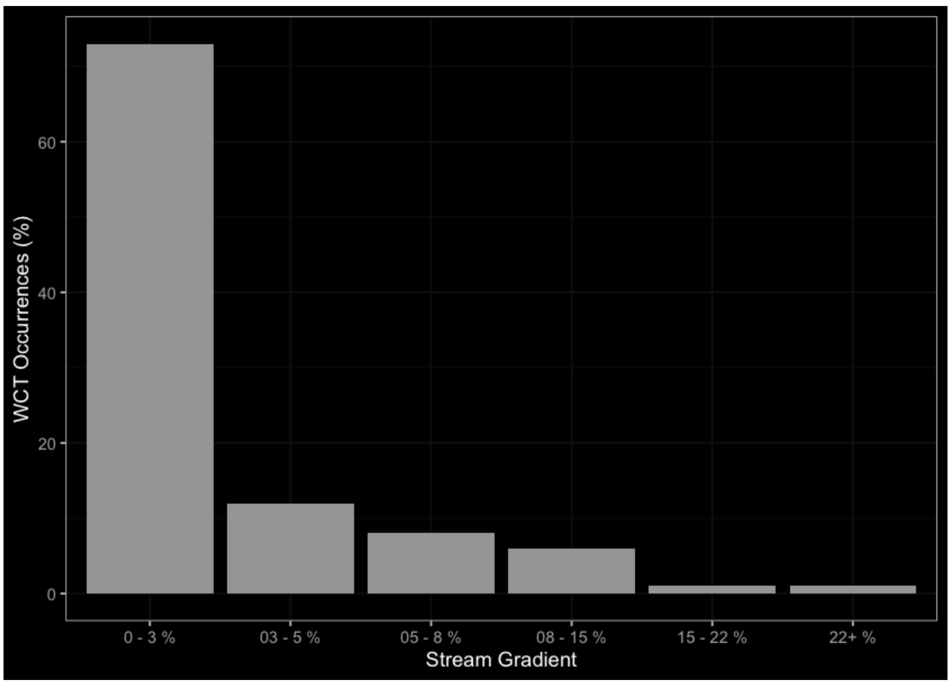

Figure 2.5: Summary of historic westslope cutthrout trout observations vs. stream gradient category.

3 Methods

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

3.1 Planning

Priorities for site assessment locations were provided by Canadian Wildlife Federation with some additional sites selected by field crews based on planning activities reported in 2021 (Irvine 2021), background literature review (Irvine 2016; VAST Resource Solutions Inc. 2013; Grainger 2011), fisheries information, PSCIS, `bcfishpass` (Norris [2020] 2021) outputs and field reconnaissance.

3.1.1 Habitat Modelling

`bcfishpass` is an open-source code repository that models aquatic connectivity based on a suite of hard coded (maximum stream slope downstream, PSCIS barrier information, dam locations and user defined parameters (gradient/width/discharge). Details of the general methodology can be found here and will be updated over time as the tools evolve. Once a development environment is properly setup, the software builds a local `postgresql` database through the utilization of other open-source tools such as `bcdata` (Norris [2016] 2021), `bcfishobs` (Norris [2018] 2021), and `fwapg` (Norris [2019] 2021) to provide connectivity models developed from analysis of the BC Freshwater Atlas, road layers, fisheries information, stream discharge estimates, measured/modeled estimates of channel width and numerous other standardized datasets downloaded directly from the BC Data Catalogue application programming interface using `bcdata`.

`bcfishpass` calculates the average gradient of BC Freshwater Atlas stream network lines at minimum 100m long intervals starting from the downstream end of the streamline segment and working upstream. The network lines are broken into max gradient categories with new segments created when the average slope of the stream line segment exceeds user provided thresholds. For this project, the user provided gradient thresholds used to delineate "potentially accessible habitat" were based on general stream morphology types (Table 3.1) and estimated max gradients that westslope cutthrout trout (22%) are likely to be capable of ascending. `bcfishpass` identifes natural barriers (ex. steep gradients for extended distances) and hydroelectric dams to classifying the accessibility upstream by fish (Norris [2020] 2021). On potentially accessible streams, scripts identify known barriers (ex. waterfalls >5m high) and additional anthropogenic features which are primarily road/railway stream crossings (i.e. culverts) that are potentially barriers. To prioritize these features for assessment or remediation, scripts report on how much modelled potentially accessible aquatic habitat the barriers may obstruct. The gradient based model can be refined with known fish observations as well as estimates of stream discharge and channel width to provide an indication of the quantity and quality of habitat potentially gained should fish passage be restored.

Table 3.1: Stream gradient categories (threshold and average) and associated channel type.

Gradient	Channel Type
0 - 3% and 3 - 5%	Riffle and cascade pool
5 - 8%	Step pool
8 - 15%	Step pool - very steep
15 - 22%	Step pool - extremely steep
>22%	Non WCT habitat

`bcfishpass` and associated tools have been designed to be flexible in analysis, accepting user defined gradient, channel width and stream discharge categories (MoE 2020c). Although currently in draft form, and subject to development revisions, Canadian Wildlife Federation assigned gradient and discharge thresholds for habitat with the highest intrinsic value for westslope cutthrout trout have been estimated and applied to model habitat upstream of stream crossing locations with thresholds estimated based on a literature review and professional opinion (Table **??**). Results from modelling are presented for habitat confirmation sites in appendices using output parameters present in Table **??**.

3.2 Fish Passage Assessments

In the field, crossings prioritized for follow-up were first assessed for fish passage following the procedures outlined in “Field Assessment for Determining Fish Passage Status of Closed Bottomed Structures” (MoE 2011). Crossings surveyed included closed bottom structures (CBS), open bottom structures (OBS) and crossings considered “other” (i.e. fords). Photos were taken at surveyed crossings and when possible included images of the road, crossing inlet, crossing outlet, crossing barrel, channel downstream and channel upstream of the crossing and any other relevant features. The following information was recorded for all surveyed crossings: date of inspection, crossing reference, crew member initials, Universal Transverse Mercator (UTM) coordinates, stream name, road name and kilometer, road tenure information, crossing type, crossing subtype, culvert diameter or span for OBS, culvert length or width for OBS. A more detailed “full assessment” was completed for all closed bottom structures and included the following parameters: presence/absence of continuous culvert embedment (yes/no), average depth of embedment, whether or not the culvert bed resembled the native stream bed, presence of and percentage backwatering, fill depth, outlet drop, outlet pool depth, inlet drop, culvert slope, average downstream channel width, stream slope, presence/absence of beaver activity, presence/absence of fish at time of survey, type of valley fill, and a habitat value rating. Habitat value ratings were based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), fish migration patterns, the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation (Table **??**). For crossings determined to be potential barriers or barriers based on the data (see Barrier Scoring (page 14)), a culvert fix and recommended diameter/span was proposed.

3.2.1 Barrier Scoring

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 **??**, Table **??**. 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).

3.2.2 Cost Benefit Analysis

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

3.2.2.1 Habitat Gain Index

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

For reporting of Phase 1 - fish passage assessments within the body of this report (Table **??**), a "total" value of habitat <20% output from `bcfishpass` was used to estimate the amount of habitat upstream of each crossing less than 20% gradient before a falls of height >5m - as recorded in MoE (2020b) or documented in other `bcfishpass` online documentation. To generate areas of habitat upstream, the estimated linear length was multiplied by the downstream channel width measured 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 do allow a rough screening to help facilitate the decision making process for selecting the best candidates for follow up with more detailed Phase 2 assessments.

For Phase 2 - habitat confirmation sites, conservative estimates of the linear quantity of habitat suitable for rearing and spawning of westslope cutthrout trout to be potentially gained by fish passage restoration, mainstem and large tributary streams (>1st order streams) segments upstream of each crossing with freshwater atlas stream layer gradients <8% and modelled at >2m wide (likely of highest value for rearing and spawning westslope cutthrout trout), below natural/manmade barriers and downstream of documented culvert barriers were measured by hand with the measure tool within QGIS (QGIS Development Team 2009). To generate estimates of the area of habitat upstream of these sites, the length of habitat was multiplied by the upstream average channel width that was measured in the field.

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

Cost estimates for structure replacement with bridges and embedded culverts were generated based on the channel width, slope of the culvert, depth of fill, road class and road surface type. Road details were sourced from FLNRORD (2020b) and FLNRORD (2020a) through `bcfishpass`. Interviews with Phil MacDonald, Engineering Specialist FLNR - Kootenay, Steve Page, Area Engineer - FLNR - Northern Engineering Group and Matt Hawkins - MoTi - Design Supervisor for Highway Design and Survey - Nelson, David Maloney - FLNR - Fish Passage Technical Working Group were utilized to help refine estimates.

Base costs for installation of bridges on forest service roads and permit roads with surfaces specified in provincial GIS road layers as rough and loose was roughly estimated at $20,000/linear m and assumed that the road could be closed during construction. For streams with channel widths <2m, embedded culverts were reported as an effective solution with total installation costs roughly estimated at $40k/crossing so as to take into account the rising costs of materials and labour since the original estimate of $25k/crossing was communicated in early 2021 (pers. comm. Phil

MacDonald, Steve Page). For larger streams (>6m), estimates of bridge span width increased proportionally to the size of the stream (ex. for an 8m wide stream a 14m wide span was estimated vs. the 12m wide span estimated for a 6m wide 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 also generated to estimate incremental cost increases with dollar amounts estimated for structure replacement on paved surfaces, railways and arterial/highways up to 30 times more than forest service roads due to expenses associated with design/engineering requirements, traffic control and paving. The cost multiplier table (Table **??**) should be considered very approximate with refinement recommended for future projects.

3.3 Habitat Confirmation Assessments

Following fish passage assessments, habitat confirmations were completed in accordance with procedures outlined in the document “A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation of a Stream Crossing” (Fish Passage Technical Working Group 2011). The main objective of the field surveys was to document upstream habitat quantity and quality as well as 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 **??**).

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

3.4 Reporting

Reporting was generated with `bookdown` (Xie 2016) from `Rmarkdown` (Allaire et al. 2023) with primarily `R` (R Core Team 2020) and `SQL` scripts. In addition to numerous spatial layers sourced through the BC Data Catalogue then stored and queried in local `postgresql` and `sqlite` databases. Raw data inputs for this project included:

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

3.5 Mapping

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

4 Recommendations

Recommendations for potential incorporation into collaborative watershed connectivity planning for the Elk River watershed group include:

- Continue to acquire background information and leverage ongoing research initiatives in the region to collaboratively clarify current conditions and identify limiting factors to inform prioritization and effectiveness monitoring programs.

- Develop strategies to explore cost and fisheries production benefits of stream crossing structure upgrades alongside alternative/additional restoration and enhancement investments such as land conservation/procurement/covenant, cattle exclusion, riparian restoration, habitat complexing, water conservation, commercial/recreational fishing management, water treatment and research. Look for opportunities to collaborate and leverage initiatives together for maximum likley restoration benefits.

- Refine barrier thresholds for road-stream crossing structures to explore metrics specific to life stage and life history types of species of interest. This will further focus efforts of potential remediation actions based on biological attributes (ex. timing of migration, size/direction of fish migrating, population dynamics, etc.) and could result in the consideration of interim "stop-gap" physical works to alter crossing characteristics that can address key connectivity issues yet be significantly less costly than structure replacements (ex. building up of downstream area with rock riffles to decrease the outlet drop size and/or increasing water depth within pipe with baffles and substrate additions).

- Model fish densities (fish/m^2) vs. habitat/water quality characteristics (i.e. gradient, discharge, alkalinity, elevation, riparian health, distance from high order streams, etc.) using historically gathered electrofishing and remotely sensed geodata to inform crossing prioritization, future data acquisition needs and the monitoring of restoration actions.

- Continue to develop `bcfishpass`,`bcfishobs`, `fwapg`, `bcdata` and share open source data analysis and presentation tools that are scaleable and facilitate continual improvement. Tools should continue to be flexible and well documented to allow the future incorporation of alternative fragmentation indicators, habitat gain/value metrics and watershed sensitivity indicators.

- Continue to collaborate with potential partners to build relationships, explore perspectives and develop "road maps" for aquatic restoration in different situations (MoT roads, rail lines, permit roads of different usages, FSRs, etc.) – documenting the people involved, discussions and processes that are undertaken, funding options, synergies, measures of success, etc.

Weigert Creek - 197534 - Appendix

Site Location

PSCIS crossing 197534 is located on Highway 43, approximately 23.5km north of the town of Sparwood. Crossing 197534 was located approximately 1.3km upstream from the confluence with the Elk River and is the responsibility of the Ministry of Transportation and Infrastructure.

Table 4.1: Summary of derived upstream watershed statistics for PSCIS crossing 197534.

Site	Area Km	Elev Site	Elev Max	Elev Median	Elev P60	Aspect
197534	43.3	1253	2938	2019	1929	SE

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

A summary of habitat modelling outputs is presented in Table 4.2 and a map of the watershed is provided in map attachment 082G.123.

Table 4.2: Summary of fish habitat modelling for PSCIS crossing 197534.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	8.2	3.3	40
WCT Rearing (km)	11.1	4.6	41
WCT Stream (km)	20.3	5.4	27
WCT Network (km)	20.3	5.4	27
WCT Lake Reservoir (ha)	–	0.0	–
WCT Wetland (ha)	–	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	3.0	2.1	70
WCT Slopeclass05 (km)	6.0	1.2	20
WCT Slopeclass08 (km)	3.6	1.5	42
WCT Slopeclass15 (km)	5.9	0.3	5
WCT Slopeclass22 (km)	1.9	0.3	16

* Model data is preliminary and subject to adjustments.

Fish Sampling

Electrofishing was conducted with results summarised in Tables 4.4 - 4.5 and Figure 4.1. Habitat details are summarised in Table 4.3.

Table 4.3: Summary of habitat details for electrofishing sites upstream and downstream of PSCIS crossing 197534.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197534	ds_ef1	520	4.4	3.5	0.8	3.1	moderate	Medium
197534	ds_ef2	1240	–	–	–	–	–	–
197534	us4	440	6.8	5.7	0.6	5.5	moderate	Medium
197534	us5	450	6.7	4.8	0.6	3.5	moderate	Medium
197534	us_ef1	–	6.2	4.4	–	6.6	–	–
197534	us_ef2	300	5.6	5.0	0.5	5.2	moderate	High
197534	us_ef3	–	6.4	4.4	0.6	3.8	–	High
197534	us_ef4	330	5.0	4.0	0.7	6.7	moderate	Medium
197534	us_ef5	300	4.9	–	–	–	abundant	–
197534	us_ef6	550	7.0	4.9	0.4	4.0	abundant	–

Table 4.4: Fish sampling site summary for 197534.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
197534_ds_ef1	1	520	3.480	1809.6	open
197534_ds_ef2	1	–	–	–	open
197534_us_ef1	1	–	4.400	–	open
197534_us_ef2	1	300	4.960	1488.0	open
197534_us_ef3	1	–	4.440	–	open
197534_us_ef4	1	330	2.040	673.2	open
197534_us_ef5	1	300	1.525	457.5	open
197534_us_ef6	1	550	4.900	2695.0	open

Table 4.5: Fish sampling density results summary for 197534.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197534_ds_ef1	BT	adult	1	0.1	FALSE
197534_ds_ef1	EB	fry	1	0.1	FALSE
197534_ds_ef1	EB	parr	1	0.1	FALSE
197534_ds_ef1	EB	juvenile	1	0.1	FALSE
197534_ds_ef1	MW	juvenile	1	0.1	FALSE
197534_ds_ef1	WCT	parr	3	0.2	FALSE
197534_ds_ef1	WCT	juvenile	2	0.1	FALSE
197534_ds_ef2	WCT	adult	1	–	FALSE
197534_us_ef1	NFC	–	0	–	TRUE
197534_us_ef2	WCT	juvenile	1	0.1	FALSE
197534_us_ef2	WCT	adult	6	0.4	FALSE
197534_us_ef3	NFC	–	0	–	TRUE
197534_us_ef4	NFC	–	0	0.0	TRUE
197534_us_ef5	NFC	–	0	0.0	TRUE
197534_us_ef6	WCT	juvenile	1	0.0	FALSE
197534_us_ef6	WCT	adult	1	0.0	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.

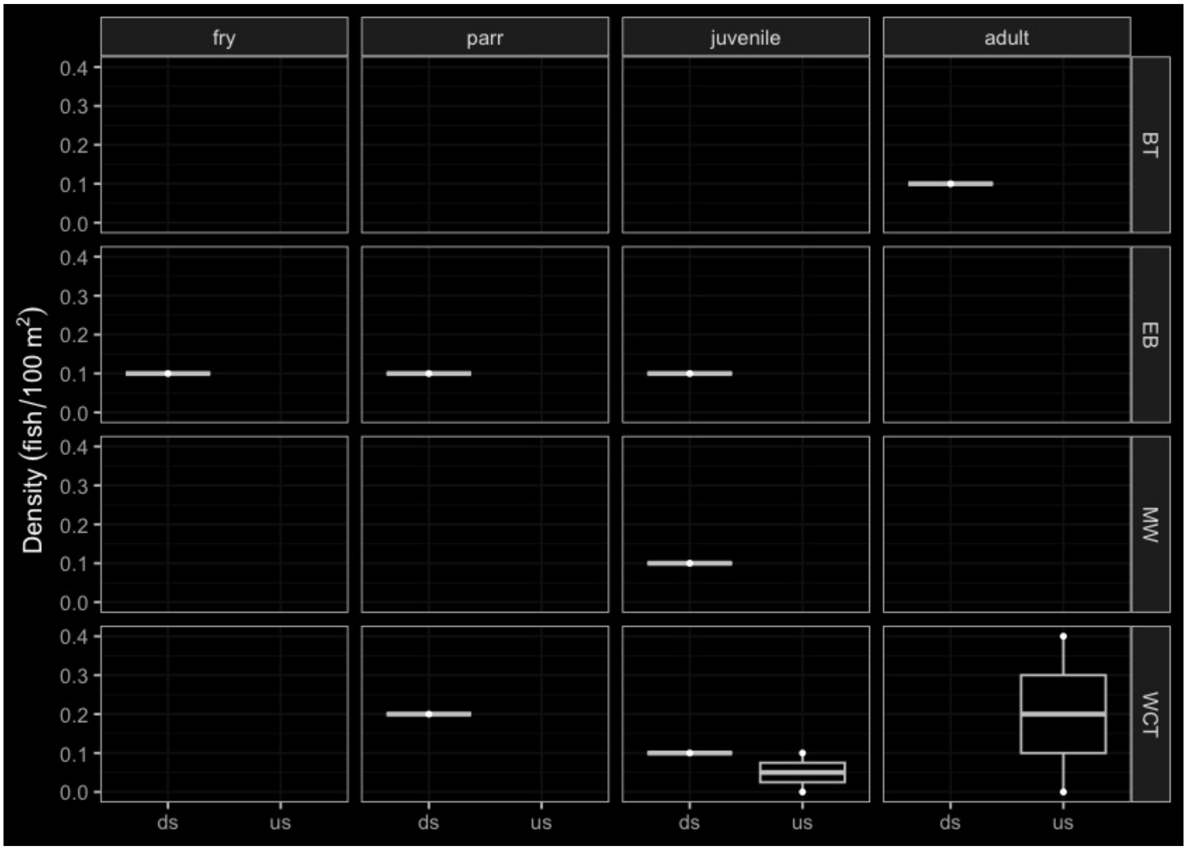

Figure 4.1: Densites of fish (fish/100m2) captured upstream and downstream of PSCIS crossing 197534.

Brule Creek - 197559 - Appendix

Site Location

PSCIS crossings 197533 and 197559 are located approximately 20km north of the town of Sparwood approximately 0.6 and 0.7km upstream from the confluence with the Elk River. The crossings are located on Busato Road and Highway 43 and are the responsibility of the Ministry of Transportation and Infrastructure.

4.1 Background

At the highway, Brule Creek is a 5th order stream with watershed characteristics detailed in Table 4.6. Brule Creek is known to contain westslope cutthrout trout, rainbow trout and bull trout downstream of the subject culverts and westslope cutthrout trout and rainbow trout above (MoE 2020b). On the south side of the upper watershed, at an elevation of 2000m, is the 5ha Josephine Lake (also known as Big Lake). The lake was stocked with westslope cutthrout trout from 1983 - 2000 (MoE 2020b; “Fish Inventories Data Queries” 2020). PSCIS stream crossings 197533 and 197559 were ranked as high priorities for follow up with new structure designs following habitat confirmations by Irvine (2021) due to the large size of the stream network upstream of the highway and because Brule Creek is a 5th order stream. Detailed reporting can be found here.

Table 4.6: Summary of derived upstream watershed statistics for PSCIS crossing 197559.

Site	Area Km	Elev Site	Elev Max	Elev Median	Elev P60	Aspect
197559	82.1	1229	2938	1966	1872	SSE

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

A summary of habitat modelling outputs is presented in Table 4.7 and a map of the watershed is provided in map attachment 082G.123.

Table 4.7: Summary of fish habitat modelling for PSCIS crossing 197559.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	18.8	18.8	100
WCT Rearing (km)	21.6	21.6	100
WCT Stream (km)	36.7	34.6	94
WCT Network (km)	37.4	35.2	94
WCT Lake Reservoir (ha)	1.9	1.9	100
WCT Wetland (ha)	0.6	0.6	100
WCT Slopeclass03 Waterbodies (km)	0.7	0.0	0
WCT Slopeclass03 (km)	15.2	15.2	100
WCT Slopeclass05 (km)	5.7	5.7	100
WCT Slopeclass08 (km)	2.2	2.2	100
WCT Slopeclass15 (km)	10.5	8.5	81
WCT Slopeclass22 (km)	2.7	2.5	93

* Model data is preliminary and subject to adjustments.

Fish Sampling

Electrofishing was conducted at two sites upstream of the highway with no fish captured at either site Tables 4.9 - 4.10. Habitat details are summarised in Table 4.8.

Table 4.8: Summary of habitat details for electrofishing sites upstream of PSCIS crossing 197559.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197559	us_ef1	600	6.0	3.5	0.6	2.8	abundant	–
197559	us_ef2	310	7.5	4.9	0.6	2.1	moderate	High

Table 4.9: Fish sampling site summary for 197559.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
197559_us_ef1	1	600	3.50	2100.0	open
197559_us_ef2	1	310	3.96	1227.6	open

Table 4.10: Fish sampling density results summary for 197559.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197559_us_ef1	NFC	–	0	0	TRUE
197559_us_ef2	NFC	–	0	0	TRUE

* 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.

Bighorn Creek - 197844 - Appendix

Site Location

PSCIS crossing 197844 is located on a tributary to Bighorn Creek on the Cabin FSR approximately 11km west of the junction with the Wigwam FSR at a point approximately 30k south of Morrissey. Cabin FSR (forest file ID 5466) is ultimately the responsibility of Ministry of Forests - Rocky Mountain Forest District. Although unconfirmed, Canfor may have a road use permit for this section of FSR.

Background

Table 4.11: Summary of derived upstream watershed statistics for PSCIS crossing 197844.

Site	Area Km	Elev Site	Elev Max	Elev Median	Elev P60	Aspect
197844	13.5	1315	2585	1976	1927	SSW

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

PSCIS crossing 197844 was assessed in 2021 by (Irvine 2022) and ranked as a barrier for upstream fish migration. The site was noted as having a significantly sized outlet drop (1.2m) and good flow with a location very close to the mainstem of Bighorn Creek which contains confirmed spawning habitat for westslope cutthrout trout. There was 0.8km of steep but viable juvenile rearing habitat surveyed upstream of crossing 197844 in 2021. Bighorn Creek has been noted as contributing significantly to habitat suitable for bull trout spawning in the Wigwam River system with spawning been noted just upstream of the confluence with the Wigwam River. The Wigwam River has been characterized as the most important spawning system in the East Kootenay region, supporting some of the largest westslope cutthrout trout in the Kootenay Region and is located ~11.5km downstream of the subject culvert (Strong and K. D. 2015; R. S. Cope and Morris 2001). A detailed write up of habitat details and stream characteristics can be found in the 2021 report memo linked here. A summary of habitat modelling outputs is presented in Table 4.12 and a map of the watershed is provided in map attachment 082G.108.

Table 4.12: Summary of fish habitat modelling for PSCIS crossing 197844.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	0.1	0.1	100
WCT Rearing (km)	0.3	0.3	100
WCT Stream (km)	3.1	3.0	97
WCT Network (km)	3.1	3.0	97
WCT Lake Reservoir (ha)	–	0.0	–
WCT Wetland (ha)	–	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	0.0	0.0	–
WCT Slopeclass05 (km)	0.1	0.1	100
WCT Slopeclass08 (km)	0.5	0.5	100
WCT Slopeclass15 (km)	2.3	2.3	100
WCT Slopeclass22 (km)	0.2	0.1	50

* Model data is preliminary and subject to adjustments.

Fish Sampling

Electrofishing was conducted with results summarised in Tables 4.14 - 4.15 and Figure 4.2. Habitat details are summarised in Table 4.13. Note that the first site (197844_ds_ef1) was located on the mainstem of Bighorn Creek, while all other sites were located on a tributary to Bighorn Creek.

Table 4.13: Summary of habitat details for electrofishing sites upstream and downstream of PSCIS crossing 197844.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197844	ds_ef1	265	11.0	6.5	0.7	–	moderate	High
197844	ds_ef2	–	5.0	2.0	–	3.2	–	Medium
197844	us_ef1	300	2.3	2.0	0.4	9.3	moderate	Medium
197844	us_ef2	225	2.1	1.5	0.4	8.7	moderate	Medium

Table 4.14: Fish sampling site summary for 197844.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
197844_ds_ef1	1	265	6.533333	1731.3	open
197844_ds_ef2	1	95	5.666667	538.3	open
197844_us_ef1	1	300	4.820000	1446.0	open
197844_us_ef2	1	225	2.033333	457.5	open

Table 4.15: Fish sampling density results summary for 197844.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197844_ds_ef1	BT	parr	5	0.3	FALSE
197844_ds_ef1	BT	juvenile	6	0.3	FALSE
197844_ds_ef1	BT	adult	10	0.6	FALSE
197844_ds_ef1	NFC	juvenile	0	0.0	TRUE
197844_ds_ef1	WCT	adult	1	0.1	FALSE
197844_ds_ef2	BT	adult	5	0.9	FALSE
197844_us_ef1	NFC	–	0	0.0	TRUE
197844_us_ef2	NFC	–	0	0.0	TRUE

* 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.

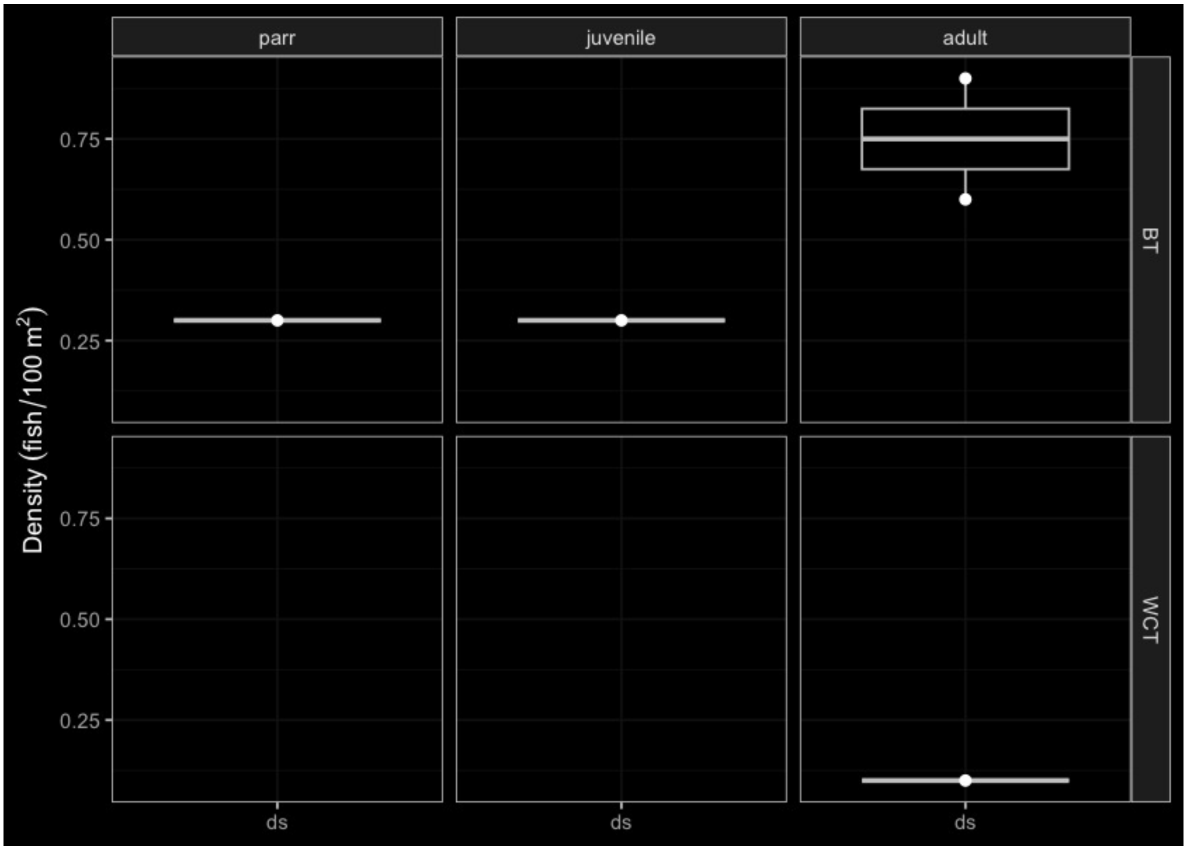

Figure 4.2: Densites of fish (fish/100m2) captured downstream of PSCIS crossing 197844.

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Session Info

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classInt_0.4-8           cli_3.6.0
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