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DRAFT - Elk River Watershed Group Fish Passage Restoration Planning 2021

Prepared for
Nupqu Resource Limited Partnership

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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 of those that have lived in harmony with the land for many thousands of years. That harm extends naturally to the ecosystems themselves.

Executive Summary

Nupqu Resource Limited Partnership was retained by the Canadian Wildlife Federation in the summer of 2021 to conduct fish passage and habitat confirmation assessments at road-stream crossings and dams 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 Limited Partnership to assist with project delivery. The assessments conducted in 2021 compliment work completed in 2020 which can be viewed interactively online at https://newgraphenvironment.github.io/fish_passage_elk_2020_reporting_cwf/ (Irvine 2021). This report is available as pdf and as an online interactive report at https://newgraphenvironment.github.io/fish_passage_elk_2021_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.

In 2021, fish passage assessments were conducted at 89 stream crossing sites with 19 crossings considered “passable,” 1 crossing considered “potential” barriers and 31 crossing considered “barriers” according to threshold values based on culvert embedment, outlet drop, slope, diameter (relative to channel size) and length (MoE 2011a). Additionally, although all were considered fully passable, 38 crossings assessed were fords and thus assigned “unknown” status according to the provincial protocol. In addition, three historic dam locations were assessed for fish passage including sites on Hartley Creek, Boivin Creek, and Harmer Creek.

In 2021, habitat confirmation assessments were conducted at 15 sites in the Elk River watershed group with a total of approximately 12km of stream suveyed. As these assessments are intended to supplement data and insights from numerous other programs underway in the region and because collaborative decision making was ongoing at the time of reporting, site prioritizations can be considered preliminary and a starting point for discussions with connectivity partners, stakeholders and industry/regulatory professionals. Five crossings were rated as high priorities for proceeding to design for replacement, 7 crossings were rated as moderate priorities, and 3 crossings were rated as low priorities. Only summary tables and raw data is provided for surveys conducted within the Flathead River sub-basin (Hartley Creek, Boivin Creek, and Harmer Creek) with additional reporting potentially provided for these sites in the future under separate cover. Detailed information for each

site assessed with Phase 2 assessments on streams that drain into the Elk River are presented within site specific appendices to this document.

Effective connectivity restoration planning incorporates a watershed based approach and develops an understanding of subject aquatic systems to a level where actions prioritized are highly likely to address limiting factors and increase the productivity of local fish populations. Leveraging of research initiatives in the region as well as baseline and follow up monitoring is important to foster this understanding in the Elk River watershed group where there are 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.

1 Introduction

Nupqu Resource Limited Partnership was retained by the Canadian Wildlife Federation in the summer of 2021 to conduct fish passage and habitat confirmation assessments at road-stream crossings and dams 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 Limited Partnership to assist with project delivery. The assessments conducted in 2021 compliment work completed in 2020 (72 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). This report is available as pdf and as an online interactive report at https://newgraphenvironment.github.io/fish_passage_elk_2021_reporting/. Viewing online is recommended as the web-hosted version contains more features and is more easily navigable.

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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).

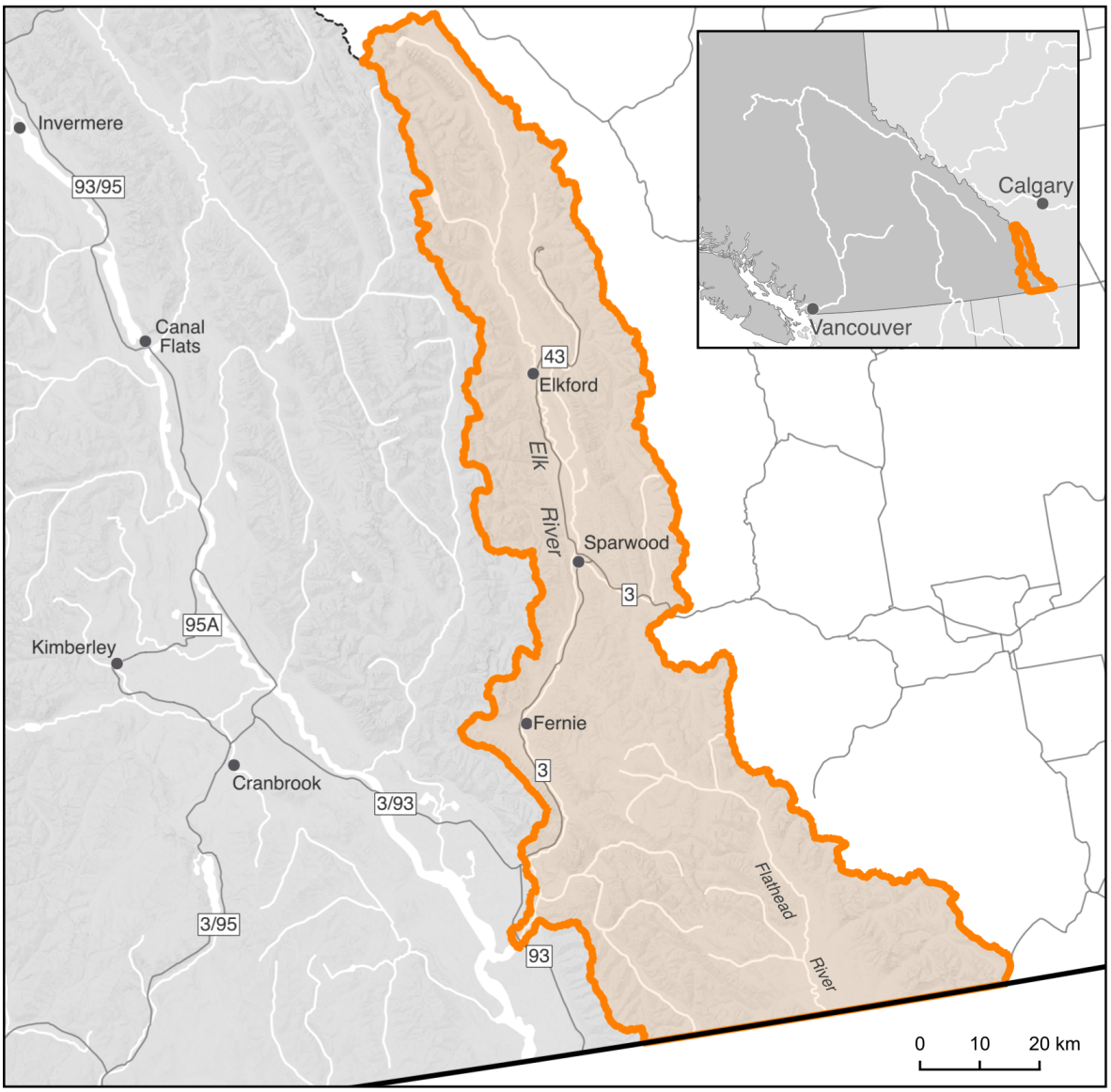


Figure 2.1: Overview map of Study Area

2.1 Project Location

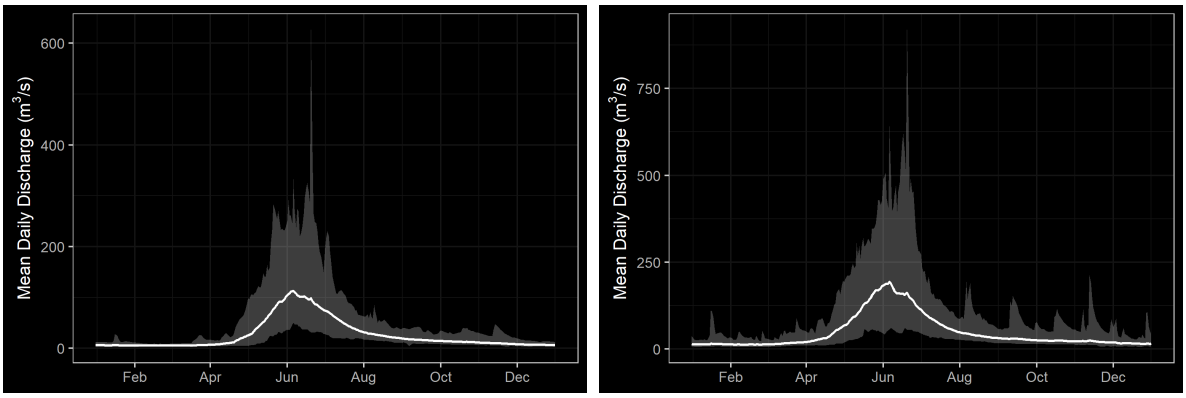


Figure 2.2: Hydrograph for Elk River near Sparwood (Station #08NK016) and near Fernie (Station #08NK002).

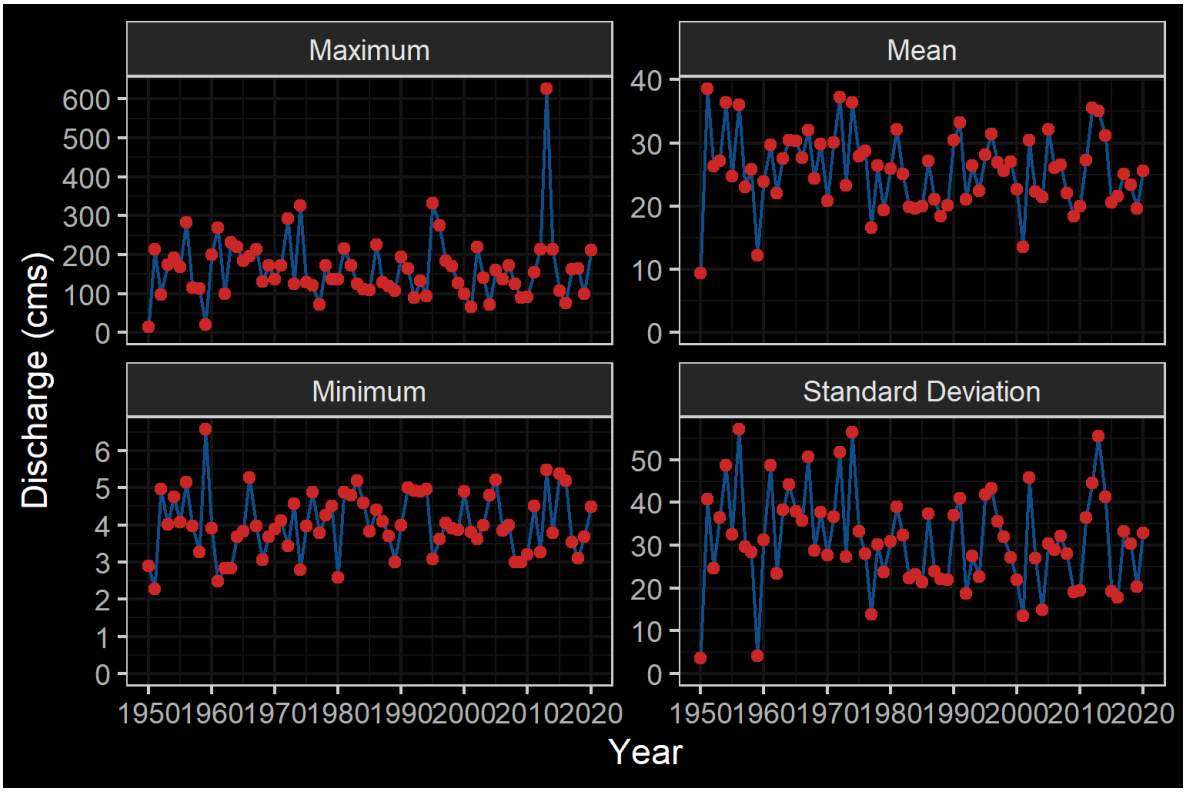


Figure 2.3: Elk River Near Sparwood (Station #08NK016 - Lat 49.86562 Lon -114.86868). Available daily discharge data from 1950 to 2020.

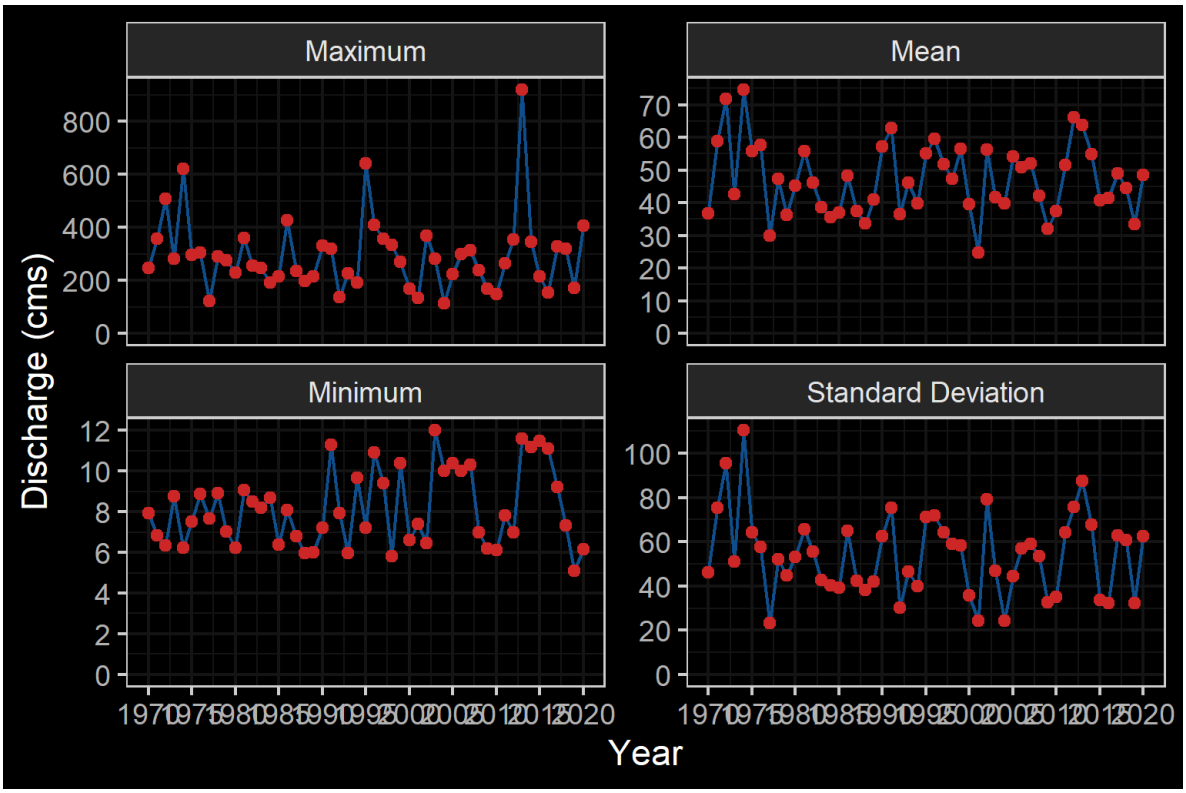


Figure 2.4: Elk River At Fernie (Station #08NK002 - Lat 49.50347 Lon -115.07013). Available daily discharge data from 1970 to 2020.

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);
- ʔakink̓um‡asnuq‡iʔit- Tobacco Plains Band (Grasmere, BC);
- yaqan nuʔkiy- Lower Kootenay Band (Creston, BC);
- kyaknuq‡iʔit- 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:

“Kɸmaǩqa ksukłuła·k kuǩqani ɸ ǩitqakiɬ haqa ksiʔɬ ɸxa ʔa·kłukqaʔis ksukiɬq̓ukaʔmi·k kiʔin Ktunaxa naʔs ʔamaǩʔis. Qus piǩaksɸ naʔs ɸxaɬ yaqanakiɬ haqaʔki. Ǩitqawiɸmu kakiɬwiɸkiɬ ʔamakʔis ǩisnikɸik kɸxaɬ qa kiɬkǩaxuxami·k ǩitqakiɬ haqa ɸ ǩisʔin ʔaknumuɸtiɬʔis.”

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 cutthroat 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).

2.2 Fisheries

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).

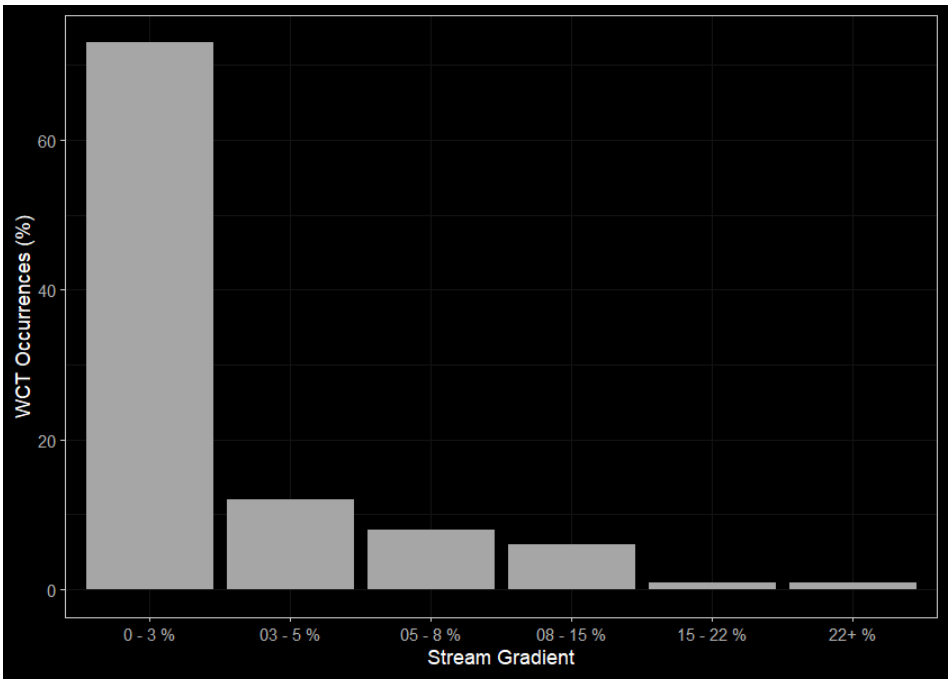


Figure 2.5: Summary of historic westslope cutthrout trout observations vs. stream gradient category.

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 2020e). 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 3.2). Results from modelling are presented for habitat confirmation sites in appendices using output parameters present in Table 3.3.

Table 3.2: Stream gradient and channel width thresholds used to model potentially highest value westslope cutthrout trout habitat.

Variable	Value
Spawning Gradient Max (%)	5
Spawning MAD Min (m3/s)	0.050
Spawning MAD Max (m3/s)	76.00
Rearing Gradient Max (%)	7.0
Rearing MAD Min (m3/s)	0.02
Rearing MAD Max (m3/s)	30

Table 3.3: bcfishpass outputs and associated definitions

Attribute	Definition
Attribute	**Definition**
WCT Spawning (km)	Length of stream upstream of point modelled as potential Westslope Cutthroat spawning habitat
WCT Rearing (km)	Length of stream upstream of point modelled as potential Westslope Cutthroat rearing habitat
WCT Stream (km)	Westslope Cuthroat Trout model, total length of streams and rivers potentially accessible upstream of point (does not include network connectors in lakes etc)
WCT Network (km)	Westslope Cuthroat Trout model, total length of stream network potentially accessible upstream of point
WCT Lake Reservoir (ha)	Westslope Cuthroat Trout model, total area lakes and reservoirs potentially accessible upstream of point
WCT Wetland (ha)	Westslope Cuthroat Trout model, total area wetlands potentially accessible upstream of point
WCT Slopeclass03 Waterbodies (km)	Westslope Cutthroat Trout model, length of stream connectors (in waterbodies) potentially accessible upstream of point with slope 0-3%
WCT Slopeclass03 (km)	Westslope Cutthroat Trout model, length of stream potentially accessible upstream of point with slope 0-3%
WCT Slopeclass05 (km)	Westslope Cutthroat Trout model, length of stream potentially accessible upstream of point with slope 3-5%
WCT Slopeclass08 (km)	Westslope Cutthroat Trout model, length of stream potentially accessible upstream of point with slope 5-8%
WCT Slopeclass15 (km)	Westslope Cutthroat Trout model, length of stream potentially accessible upstream of point with slope 8-15%
WCT Slopeclass22 (km)	Westslope Cutthroat Trout model, length of stream potentially accessible upstream of point with slope 15-22%

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 2011a). 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 3.4). For crossings determined to be potential barriers or barriers based on the data (see Barrier Scoring (page 15)), a culvert fix and recommended diameter/span was proposed.

value criteria (Fish Passage Technical Working Group, 2011).

Habitat Value	Fish Habitat Criteria
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).

3.2.1 Barrier Scoring

Fish passage potential was determined for each stream crossing identified as a closed bottom structure as per MoE (2011a). 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 3.5, Table 3.6. These criteria were developed based on data obtained from various studies and reflect an estimation for the passage of a juvenile salmon or small resident rainbow trout (Clarkin et al. 2005 ; Bell 1991; Thompson 2013).

Table 3.5: Fish Barrier Risk Assessment (MoE 2011).

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

Table 3.6: Fish Barrier Scoring Results (MoE 2011).

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

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 3.5), a "total" value of habitat <20% output from `bcfishpass` was used to estimate the amount of habitat upstream of each crossing less than 20% gradient before a falls of height >5m - as recorded in MoE (2020c) 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 (2011a) 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. It should be noted however, that box culverts could be considered a viable and economical option as they have been observed as successfully facilitating fish passage on the west coast of the province (Betty Rebellato, Canadian Wildlife Federation - Project Biologist).
- 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 (2020c) 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 3.7) should be considered very approximate with refinement recommended for future projects.

surface type.

Class	Surface	Class Multiplier	Surface Multiplier	Bridge $K/10m	Streambed Simulation $K
Class	Surface	Class Multiplier	Surface Multiplier	Bridge $K/10m	Streambed Simulation $K
Forest Service Road	Loose	1	1	200	40
Recreation	Loose	1	1	200	40
Resource	Rough	1	1	200	40
Resource	Loose	1	1	200	40
Road Permit	Loose	1	1	200	40
Unclassified	Rough	1	1	200	40
Unclassified	Loose	1	1	200	40
Resource	Paved	1	2	400	80
Unclassified	Overgrown	1	2	400	80
Unclassified	Paved	1	2	400	80
Unclassified	Unknown	1	2	400	80
Local	Paved	4	2	1600	320
Arterial	Paved	15	2	6000	1200
Highway	Paved	15	2	6000	1200
Rail	Rail	15	2	6000	1200

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 3.4).

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. 2022) 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 Results and Discussion

4.1 Phase 1

Field assessments were conducted between July 27 2021 and November 03 2021 by Allan Irvine, R.P.Bio., Kyle Prince, P.Biol., Stevie Syer, Rafael Acosta Lugo and Brody Klenk. A total of 89 Phase 1 assessments were conducted at 89 sites with 19 crossings considered “passable,” 1 crossing considered “potential” barriers and 31 crossing considered “barriers” according to threshold values based on culvert embedment, outlet drop, slope, diameter (relative to channel size) and length (MoE 2011a). Additionally, although all were considered fully passable, 38 crossings assessed were fords. Georeferenced field maps are presented in Attachment 1. A summary of crossings assessed, a cost benefit analysis and priority ranking for follow up for Phase 1 sites presented in Table 4.1. Detailed data with photos are presented in Attachment 3.

“Barrier” and “Potential Barrier” rankings used in this project followed MoE (2011a) and reflect an assessment of passability for juvenile salmon or small resident rainbow trout at any flows potentially present 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.

PSCIS ID	External ID	Stream	Road	Result	Habitat value	Stream Width (m)	Priority	Fix	Cost Est ($K)	Habitat Upstream (km)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
50075	–	Tributary to Flathead FSR	Commerce FSR	Barrier	Low	1.90	low	SS-CBS	40	1.97	49.2	46.8
50084	–	Tributary to Flathead River	Flathead FSR	Potential	Medium	2.40	low	OBS	240	2.26	9.4	11.3
50085	–	Tributary to Couldrey Creek	Flathead FSR	Barrier	Low	2.40	low	OBS	240	4.05	16.9	20.2
50091	–	Tributary to Calder Creek	Spur	Barrier	Low	1.50	low	SS-CBS	40	2.31	57.8	43.3
197835	4600088	Hosmer Creek	Stephenson Road	Barrier	Medium	4.10	mod	OBS	1920	–	–	–
197833	4600129	Hosmer Creek	Highway 3	Barrier	Medium	3.00	mod	OBS	7200	–	–	–
197863	4600761	Tributary to Lizard Creek	Unnamed	Barrier	Low	2.00	low	OBS	240	–	–	–
197827	4600762	Fording River	FRO Coal Haul	Barrier	High	16.00	high	OBS	660	–	–	–
197866	4600992	Hosmer Creek	Unnamed	Barrier	High	4.10	high	OBS	240	–	–	–
197796	4601984	Tributary to Lodgepole Creek	Spur	Barrier	Low	3.80	low	OBS	240	–	–	–
197825	4604677	Henretta Creek	–	Barrier	High	12.00	high	OBS	360	–	–	–
197851	4605462	Tributary to Flathead River	Kishinea FSR	Barrier	Low	1.20	low	SS-CBS	40	–	–	–
197843	4605502	Tributary to Bighorn Creek	Cabin FSR	Barrier	Medium	1.80	mod	SS-CBS	40	–	–	–
197842	4605504	Tributary to Bighorn Creek	Cabin FSR	Barrier	Medium	2.10	mod	OBS	240	–	–	–
197844	4605514	Tributary to Bighorn Creek	Cabin FSR	Barrier	Medium	2.20	mod	OBS	240	–	–	–
197798	4605518	Tributary to Bighorn Creek	Cabin FSR	Barrier	Low	1.00	low	SS-CBS	40	–	–	–
197799	4605522	Tributary to Bighorn Creek	Cabin FSR	Barrier	Low	1.30	low	SS-CBS	40	–	–	–
197800	4605525	Tributary to Bighorn Creek	Cabin FSR	Barrier	Medium	1.90	mod	SS-CBS	40	–	–	–
197845	4605531	Tributary to Bighorn Creek	Cabin FSR	Barrier	Low	2.50	low	OBS	240	–	–	–
197802	4605540	Tributary to Bighorn Creek	Cabin FSR	Barrier	Low	1.60	low	SS-CBS	40	–	–	–
197850	4605584	Tributary to Sage Creek	Flathead-Nettie FSR	Barrier	Low	2.10	low	OBS	240	–	–	–
197849	4605585	Tributary to Sage Creek	Flathead-Nettie FSR	Barrier	Low	1.70	low	SS-CBS	40	–	–	–
197865	4605652	Tributary to Elk River	Elk River Main FSR	Barrier	Low	1.00	low	SS-CBS	40	–	–	–
197828	4605671	Tributary to Elk River	Elk FSR	Barrier	Low	1.30	low	SS-CBS	40	–	–	–
197829	4605698	Tributary to Elk River	Elk FSR	Barrier	Low	0.95	low	SS-CBS	40	–	–	–
197830	4605731	Tributary to Elk River	Elk FSR	Barrier	Medium	2.00	mod	OBS	240	–	–	–
197783	4605937	Tributary to Wigwam River	Wigwam FSR	Barrier	Low	0.60	low	SS-CBS	40	–	–	–

PSCIS ID	External ID	Stream	Road	Result	Habitat value	Stream Width (m)	Priority	Fix	Cost Est ($K)	Habitat Upstream (km)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
197817	4605995	Tributary to Weigert Creek	Weigert FSR	Barrier	Low	2.40	low	OBS	240	–	–	–
197785	4606129	Tributary to Wigwam River	–	Barrier	Low	0.00	low	SS-CBS	40	–	–	–
197793	4606347	Tributary to Bean Creek	Lodgepole FSR	Barrier	Low	5.30	low	OBS	240	–	–	–
197787	4606370	Lodgepole Creek	Harvey FSR	Potential	Medium	3.26	low	OBS	240	–	–	–
197786	4606398	Lodgepole Creek	Harvey FSR	Barrier	Medium	2.00	mod	OBS	240	–	–	–
197809	4606597	Tributary to Flathead River	Commerce FSR	Barrier	Low	0.90	low	SS-CBS	40	–	–	–
197834	4606711	Hosmer Creek	CP Railway	Barrier	High	3.90	high	OBS	7200	–	–	–
197855	24740603	Tributary to Calder Creek	Spur 1000	Barrier	Low	0.80	low	SS-CBS	40	–	–	–
197864	2021101302	Tributary to Lizard Creek	Unnamed	Barrier	Low	0.50	low	SS-CBS	40	–	–	–

4.2 Dam Assessments

Three historic dam locations were assessed for fish passage including sites on Hartley Creek, Boivin Creek, and Harmer Creek. Results are presented in Table 4.2

Table 4.2: Results from fish passability assessments at dams.

Site	Stream	Easting	Northing	Mapsheet	Barrier	Notes
197542	Hartley Creek	643537	5490723	082G.113	T	Two small dams (30cm and 40cm high) located just upstream (7m and 20m) of Dicken Road. Likely easily passable by adult WCT but barrier to fry and small juveniles. If culvert replaced these could potentially be fixed at the same time.
1100000129	Boivin Creek	647275	5541987	082J.103	F	Remnant dam not located in main channel.
1100002016	Harmer Creek	657051	5522119	082G.123	T	Large dam (15m high at 55% grade) located in main channel. No fish ladder.

* UTM Zone 11

Figure 4.1: Left: Small dam ~7m upstream of PSCIS crossing 197542 on Hartley Creek. Right: Small dam ~20m upstream of PSCIS crossing 197542 on Hartley Creek.

Figure 4.2: Left: Teck Coal Limited dam (15m high and 55% gradient) on Harmer Creek. Right: Historic dam structure adjacent to Boivin Creek.

4.3 Phase 2

During 2021 field assessments, habitat confirmation assessments were conducted at 15 sites in the Elk River watershed group with a total of approximately 12km of stream assessed. Georeferenced field maps are presented in Attachment 1.

As collaborative decision making was ongoing at the time of reporting, site prioritization can be considered preliminary. Five crossings were rated as high priorities for proceeding to design for replacement, 7 crossings were rated as moderate priorities, and 3 crossings were rated as low priorities. Results are summarized in Table 4.3) with raw habitat and fish sampling data included in digital format as Attachment 4. A summary of watershed statistics from derived watershed areas

and preliminary modeling results illustrating the quantities of westslope cutthrout trout spawning and rearing habitat potentially available upstream of each crossing as estimated by upstream accessible stream length are presented in Table 4.7 and Figure 4.3. Only summary tables and raw data is provided for surveys conducted within the Flathead River sub-basin (Parker Creek, Morris Creek, Fuel Creek and Kisoo Creek) with detailed reporting potentially provided in the future under separate cover. Detailed information for each site assessed with Phase 2 assessments (including georeferenced maps) on streams that drain into the Elk River are presented within site specific appendices to this document.

Table 4.3: Overview of habitat confirmation sites.

PSCIS ID	Stream	Road	UTM (11U)	Fish Species	Habitat Gain (km)	Habitat Value	Priority	Comments
50061	Fuel Creek	Harvey FSR	667651 5459223	WCT	2.0	Medium	moderate	Signs of extremely high flows with large islands and dry side channels. First 200m were dry. Old road sluffing at times and for ~50m was right beside creek eliminating riparian veg. Ranked as high priority for follow up in Irvine 2021.
50063	Kisoo Creek	Harvey FSR	668961 5458806	–	1.3	Medium	moderate	Fairly steep system with frequent pockets of gravels available for spawning. Cold high elevation system with good flow and abundant undercut banks.
50067	Parker Creek	Flathead FSR	679597 5453756	WCT	6.0	High	high	Parker creek remnant channel similar to upstream size and depth with no water. Channel relocation related to Flathead FSR with several large volume beaver controlled wetland areas upstream in historic channel. Aerial survey conducted. Needs to be fixed in conjunction with mocelled crossing 4606967 upstream (currently no structure there). Great opportunity for restoration.
61504	Coal Creek	Coal Creek Road	645313 5483687	WCT, BT	14.5	–	high	Issue is not structure but debris in channel producing small drop/cascade from 20 - 60cmin height. Some deep pools up to ~1.8m available for overwintering westslope cutthroat trout adults. Some pockets for spawning, large system with low gradient. Mature ACT riparian area with intermittent large woody debris structures throughout.
62122	Morris Creek	Flathead FSR	676913 5459598	–	3.0	Medium	moderate	Good flow, frequent pockets of gravels present suitable for westslope cutthroat trout spawning. Unlicensed dam located upstream of road ~100m. Main flow of stream is north fork with small amount of flow from southern forks. Erroneosly ranked as low priority for follow up in Irvine 2021 due to incorrect mapping of mainstem of channel.
62181	Dry Creek	CP Railway	656409 5544755	WCT	4.3	Medium	high	Line Creek Operations Local Aquatic Effects Monitoring Program underway here with plan for fish passage remediation part of Teck's Tributary management Plan. Flagging from FHAP conducted by other crews. High value habitat due to flow and size, occasional pockets of gravel and intermittent pools.
62182	Dry Creek	Fording Highway	656390 5544771	WCT	0.0	Medium	high	FHAP conducted here by other crews. High value habitat due to flow and size, occasional pockets of gravel and intermittent pools.
62505	Tributary to Lizard Creek	Mt. Fernie Park Road	636942 5483777	–	0.7	Medium	moderate	Occasional pools present suitable for juvenile westslope cutthroat trout overwintering. Frequent pockets of gravel present suitable for spawning. Good flow. Fairly steep system with intermittent small woody debris / root drops between 0.5 and 1m.
197786	Lodgepole Creek	Harvey FSR	665796 5462152	–	0.6	Medium	moderate	Small stream with good flow. Abundant gravels suitable for spawning throughout the first ~300m then pockets throughout. Large waterfall >30m at top end of site ~540m u/s of culvert. Some shallow pools present intermittently created by large woody debris.
197787	Lodgepole Creek	Harvey FSR	664905 5462562	WCT	1.1	Medium	moderate	Drains out of Lodgepole Lake. Beaver Dam (1.2m) at lake. Abundant gravels suitable for spawning throughout. Stream primarily had low complexity due to the primarily straight riffle type habitat. Some shallow pools and large woody debris present.
197793	Bean Creek	Lodgepole FSR	650415 5463819	–	1.8	Low	low	Dry stream, no water. Has very large channel and shows evidence of extensive scour and large volumes of water but

PSCIS ID	Stream	Road	UTM (11U)	Fish Species	Habitat Gain (km)	Habitat Value	Priority	Comments
completely dry.								
197796	Tributary to Lodgepole Creek	Spur	654302 5458678	–	0.1	Low	low	2.3m high rock falls at ~60m upstream is permanent barrier to upstream migration.
197844	Tributary to Bighorn Creek	Cabin FSR	657920 5452802	–	3.0	Medium	moderate	Sections getting steep (up to 12.5%) with periodic deep pools under embedded / functional large woody debris. Likely barrier (1.1m high rock) located at top of area surveyed 840m upstream of the FSR. Frequent cascading into pools. Confined at times.

Table 4.4: Summary of Phase 2 fish passage reassessments.

PSCIS ID	Embedded	Outlet Drop (m)	Diameter (m)	SWR	Slope (%)	Length (m)	Final score	Barrier Result
50061	Yes	0.00	0.9	3.2	3.0	14	16	Potential
50063	No	0.65	1.2	2.3	5.0	45	42	Barrier
50067	No	0.00	0.6	8.7	3.0	11	26	Barrier
61504	–	–	24.0	0.0	–	4	0	Passable
62122	No	0.00	0.9	1.7	4.5	10	26	Barrier
62181	Yes	0.00	1.8	2.1	2.6	17	19	Potential
62182	No	0.00	1.8	2.1	3.6	24	29	Barrier
62505	No	0.25	0.9	3.2	5.0	10	31	Barrier
197786	No	0.00	1.2	1.7	1.7	10	21	Barrier
197787	No	0.00	2.0	1.6	0.5	18	19	Potential
197793	No	0.00	1.5	3.5	2.5	14	21	Barrier
197796	No	0.60	1.6	2.4	5.0	14	36	Barrier
197844	No	1.20	1.2	1.8	5.0	12	36	Barrier

Table 4.5: Cost benefit analysis for Phase 2 assessments.

PSCIS ID	Stream	Road	Result	Habitat value	Stream Width (m)	Fix	Cost Est (in $K)	Habitat Upstream (m)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
50061	Fuel Creek	Harvey FSR	Potential	Medium	3.1	OBS	240	2000	8.3	25.8
50063	Kisoo Creek	Harvey FSR	Barrier	Medium	2.8	SS-CBS	80	1280	16.0	44.8
50067	Parker Creek	Flathead FSR	Barrier	High	5.2	OBS	500	6000	12.0	62.4
61504	Coal Creek	Coal Creek FSR	Passable	–	12.1	–	–	14500	–	–
62122	Morris Creek	Flathead FSR	Barrier	Medium	1.4	SS-CBS	40	3000	75.0	105.0
62181	Dry Creek	CP Railway	Potential	Medium	4.1	OBS	7200	4275	0.6	2.4
62182	Dry Creek	Fording Highway	Barrier	Medium	4.1	OBS	7200	25	0.0	0.1
62505	Tributary to Lizard Creek	Mt. Fernie Park Road	Barrier	Medium	2.9	OBS	240	680	2.8	8.2
197786	Lodgepole Creek	Harvey FSR	Barrier	Medium	2.0	OBS	240	580	2.4	4.8
197787	Lodgepole Creek	Harvey FSR	Potential	Medium	3.3	OBS	240	1125	4.7	15.5
197793	Tributary to Bean Creek	Lodgepole FSR	Barrier	Low	5.3	OBS	240	1800	7.5	39.8
197796	Tributary to Lodgepole Creek	Spur	Barrier	Low	3.8	OBS	240	60	0.2	0.9
197844	Tributary to Bighorn Creek	Cabin FSR	Barrier	Medium	3.3	OBS	240	3000	12.5	41.2

Table 4.6: Summary of Phase 2 habitat confirmation details.

PSCIS ID	Length surveyed upstream (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
50061	620	3.1	1.7	0.3	2.9	moderate	medium
50063	370	2.8	1.7	0.3	10.0	moderate	medium
50067	1200	5.2	–	–	0.8	–	high
61504	520	12.1	11.2	1.0	2.8	abundant	high
62122	735	1.4	1.3	–	2.3	moderate	medium
62181	650	4.1	3.0	–	3.3	–	high
62182	30	4.1	3.0	0.3	3.3	abundant	high
62505	700	2.9	1.4	0.3	7.6	moderate	medium
197786	580	2.0	1.8	0.3	3.8	moderate	medium
197787	315	3.3	2.3	0.3	2.8	moderate	high
197793	900	5.3	–	0.7	2.7	moderate	low
197796	110	3.8	1.9	0.6	8.5	–	low
197844	840	3.3	2.7	0.5	8.8	moderate	medium
197863	100	2.0	1.3	0.3	12.0	moderate	medium
4606967	590	6.5	5.2	–	0.7	–	high

Table 4.7: Summary of watershed area statistics upstream of Phase 2 crossings.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
50061	4.8	1616	1622	2542	1948	1925	1849
50063	1.4	1583	1612	2157	1832	1821	1780
50067	13.1	1356	1354	2207	1615	1559	1469
61504	98.7	1132	1050	2241	1782	1823	1776
62122	7.1	1418	1422	2236	1665	1593	1530
62181	25.5	1532	–	2594	2061	2078	2019
62182	25.5	1532	–	2594	2061	2078	2019
62505	0.9	1048	1038	1449	1206	1192	1168
197786	3.6	1681	1592	2456	1949	1937	1889
197787	5.2	1664	1592	2456	1936	1920	1883
197793	9.4	1147	1146	2198	1563	1488	1427
197796	3.8	1608	1548	2318	1932	1940	1887
197844	13.5	1316	1305	2585	1959	1976	1927

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

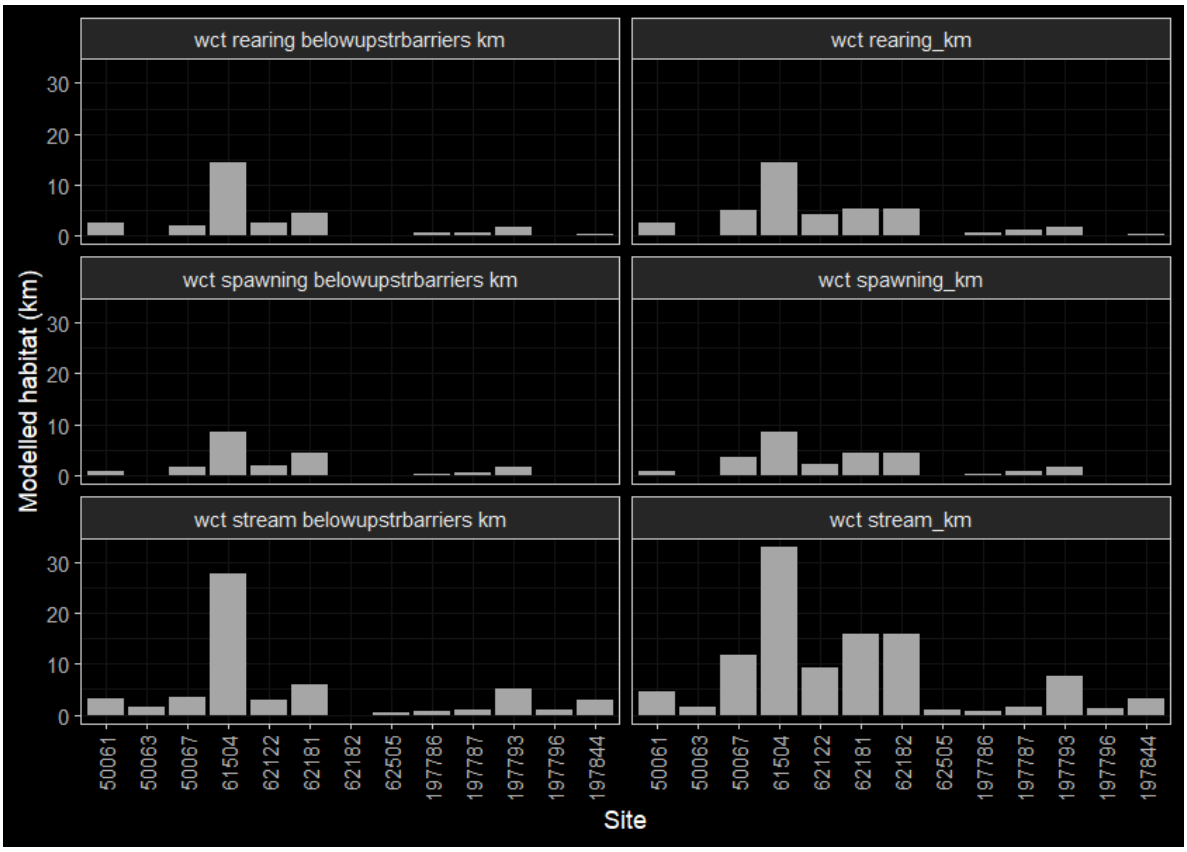


Figure 4.3: Summary of linear lengths of potential habitat upstream of habitat confirmation assessment sites estimated based on modelled discharge and gradient.

5 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.

Appendix - 61504 - Coal Creek

Site Location

PSCIS crossing 61504 is located on Coal Creek on the Coal Creek Road 5.5km east of Fernie, BC. The Coal Creek Road is classified as an unpaved local road with the Ministry of Transportation and Infrastructure detailed as a custodian partner within the digital road atlas (FLNRORD 2020c).

Background

Coal Creek drains in a western direction from Leach Ridge to the confluence with the Elk River located with the City of Fernie municipal boundaries. At crossing 61504, Coal Creek is a fifth order stream with a watershed area upstream of the crossing of approximately 98.7km^2. The elevation of the watershed ranges from a maximum of 2241m to 1132m at PSCIS crossing 61504. Within Coal Creek westslope cutthroat trout and bull trout have been recorded upstream of the subject bridge (MoE 2020a; Norris 2020). There are numerous stream crossing structures located on Coal Creek upstream of 61504 however there are no crossings assessed as barriers on the mainstem.

The site is located to the historic Coal Creek town site where a historic coal mine was located. The town had an estimated 1000 residents in 1905 and operations at the mine ended on January 30, 1958 (Foster and Bachusky 2005).

A large flood event on Coal Creek in 1995 caused overbank flooding, channel shifting, bank erosion, coarse sediment deposition, and damage to private and public property near the stream. Floodplain mapping for the stream was completed in 2014 including an assessment of flood hazards, hydrologic estimates of the 200-year instantaneous design flow, 200-year estimated inundation extents and flood construction levels (Northwest Hydraulic Consultants 2014).

Hughes and Millions (2020) report that riprap to stabilize the streambanks and reduce meandering is frequently employed near existing and historical infrastructure on Coal Creek. Elk River Alliance have drafted a plan to restore the floodpain adjacent to the historic township through removal of invasive species and planting/seeding of native vegetation (Hughes and Millions 2020). A major storm event on November 14-15, 2021 caused extensive damage to Coal Creek Road and changed the course of the river near the historic townsite (Tibballs 2021).

Elk River Alliance (2020) conducted redd surveys in Coal Creek in 2019 along with Morrissey Creek, Lizard Creek and Forsyth Creek. No redds were identified within the 1.3km surveyed within Coal Creek.

The bridge where PSCIS crossing 61504 is located on the outside bend of Coal Creek and has been extensively armored with large riprap on the west side of the river upstream of the bridge likely to protect bridge pilings/abutments. At the time of the survey it appeared as though significant amounts of riprap as well as what appeared to be a historic stream abutment was slightly constricting the channel and creating a small cascade (20 - 55cm high) across the stream width adjacent to the downstream end of the bridge abutments. Through connectivity restoration planning activities, this constriction of the channel and presence of cascade was brought to the attention of Canadian Wildlife Federation and the site was assigned a high priority for follow up. Table 5.1 presents preliminary fish passage modelling data for crossing 61504 with linear length of spawning and rearing habitat estimated for westslope cutthrout trout at 8.5km and 14.5km respectively. A map of the watershed is provided in map attachment 082G.113.

Table 5.1: Summary of fish habitat modelling for PSCIS crossing 61504.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	8.5	8.5	100
WCT Rearing (km)	14.5	14.5	100
WCT Stream (km)	33.1	27.7	84
WCT Network (km)	33.1	27.7	84
WCT Lake Reservoir (ha)	–	0.0	–
WCT Wetland (ha)	–	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	4.2	4.2	100
WCT Slopeclass05 (km)	4.5	4.5	100
WCT Slopeclass08 (km)	10.3	7.3	71
WCT Slopeclass15 (km)	13.1	10.9	83
WCT Slopeclass22 (km)	0.9	0.9	100

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossing

At the time of the survey, the PSCIS bridge crossing span was measured at 61504 24m and the width was 4m. As an open bottomed structure, the crossing was not considered a barrier or partial barrier to fish passage (Table 5.3). Water temperature was 4°C, pH was 8.3 and conductivity was 170uS/cm.

To gather data to help assess the degree to which the cascade potentially hindered upstream fish migration, velocity measurements were taken at five locations even distributed across the wetted width of the cascade using a Hach FH handheld flow meter (Figure 5.1). Measurements were taken on October 15, 2021 at depths equivalent to 60% of the depth of the water. Light rain was falling at the time of the survey. Flow velocities at the cascade ranged from 0.31m/s to 0.31m/s (Table 5.2). 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.

Table 5.2: Summary of velocities at debris influenced cascade adjacent to PSCIS crossing 61504.

Distance	Velocity
6.6	0.31
7.2	0.64
8.8	1.91
10.6	1.15
12.4	1.60

* Velocities measured at 60% of wetted depth. Distance was measured from top of bank.

Stream Characteristics Downstream

The stream was surveyed downstream from 61504 for 365m (Figure 5.1). Overall, total cover amount was rated as abundant with boulders dominant undercut banks subdominant (Table 5.4). The average channel width was 27.8m, the average wetted width was 10.5m and the average gradient was 2.8%. The dominant substrate was NA with NA subdominant. Some pockets of gravel suitable for westslope cutthrout trout spawning were observed. Habitat value was rated as high within the large system with abundant habitat available for fry/juvenile salmonid rearing.

Stream Characteristics Upstream

The stream was surveyed upstream from 61504 for 520m (Figure 5.2). Within the area surveyed, total cover amount was rated as abundant with boulders dominant. Cover was also present as large woody debris and deep pools (Table 5.4). The average channel width was 12.1m, the average wetted width was 11.2m and the average gradient was 2.8%. Some deep pools up to ~1.8m deep were available for overwintering westslope cutthroat trout adults and occasional pockets of gravel suitable for spawning were present. The riparian area was comprised of mature black cottonwood with intermittent naturally formed large woody debris structures throughout providing structure and cover. Beaver dams were located within the area surveyed primarily on tributaries or side-channels with one dam noted as partially spanning the main channel. Habitat value was rated as high for salmonid rearing and spawning.

Remediation and Cost Estimate

A rough estimate of the cost of works to remove the debris creating cascade adjacent to PSCIS bridge 61504 is $20,000.

Conclusion

Although the 30 - 55cm high cascade adjacent to PSCIS bridge 61504 is unlikely to be a signifcant barrier for the movement of migrating adult westslope cutthrout trout the obstacle may prevent movement upstream by fry and juveniles. There is an estimated 14.5km of westslope cutthrout trout rearing and/or spawning habitat upstream of crossing 61504. Although, small cascades within stream networks are common and often present opportunities for upstream passage (particularly for adult fish) at different flows, removal of debris from the channel adjacent to 61504 could reduce the risk that the cascade may impact fish migration (particularly for younger life stages). Habitat in the area surveyed was rated as high value for salmonid rearing/spawning as this is a large system with deep pools and gravels present suitable for spawning. Overall, the site was ranked as a moderate priority for remedial works which would include removal of debris from the channel.

Table 5.3: Summary of fish passage assessment for PSCIS crossing 61504.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2021-10-04	Crossing Sub Type	Bridge
PSCIS ID	61504	Diameter (m)	24
External ID	–	Length (m)	4
Crew	KP	Embedded	–
UTM Zone	11	Depth Embedded (m)	–
Easting	645312.9	Resemble Channel	–
Northing	5483687	Backwatered	–
Stream	Coal Creek	Percent Backwatered	–
Road	Coal Creek Road	Fill Depth (m)	–
Road Tenure	Unknown	Outlet Drop (m)	–
Channel Width (m)	–	Outlet Pool Depth (m)	–
Stream Slope (%)	–	Inlet Drop	–
Beaver Activity	–	Slope (%)	–
Habitat Value	–	Valley Fill	–
Final score	0	Barrier Result	Passable
Fix type	–	Fix Span / Diameter	–
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Habitat confirmation conducted due to debris in stream that causes small drop across stream (0.2 - 0.6m high) just downstream of the bridge. 9:20

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
61504	Upstream	520	12.1	11.2	1.0	2.8	abundant	high
61504	Downstream	365	27.8	10.5	0.5	2.8	abundant	high

Figure 5.1: Left: Cascade adjacent to PSCIS crossing 61504. Right: Flow velocity measurement adjacent to PSCIS crossing 61504.

Figure 5.2: Left: Typical habitat downstream of PSCIS crossing 61504. Right: Typical habitat downstream of PSCIS crossing 61504.

Figure 5.3: Left: Typical habitat upstream of PSCIS crossing 61504. Right: Typical habitat upstream of PSCIS crossing 61504.

Appendix - 62181 & 62182 - Dry Creek

Site Location

PSCIS crossing 62181 is located on Dry Creek on the CP Railway 11km east of Elkford, BC. PSCIS crossing 62182 is located approximately 30m downstream of the railway on the Fording Highway. The Fording Highway is detailed as a local road within the municipal boundaries of the District of Elkford with the Ministry of Transportation and Infrastructure detailed as a custodian partner within the digital road atlas (FLNRORD 2020b). The road accesses the Fording River Operations which is a steelmaking coal operation owned by Teck Coal Limited.

Background

Dry Creek drains in a northern direction to the confluence with the Fording River at a location approximately 10km east of Elkford, BC. At crossing 62181, Dry Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 25.5km^2. The elevation of the watershed ranges from a maximum of 2280 to 1540m at PSCIS crossing 62181. Dry Creek is known to contain westslope cutthroat trout upstream of the subject culvert (MoE 2020a; Norris 2020). There are numerous stream crossing structures located on Dry Creek upstream of 62181 however there are no crossings assessed as barriers on the mainstem to directly below the location of the wasterock as indicated by aerial imagery. Dry Creek drains into to the Fording River upstream of Josephine Falls, a 25 m waterfall that limits the upstream passage of fish (Teck Coal Limited Line Creek Operations 2009).

Table 5.5: Summary of derived upstream watershed statistics for PSCIS crossing 62181.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
62181	25.5	1532	–	2594	2061	2078	2019

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

The upper end of the watershed is within Phase II of Teck Coal Limited's (Teck) – Line Creek Operation area (LCOII). Hasek and Batchelar (2021) report that waste rock placement in the watershed began in 2015. A review of aerial imagery from March of 2021 indicated that the total area of waste rock placement within the watershed was approximately 300ha. In order to comply with discharge requirements for total suspended solids (Permit 106970), Teck began operating the Line Creek Operation Dry Creek Water Management System (LCODCWMS) in 2015. The LCODCWMS collects upper Dry Creek water in a headpond which then conveys the water into two lined sedimentation ponds. Discharge from the sedimentation ponds is subsequently combined and is conveyed to a constructed discharge channel which flows continuously into Dry Creek downstream. The Line Creek Operations Local Aquatic Effects Monitoring Program (LCOLAEMP) to assess potential effects of Line Creek Operations on Dry Creek, Grace Creek and an Unnamed Creek has been in operation since 2014 as per another LCOII permitting requirement (Hasek and

Batchelar 2021). A Structured Decision Making (SDM) process was initiated in 2016 to develop recommendations for water qualty site performatnce objective (SPOs) and in-stream flow requirements (IFRs) for Dry Creek, along with an updated LCO Dry Creek Water Management Plan that included water management activities, physical ,works, and LCOII operational procedures with the entent to acheieve the recommneded SPOs and IFRs, to inform monitoring as well as adaptive management recommendations. The SDM process includes a working group comprised of Ktunaxa Nation Council; BC Ministry of Environment; Ministry of Forests, Lands, Natural Resource Operations and Rural Development; the Ministry of Energy, Mines and Petroleum Resources; Fisheries and Oceans Canada and Teck. The SDM process develops operational recommendations informed throughout the year by the LCOLAEM with results from 2020 summarized below (Hasek and Batchelar 2021).

1. Aqueous concentrations of nitrate, sulphate, nickel, selenium, total cadmium, and other constituents were greater within Dry Creek than reference and normal ranges with frequent guideline and benchmark exceedances.
2. Water collected at the outlet of the LCODCWMS had no increases in acute toxicity in 2020 and water sampled from within Dry Creek had no change in frequency or severity of potential adverse responses in chronic toxicity testing.
3. Multiple metrics of benthic invertebrate community composition that indicate negative water quality effects (decreasing %Ephemeroptera , decreaseing %EPT, increasing %Chironomidae) were noted at multiple Dry Creek sample sites in 2020.
4. Benthic invertebrate tissue selenium concentrations were observed to be greater than normal range in samples from all areas downstream of the LCODCWMS.
5. In response to 3 and 4, operational changes to the LCODCWMS were implemented in 2020 to minimize the retention time in the pond to reduce bioaccumulation of selenium. Water from the headpond bypassed the sedimentation ponds seasonally, only filling them during freshet and higher-flow periods.

A pipeline and power line corridor (Dry Creek Water Conveyance and Supplementation Project) are currently under construction in the watershed to mitigate the risks to the water quality / flow regulation in Dry Creek and meet site performance measures and instream flow requirements (Burns et al. 2021; Chapman and Hatfield 2021). The project infrastructure will collect mine-affected water in the headwaters of Dry Creek and divert it into the Fording River while water from the Fording River upstream of the Dry Creek conveyance outlet will be pumped to Dry Creek at or near the point of diversion. Chapman and Hatfield (2021) conducted Fisheries Habitat Assessment Procedure (FHAP) surveys and mapping in the Fording River and a perrenial tributary to Dry Creek (T5) in 2021 to supplement FHAP data collected in the mainstem of Dry Creek by Buchanan et al. (2017) and support the design and permitting for the project.

S. Cope (2020) have conducted three pass removal depletion electrofishing in the lower section of Dry Creek below crossing 62181 as part of the Upper Fording River Westslope Ctthroat Trout Population Monitoring Project in 2013, 2014, 2015, 2017 and 2019 with fish densities sampled ranging from 2.25 to 16.5 fish/100m^2. Sampling was continued in 2020 along with redd surveys in the lower reach of the stream with results presented in Thorley, Kortello, and Robinson (2021).

Analysis by Thorley, Kortello, and Robinson (2021) indicates that there was a substantial decline in the number of adult westslope cutthroat trout in the Upper Fording River between 2017 and 2019 with no evidence of further decline between 2019 and 2020 suggesting the mortality may have been due to a short-term event opposed to chronic conditions.

In 2014, PSCIS stream crossings 62181 and 62182 were the sites of habitat confirmation assessments by Masse Environmental Consultants Ltd. (2015). The crossings were subjectively assessed as passable during the field assessments due to the low gradients and embeddedness of the pipes with the crossings not recommended for replacement at that time. Masse Environmental Consultants Ltd. (2015) did however recommend reassessment of the sites every 5 to 10 years due to likely substrate movement at the crossing locations. Upon review of this background reporting, and due to the likely presence of significant quantities of upstream habitat suitable for WCT rearing and spawning based on `bcfishpass` outputs, the Canadian Wildlife Federation assigned these sites as high priorities for follow up (Table 5.6). A map of the watershed is provided in map attachment 082J.103.

Table 5.6: Summary of fish habitat modelling for PSCIS crossing 62181.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	4.4	4.3	98
WCT Rearing (km)	5.4	4.5	83
WCT Stream (km)	15.9	5.9	37
WCT Network (km)	15.9	5.9	37
WCT Lake Reservoir (ha)	–	0.0	–
WCT Wetland (ha)	–	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	1.6	1.6	100
WCT Slopeclass05 (km)	3.0	2.9	97
WCT Slopeclass08 (km)	2.8	0.6	21
WCT Slopeclass15 (km)	7.1	0.6	8
WCT Slopeclass22 (km)	1.3	0.4	31

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Permit 107517, issued to Teck in November 2014 under provisions of the *Environmental Management Act* required development of a Tributary Management Plan for tributaries to the Elk and Fording Rivers that will incorporate protection and rehabilitation goals for tributaries to support achieving the area-based objectives of the Elk Valley Water Quality Plan (Teck Coal Limited 2020; Teck Resources Limited 2014). As part of the Tributary Management Plan, design work for fish passage improvement at the Highway and Railway is scheduled for 2021-2022 based on pre-construction data that was scheduled to be collected in 2021. Construction of restoration works has been slated for 2023 based on progress of a partnership and agreement on design between the Ministry of Transportation and Infrastructure, CP Railway and Teck (Teck Coal Limited 2020).

Stream Characteristics at Crossings

At the time of the survey, the PSCIS crossing 62181 was embedded, non-backwatered and considered a potential barrier to upstream fish passage according to the provincial metric. The pipes were 1.8m each in diameter with lengths of 17m, culvert slopes of 2.6%, a stream width ratio of 2.1 and an outlet drop of 0m (Table 5.7). Water temperature was 5°C, pH was 8.2 and conductivity was 810uS/cm.

PSCIS crossing 62182 was comprised of two pipes. As per the provincial methodology, only data from the pipe with the lowest outlet elevation was entered into the provincial database (MoE 2011b). Although the lower of the two 1.8m diameter pipes was embedded for the majority of its length, it was not embedded near the inlet and there was a significantly sized inlet drop present (0.4m). The crossing was non-backwatered and considered a barrier to upstream fish passage according to the

provincial metric. The pipe lengths were 17m, with the lower elevation pipe slope measured at 2.6%. The stream width ratio was 2.1 and the outlet drop was 0m (Table 5.8).

Stream Characteristics Downstream

The stream was surveyed downstream from 62182 for 500m (Figure 5.4). Overall, total cover amount was rated as abundant with undercut banks dominant. Cover was also present as deep pools and overhanging vegetation (Table 5.9). The average channel width was 3.9m, the average wetted width was 3.1m and the average gradient was 2%. The dominant substrate was cobbles with gravels subdominant. During the downstream survey the stream was observed to be quite open with all riparian vegetation comprised as shrub before transitioning into mature mixed forest. Pools and undercut banks were noted with their frequency increasing further downstream. The stream was noted as very braided at times and had appeared to have shifted into a new channel, indicated by fine substrate, mid stream standing and dead conifers and no major channel development (ie. wetted channel was equivalent to channel width in these areas). Substrate was noted well outside the normal high water mark suggesting high flows and channel movement. Sharp bends in the stream resulted in deep pools and undercut banks. A climate and hydrometric station was observed downstream of the highway in first few hundred meters. Habitat value was rated as high.

Stream Characteristics Upstream

The stream was surveyed upstream from 62181 for 650m (Figure 5.5). Environmental monitoring system sample location E288270 (EQuiS: LC_DC1) was located approximately 100m upstream of the railway at the bridge on the Fording FSR. In the area surveyed, total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation (Table 5.9). The average channel width was 4.1m, the average wetted width was 3m and the average gradient was 3.3%. Habitat value was rated as high for salmonid rearing and spawning due to good flow, larger channel size, occasional pockets of gravel and the presence of intermittent pools.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (12m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 62181. The cost of the work is estimated at $7,200,000 for a cost benefit of 0.6 linear m/$1000 and 2.4$m^2$/$1000.

Conclusion

There is an estimated 4.3km of mainstem habitat upstream of crossing 62181 to the LCODCWMS headpond. Habitat in the area surveyed was rated as high value for salmonid rearing/spawning. The railway is the responsibility of Canadian Pacific Rail and the highway appears to be the responsibility of the Ministry of Transportation and Infrastructure. The crossing was ranked as a high priority for proceeding to design for replacement. Line Creek watershed is within Phase II of

Teck Coal Limited's – Line Creek Operation area with a wealth of past and current information regarding the stream available including detailed habitat assessment, water quality, benthic invertebrate, toxicity and flow data gathered through the ongoing Line Creek Operations Local Aquatic Effects Monitoring Program. At the time of reporting, the Dry Creek Water Conveyance and Supplementation Project was under construction and fish passage restoration works at the highway and railway were planned for 2023 through Teck's Tributary Management Plan and based on progress of a potential partnership and agreement on design between the Ministry of Transportation and Infrastructure, CP Railway and Teck (Burns et al. 2021; Chapman and Hatfield 2021; Teck Coal Limited 2020).

Table 5.7: Summary of fish passage assessment for PSCIS crossing 62181.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2021-09-29	Crossing Sub Type	Round Culvert
PSCIS ID	62181	Diameter (m)	1.8
External ID	–	Length (m)	17
Crew	KP	Embedded	Yes
UTM Zone	11	Depth Embedded (m)	0.35
Easting	656409	Resemble Channel	Yes
Northing	5544755	Backwatered	No
Stream	Dry Creek	Percent Backwatered	–
Road	CP Railway	Fill Depth (m)	1.2
Road Tenure	Canadian Pacific	Outlet Drop (m)	0
Channel Width (m)	3.7	Outlet Pool Depth (m)	0
Stream Slope (%)	3.3	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	2.6
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	19	Barrier Result	Potential
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Two pipes (1.8m x 1.8m). Left pipe was measured. Right pipe gradient ~3%. Right pipe partially embedded.
14:16

Location and Stream Data	•	Crossing Characteristics	–
Date	2021-09-29	Crossing Sub Type	Round Culvert
PSCIS ID	62182	Diameter (m)	1.8
External ID	–	Length (m)	24
Crew	KP	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	656390	Resemble Channel	No
Northing	5544771	Backwatered	No
Stream	Dry Creek	Percent Backwatered	–
Road	Fording Highway	Fill Depth (m)	1.8
Road Tenure	Elkford Local	Outlet Drop (m)	0
Channel Width (m)	3.7	Outlet Pool Depth (m)	0
Stream Slope (%)	3.3	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	3.6
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Two pipes (1.8m x 1.8m). Stream left pipe embedd at outlet 0.6m but not at inlet and there is a significant inlet drop. PSCIS crossing 62182 is located ~30m upstream of the crossing under the railway. 12:50

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
62182	Upstream	30	4.1	3.0	0.3	3.3	abundant	high
62182	Downstream	500	3.9	3.1	0.4	2.0	abundant	high

Figure 5.4: Left: Typical habitat downstream of PSCIS crossing 62182. Right: Typical habitat downstream of PSCIS crossing 62182.

Figure 5.5: Left: Typical habitat upstream of PSCIS crossing 62181. Right: Typical habitat upstream of PSCIS crossing 62181.

Appendix - 62505 - Tributary to Lizard Creek

Site Location

PSCIS crossing 62505 is located on a tributary to Lizard Creek 2.5km west of Fernie on Mt. Fernie Park Road. The crossing is located within the Mount Fernie Provincial Park Boundary and approximately 75m upstream from the confluence with Lizard Creek and the responsibility of the Ministry of Environment and Climate Change Strategy. The area is a popular recreational destination for hikers and mountain bikers.

Background

At crossing 62505, tributary to Lizard Creek is a first order stream with a watershed area upstream of the crossing of approximately 0.9km^2. The elevation of the south-west facing watershed ranges from a maximum of 1449m to 1048m at the crossing (Table 5.10). Upstream of Mt. Fernie Park Road, no fish have previously been recorded (MoE 2020b). Downstream, Lizard Creek supports westslope cutthroat trout, bull trout, mountain whitefish, brook trout, longnose sucker and longnose dace (MoE 2020a). Elk River Alliance (2020) conducted redd surveys in Lizard Creek in 2019 along with Morrissey Creek, Coal Creek and Forsyth Creek. A total of 55 redds were observed within a 2.4km section of Lizard Creek comprising the largest densities of redds of the four tributaries surveyed (22.9 redds/km).

Table 5.10: Summary of derived upstream watershed statistics for PSCIS crossing 62505.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
62505	0.9	1048	1038	1449	1206	1192	1168

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

PSCIS crossing 62505 was prioritized for assessment due to it's location within provincial park boundaries and the associated positive implications for restoration potential. Although assessed as a low priority for follow up in planning for 2020 field work (Irvine 2021), during 2020 field surveys the site was noted as having a significant sized outlet drop, good flow during the dryest part of the year and a location directly adjacent to Lizard Creek which contains confirmed spawning habitat for westslope cutthrout trout. Table 5.11 presents preliminary fish passage modelling data for crossing 62505 with linear length of habitat <8% upstream estimated at 0.4km and an additional 0.5km of habitat modeled between 8 - 15%. A map of the watershed is provided in map attachment 082G.113.

Table 5.11: Summary of fish habitat modelling for PSCIS crossing 62505.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	0.0	0.0	–
WCT Rearing (km)	0.0	0.0	–
WCT Stream (km)	0.9	0.5	56
WCT Network (km)	0.9	0.5	56
WCT Lake Reservoir (ha)	0.0	0.0	–
WCT Wetland (ha)	0.0	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	0.0	0.0	–
WCT Slopeclass05 (km)	0.0	0.0	–
WCT Slopeclass08 (km)	0.4	0.0	0
WCT Slopeclass15 (km)	0.5	0.5	100
WCT Slopeclass22 (km)	0.0	0.0	–

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Mt. Fernie Park Road was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011b). The pipe was 0.9m in diameter with lengths of 10m, a culvert slope of 5%, a stream width ratio of 3.2 and an outlet drop of 0.25m (Table 5.12). Water temperature was 3°C, pH was 8 and conductivity was 312uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 75m to the confluence with Lizard Creek (Figure 5.6). Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris and overhanging vegetation (Table 5.13). The average channel width was 2.5m and the average gradient was 4.8%. The dominant substrate was gravels with cobbles subdominant. No barriers were noted downstream and there were gravels suitable for spawning westslope cutthroat trout throughout. The habitat was rated as medium value for resident salmonid rearing due to a lack of water.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 62505 for approximately 700m to ~60m above PSCIS culvert 197863 (Figure 5.7). Immediately above culvert 197863 the stream became very steep with gradients exceeding 20%. Within the area surveyed, total cover amount was rated

as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation (Table 5.13). The average channel width was 2.9m, the average wetted width was 1.4m and the average gradient was 7.6%. The dominant substrate was gravels with cobbles subdominant. Occasional pools suitable for juvenile westslope cutthroat trout overwintering and frequent pockets of gravel present suitable for spawning were noted throughout. The fairly steep system had good flow with intermittent small woody debris drops between 0.5 and 1m in height. Habitat value was rated as medium with moderate potential for juvenile salmonid rearing.

Structure Remediation and Cost Estimate

Should restoration/maintenance activities proceed at the site, replacement of PSCIS crossing 62505 with a bridge (12m span) is recommended. The cost of the work is estimated at $240,000 for a cost benefit of 2.8 linear m/$1000 and 8.2$m^2$/$1000.

Conclusion

There was 0.7km of viable juvenile rearing habitat upstream of crossing 62505. Habitat in the areas surveyed upstream of the culvert were rated as medium value for salmonid rearing. Mt. Fernie Park Road, at the crossing location, is located within the Mount Fernie Provincial Park Boundary and is the responsibility of the Ministry of Environment and Climate Change Strategy. As the crossing is located approximately 75m upstream from the confluence with Lizard Creek where westslope cutthrout trout spawning is known to occur, remediation of fish passage at the site could provide sdditional habitat for fry and juveniles migrating from the mainstem of Lizard Creek. Crossing 62505 was ranked as a moderate priority for proceeding to design for replacement.

Table 5.12: Summary of fish passage assessment for PSCIS crossing 62505.

Location and Stream Data	•	Crossing Characteristics	–
Date	2021-10-13	Crossing Sub Type	Round Culvert
PSCIS ID	62505	Diameter (m)	0.9
External ID	–	Length (m)	10
Crew	AI BK SS	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	636941.9	Resemble Channel	No
Northing	5483777	Backwatered	No
Stream	Tributary to Lizard Creek	Percent Backwatered	–
Road	Mt. Fernie Park Road	Fill Depth (m)	0.3
Road Tenure	Recreation	Outlet Drop (m)	0.25
Channel Width (m)	2.9	Outlet Pool Depth (m)	0.45
Stream Slope (%)	7.6	Inlet Drop	No
Beaver Activity	No	Slope (%)	5

Location and Stream Data	•	Crossing Characteristics	–
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Comments: Very close to Lizard Creek mainstem. 10:43			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Table 5.13: Summary of habitat details for PSCIS crossing 62505.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
62505	Upstream	700	2.9	1.4	0.3	7.6	moderate	medium
62505	Downstream	75	2.5	1.3	–	4.8	moderate	medium

Figure 5.6: Left: Habitat downstream of crossing 62505. Right: Confluence with Lizard Creek located ~70m downstream of crossing 62505.

Figure 5.7: Left: Habitat upstream of PSCIS crossing 62505. Right: Habitat upstream of PSCIS crossing 62505.

Appendix - 197787 & 197786 - Lodgepole Creek

Site Location

PSCIS crossing 197787 is located on Lodgepole Creek on the Harvey FSR approximately 35km south-east of Fernie, BC and accessed from the Lodgepole FSR. PSCIS crossing 197786 is located approximately 875 upstream of 197787 and is also on the Harvey FSR. The Harvey FSR (forest file ID 5466) is under the jurisdiction of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development District Manager for the Rocky Mountain Forest District (FLNRORD 2020d).

Background

Lodgepole Creek drains in a generally western direction to the confluence with the Wigwam River before flowing 10km to the Elk River at a location approximately 7km downstream of the Elko Dam. At crossing 197787, Lodgepole Creek is a third order stream with a watershed area upstream of the crossing of approximately 5.2km^2. The elevation of the watershed ranges from a maximum of 2456m to 1592m near PSCIS crossing 197787 (Table 5.14). Lodgepole Creek is known to contain westslope cutthroat trout upstream of the subject culvert (MoE 2020a; Norris 2020). The only stream crossing upstream of 197787 on the mainstem of the stream before extreme gradients is crossing 197786. Lodgepole Lake is located approximately 300m upstream of 197787 and is approximately 2ha in area.

Table 5.14: Summary of derived upstream watershed statistics for PSCIS crossing 197787.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
197787	5.2	1664	1592	2456	1936	1920	1883

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

Due to the potential for significant quantities of upstream habitat suitable for WCT rearing and spawning based on `bcfishpass` outputs, the Canadian Wildlife Federation assigned these sites as high priorities for follow up. Table 5.15 presents preliminary fish passage modelling data for crossing 197787 with linear length of spawning and rearing habitat estimated for westslope cutthrout trout at 0.5km and 0.6km respectively. A map of the watershed is provided in map attachment 082G.109.

Table 5.15: Summary of fish habitat modelling for PSCIS crossing 197787.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	0.8	0.5	62
WCT Rearing (km)	1.1	0.6	55
WCT Stream (km)	1.6	1.0	62
WCT Network (km)	2.1	1.5	71
WCT Lake Reservoir (ha)	–	0.0	–
WCT Wetland (ha)	1.9	1.9	100
WCT Slopeclass03 Waterbodies (km)	0.5	0.0	0
WCT Slopeclass03 (km)	0.2	0.2	100
WCT Slopeclass05 (km)	0.6	0.3	50
WCT Slopeclass08 (km)	0.4	0.1	25
WCT Slopeclass15 (km)	0.4	0.4	100
WCT Slopeclass22 (km)	0.0	0.0	–

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossings

At the time of the survey, the PSCIS crossing 197787 was un-embedded, non-backwatered and considered a potential barrier to upstream fish passage according to the provincial metric. The pipes were 2m each in diameter with lengths of 18m, culvert slopes of 0.5%, a stream width ratio of 1.6 and an outlet drop of 0m (Table 5.16). Water temperature was 7°C, pH was 7.6 and conductivity was 261uS/cm.

PSCIS crossing 197786 was comprised of two pipes. As per the provincial methodology, because the outlet height of each of the two 1m pipes were equivalent, the diameters of the two pipes were summed for input into PSCIS and the the stream width ratio was calculated as though the structure diameter was 2m (MoE 2011b). The crossing was non-embedded, not backwatered and considered a potential barrier to upstream fish passage according to the provincial metric. The pipe lengths were 18m, with pipe slopes measured at 0.5%. The stream width ratio was 1.6 and the outlet drop was 0m (Table 5.17).

Stream Characteristics Downstream of 197787

The stream was surveyed downstream from 197787 for 285m (Figure 5.8). Overall, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, undercut banks, and overhanging vegetation (Table 5.18). The average channel width was 4.4m, the average wetted width was 3.2m and the average gradient was 6.2%. The dominant substrate was boulders with gravels subdominant. Habitat value was rated

as medium as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

A 10m high falls was reported as present within the Provincial Obstacles to Fish Passage spatial spatial layer of the provincial Data Catalogue in the mainstem of Lodgepole Creek approximately 12.5km downstream of PSCIS crossing 197787 (MoE 2020d). The potential presence of this falls was considered relevant for assessment of PSCIS crossing 197787 so a 1100m section of stream was surveyed spanning the reported falls location (survey track is shown in map attachment 082G.109). No falls were observed within the area surveyed.

Stream Characteristics Upstream of 197787 and downstream of 197786

The stream was surveyed upstream from 197787 for 315m to the outlet of Lodgepole Lake where a beaver dam ~1.2m in height was observed (Figures 5.9 - 5.10). Numerous fish (150 - 200m) were observed above the beaver dam. Within the area surveyed, total cover amount was rated as moderate with large woody debris dominant. Cover was also present as overhanging vegetation (Table 5.18). The average channel width was 3.3m, the average wetted width was 2.3m and the average gradient was 2.8%. Abundant gravels suitable for spawning were observed between the FSR and the lake outlet. Within this area of the survey the stream primarily had low complexity due to the prevalence of straight riffle type habitat. Some shallow pools and large woody debris were present. Habitat value was rated as high value due to the presence of spawning gravels as well as the lake which likely provides overwintering habitat for resident westslope cutthrout trout.

The stream was surveyed downstream from 197786 for 540m to the inlet of Lodgepole Lake (Figure 5.11). Within the area surveyed, total cover amount was rated as moderate with large woody debris dominant. Cover was also present as overhanging vegetation (Table 5.18). The average channel width was 3.3m, the average wetted width was 2.3m and the average gradient was 2.8%. Abundant gravels suitable for spawning were observed between the FSR and the lake outlet. The channel dewatered in a section from approximately 160m upstream of the lake to the lake. Substrate in the upstream, watered portion of the stream below the culvert was comprised of gravels suitable for spawning. Several deep pools potentialy suitable for overwintering westslope cutthroat trout were also observed in this section. Two steps 30cm high and 80cmhigh were observed in channel due to small woody debris accumulation. Habitat value was rated as high overall.

5.1 Stream Characteristics Upstream of 197786

The stream was surveyed upstream from 197786 for 580m to the base of a waterfall >30m high (Figures 5.9 - 5.10). Within the area surveyed, total cover amount was rated as moderate with small woody debris dominant. Cover was also present as large woody debris, boulders, undercut banks, deep pools, and overhanging vegetation (Table 5.18). The average channel width was 2m, the average wetted width was 1.8m and the average gradient was 3.8%.
Low gradient riffle-pool habitat containing abundant gravels suitable for resident westslope cutthrout trout spawning was present throughout the first approximate 300m of stream surveyed before

gradients increased to 6-7% near the top of site. Shallow pools were present intermittently in the area surveyed, created by large woody debris. Habitat value was rated as medium value with moderate potential for salmonid spawning/rearing.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (12m span) was recommended to provide access to the stream and lake habitat located upstream of PSCIS crossing 197787. The cost of the work was estimated at $240,000 for a cost benefit of 4.7 linear m/$1000 and 15.5$m^2$/$1000.

Structure replacement with a bridge (12m span) was recommended to provide access to the habitat located upstream of PSCIS crossing 197786. The cost of the work was estimated at $240,000 for a cost benefit of 2.4 linear m/$1000 and 4.8$m^2$/$1000.

Conclusion

There is 1.1km of habitat upstream of crossing 197787 to PSCIS crossing `as.character(my_site2)`. Habitat in the area was surveyed was rated as high value for salmonid rearing/spawning primarily due to the presence of the 2ha of rearing habitat in Lodgepole Lake. The beaver dam upstream of the crossing may provide an obstacle to upstream passage for some migrating fish at some flows however they are not considered permanent, are likely important for maintaining water elevations in the lake and may be passable at some flows. There is 0.6km of habitat upstream of crossing 197786 before the impassable waterfall with habitat value rated as medium. Both crossings are on the Harvey FSR under the jurisdiction of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development District Manager for the Rocky Mountain Forest District. Due to it's status as a "potential" barrier to upstream migration, crossing 197787 was ranked as a moderate priority for proceeding to design for replacement. Crossing 197786 was ranked as a moderate priority for proceeding to design for replacement due to the streams seasonal disconnection from Lodgepole Lake and the relatively short section of habitat available upstream before the falls.

Table 5.16: Summary of fish passage assessment for PSCIS crossing 197787.

Location and Stream Data	•	Crossing Characteristics	–
Date	2021-07-29	Crossing Sub Type	Round Culvert
PSCIS ID	197787	Diameter (m)	2
External ID	–	Length (m)	18
Crew	AI TS	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	664905.1	Resemble Channel	No
Northing	5462562	Backwatered	No
Stream	Lodgepole Creek	Percent Backwatered	–

Location and Stream Data	•	**Crossing Characteristics**	–
Road	Harvey FSR	Fill Depth (m)	1.5
Road Tenure	FLNR DRM 5466	Outlet Drop (m)	0
Channel Width (m)	3.26	Outlet Pool Depth (m)	0.1
Stream Slope (%)	2.8	Inlet Drop	Yes
Beaver Activity	Yes	Slope (%)	0.5
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	19	Barrier Result	Potential
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Two pipes (1m each) but one blocked with debris. Because height of outlets equivalent widths were added together for input to stream width ratio. Large beaver dams upstream between culvert and Lodgepole Lake. 15:37

Table 5.17: Summary of fish passage assessment for PSCIS crossing 197786.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2021-07-29	Crossing Sub Type	Round Culvert
PSCIS ID	197786	Diameter (m)	1.2
External ID	–	Length (m)	10
Crew	AI TS	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	665796.1	Resemble Channel	No
Northing	5462152	Backwatered	No
Stream	Lodgepole Creek	Percent Backwatered	–
Road	Harvey FSR	Fill Depth (m)	0.1
Road Tenure	FLNR DRM 5466	Outlet Drop (m)	0
Channel Width (m)	2	Outlet Pool Depth (m)	0.1
Stream Slope (%)	3.8	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	1.7
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	21	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Small stream with good flow. Abundant gravels just upstream with gradients increasing to 6-7% near 540m upstream of culvert where large (~30m high) waterfall is located. 10:18

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197786	Upstream	580	2.0	1.8	0.3	3.8	moderate	medium
197786	Downstream	540	1.4	0.8	0.4	1.8	moderate	medium
197787	Downstream	285	4.4	3.2	0.3	6.2	moderate	medium
197787	Upstream	315	3.3	2.3	0.3	2.8	moderate	high

Table 5.19: Summary of fish habitat modelling for PSCIS crossing 197786.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	0.3	0.3	100
WCT Rearing (km)	0.5	0.5	100
WCT Stream (km)	0.6	0.6	100
WCT Network (km)	0.6	0.6	100
WCT Lake Reservoir (ha)	0.0	0.0	–
WCT Wetland (ha)	0.0	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	0.0	0.0	–
WCT Slopeclass05 (km)	0.3	0.3	100
WCT Slopeclass08 (km)	0.3	0.3	100
WCT Slopeclass15 (km)	0.0	0.0	–
WCT Slopeclass22 (km)	0.0	0.0	–

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Figure 5.8: Left: Typical habitat downstream of PSCIS crossing 197787. Right: Typical habitat downstream of PSCIS crossing 197786.

Figure 5.9: Left: Typical habitat upstream of PSCIS crossing 197787. Right: Gravels suitable for spawning located upstream of PSCIS crossing 197787.

Figure 5.10: Left: Beaver dam located upstream of PSCIS crossing 197787 and just below Lodgepole Lake. Right: Lodgepole Lake located upstream of PSCIS crossing 197787.

Figure 5.11: Left: Habitat downstream of PSCIS crossing 197786. Right: Dewatered habitat downstream of PSCIS crossing 197786.

Figure 5.12: Left: Typical habitat upstream of PSCIS crossing 197786. Right: Large falls located ~550m upstream of PSCIS crossing 197786.

Appendix - 197793 - Bean Creek

Site Location

PSCIS crossing 197793 is located on a Bean Creek 26km south Fernie on Lodgepole FSR. The crossing is located approximately 100m up from the junction of the Lodgepole FSR and the Wigwam FSR. The culverts are located approximately 2.3km upstream from the confluence with Lodgepole Creek. Lodgepole FSR (forest file ID 5466) is the responsibility of Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Rocky Mountain Forest District.

Background

At crossing 197793, Bean Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 9.4km^2. The elevation of the south-west facing watershed ranges from a maximum of 2198m to 1146m near the crossing (Table 5.20). Upstream of Lodgepole FSR, no fish have previously been recorded (MoE 2020b). A Fortis gas pipeline compression station is located approximately 600m north of the crossing adjacent to the Lodgepole FSR.

Table 5.20: Summary of derived upstream watershed statistics for PSCIS crossing 197793.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
197793	9.4	1147	1146	2198	1563	1488	1427

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

PSCIS crossing 197793 was earmarked for assessment by Canadian Wildlife Federation due to `bsfishpass` modelling which indicated potentially large quantities of habitat suitable for westslope cutthrout trout spawning and rearing upstream. Table 5.21 presents preliminary fish passage modelling data for crossing 197793 with linear length of spawning and rearing habitat estimated for westslope cutthrout trout at 1.7km and 1.8km respectively. A map of the watershed is provided in map attachment 082G.108.

Table 5.21: Summary of fish habitat modelling for PSCIS crossing 197793.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	1.7	1.7	100
WCT Rearing (km)	1.8	1.8	100
WCT Stream (km)	7.6	5.0	66
WCT Network (km)	7.6	5.0	66
WCT Lake Reservoir (ha)	0.0	0.0	–
WCT Wetland (ha)	0.0	0.0	–
WCT Slopeclass03 Waterbodies (km)	0.0	0.0	–
WCT Slopeclass03 (km)	0.3	0.3	100
WCT Slopeclass05 (km)	1.5	1.5	100
WCT Slopeclass08 (km)	0.6	0.6	100
WCT Slopeclass15 (km)	3.0	1.5	50
WCT Slopeclass22 (km)	2.2	1.2	55

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossing

At the time of the survey, the two culverts under Lodgepole FSR were un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011b). The pipes were 1.5m in diameter with lengths of 14m, a culvert slope of 2.5%, a stream width ratio of 3.5 and an outlet drop of 0m (Table 5.22). Significant damage to the crossing was apparent with the pipe split vertically through the entire culvert near the centre of the southern most pipe (Figure 5.13). The stream was completely dry at the time of the survey and the freshwater atlas stream layer indicates intermittent flow (FLNRORD 2021). Of note, the culverts are located approximately 840m upstream from the confluence with a tributary to Bean Creek and a bridge of stream of the confluence (PSCIS 197792) was assessed on this tributary. The tributary was flowing at the bridge site at the time of the survey (2021-07-30).

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 340m (Figure 5.13). Total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris and undercut banks (Table 5.23). The average channel width was 4.4m and the average gradient was 3.3%. The dominant substrate was cobbles with gravels subdominant. Although, dry at the time of the survey, there were pockets of gravels suitable for resident salmonids and there was evidence of high flows, significant erosion and a deeply incised channel and eroding banks. The habitat was rated as low value for resident salmonid rearing due to a lack of water.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 197793 for approximately 900m to a bridge (PSCIS 197794) on the Fortis gas pipline (Figure 5.14). Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, and overhanging vegetation (Table 5.23). The average channel width was 5.3m, the average wetted width was NAm and the average gradient was 2.7%. The dominant substrate was cobbles with gravels subdominant. Extensive areas of gravels suitable for spawning resident salmonids were present and there was evidence of high flows, significant erosion and a deeply incised channel and eroding banks. Habitat value was rated as low value resident salmonid rearing and spawning.

Structure Remediation and Cost Estimate

Should restoration/maintenance activities proceed at the site, replacement of PSCIS crossing 197793 with a bridge (12m span) is recommended. The cost of the work is estimated at $240,000 for a cost benefit of 7.5 linear m/$1000 and 39.8$m^2$/$1000.

Conclusion

A conservative estimate of mainstem habitat upstream of crossing 197793 is 1.8km. Habitat in the areas surveyed upstream of the culvert were rated as low value for salmonid rearing and spawning due to likely annual seasonal dewatering within the rocky south-west facing watershed. Lodgepole FSR is the responsibility of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Rocky Mountain Forest District. Crossing 197793 was ranked as a low priority for proceeding to design for replacement.

Table 5.22: Summary of fish passage assessment for PSCIS crossing 197793.

Location and Stream Data	•	Crossing Characteristics	–
Date	2021-07-30	Crossing Sub Type	Round Culvert
PSCIS ID	197793	Diameter (m)	1.5
External ID	–	Length (m)	14
Crew	AI TS	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	650414.6	Resemble Channel	No
Northing	5463819	Backwatered	No
Stream	Bean Creek	Percent Backwatered	–
Road	Lodgepole FSR	Fill Depth (m)	1
Road Tenure	FLNR DRM 5466	Outlet Drop (m)	0
Channel Width (m)	5.3	Outlet Pool Depth (m)	0.2
Stream Slope (%)	2.7	Inlet Drop	No

Location and Stream Data	•	Crossing Characteristics	–
Beaver Activity	No	Slope (%)	2.5
Habitat Value	Low	Valley Fill	Deep Fill
Final score	21	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12

Comments: Large channel but stream is completely dry. 12:11

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

Table 5.23: Summary of habitat details for PSCIS crossing 197793.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197793	Upstream	900	5.3	–	0.7	2.7	moderate	low
197793	Downstream	340	4.4	–	0.4	3.3	moderate	low

Figure 5.13: Left: Damage within PSCIS crossing 197793. Right: Habitat downstream of crossing 197793.

Figure 5.14: Left: Habitat upstream of PSCIS crossing 197793. Right: Habitat upstream of PSCIS crossing 197793.

Appendix - 197796 - Tributary to Lodgepole Creek

Site Location

PSCIS crossing 197796 is located on a tributary to Lodgepole Creek 30km south-east Fernie on an unnamed spur road. The site was located within the Wigwam Flats - Mt. Broadwood/Sportsmans Ridge access management area with a locked gate to prevent entry by motorized vehicles (“Map Wigwam Flats Mt. Boadwood Sprotsmans Ridge” 2021). The access gate is located crossing is located approximately 3km up from the junction of the Lodgepole FSR and the Wigwam FSR. The culvert was located 5.5km upstream from the confluence with Lodgepole Creek. No information was available regarding road tenure.

Background

At crossing 197796, tributary to Lodgepole Creek is a third order stream with a watershed area upstream of the crossing of approximately 3.8km^2. The elevation of the north-west facing watershed ranges from a maximum of 2318m to 1548m near the crossing (Table 5.24). Upstream of the stream crossing, no fish have previously been recorded (MoE 2020b; Norris 2020).

Table 5.24: Summary of derived upstream watershed statistics for PSCIS crossing 197796.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
197796	3.8	1608	1548	2318	1932	1940	1887

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

PSCIS crossing 197796 was earmarked for assessment by Canadian Wildlife Federation along with PSCIS site 197795 due to analysis of `bcfishpass` modelling which indicated potentially large quantities of habitat suitable for westslope cutthrout trout spawning and rearing within the greater watershed including upstream of PSCIS bridge crossing 197795 which was located 1.9km upstream from the confluence with Lodgepole Creek. Upstream of crossing 197796, there was 0.5km of habitat modelled as less than 8% gradient (Table 5.25. Evidence of a recent forest fire was apparent on the west side of the valley. A map of the watershed is provided in map attachment 082G.108.

Table 5.25: Summary of fish habitat modelling for PSCIS crossing 197796.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
WCT Spawning (km)	0.0	0.0	–
WCT Rearing (km)	0.0	0.0	–
WCT Stream (km)	1.2	1.0	83
WCT Network (km)	1.2	1.0	83
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)	0.0	0.0	–
WCT Slopeclass08 (km)	0.5	0.5	100
WCT Slopeclass15 (km)	0.5	0.4	80
WCT Slopeclass22 (km)	0.2	0.1	50

* Model data is preliminary and subject to adjustments.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossing

At the time of the survey, the culvert was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011b). The pipe was extensively damaged (seperating within the centre of the road),1.6m in diameter with a length of 14m, a culvert slope of 5%, a stream width ratio of 2.4 and an outlet drop of 0.6m (Table 5.26).

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 125m (Figure 5.15). Total cover amount was rated as NA with large woody debris dominant. Cover was also present as small woody debris, boulders, undercut banks, deep pools, and overhanging vegetation (Table 5.27). The average channel width was 4.1m and the average gradient was 7%. The dominant substrate was large rock/bedrock with boulders subdominant. There steep sections to ~15% with steps to 1.8m in height created by large woody debris and bedrock throughout the area surveyed. The habitat was rated as low value for resident salmonid rearing due primarily to the steep grades.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 197796 for approximately 110m to a 2.4m high rock falls that represents a permanent barrier to upstream fish passage in the watershed (Figure 5.16). Within the area surveyed, total cover amount was rated as NA with large woody debris dominant. Cover was also present as small woody debris, boulders, undercut banks, and

overhanging vegetation (Table 5.27). The average channel width was 3.8m, the average wetted width was 1.9m and the average gradient was 8.5%. The dominant substrate was large rock/bedrock with boulders subdominant. Habitat value was rated as low value resident salmonid rearing and spawning due to the small amount of habitat available.

Structure Remediation and Cost Estimate

Should restoration/maintenance activities proceed at the site, replacement of PSCIS crossing 197796 with a bridge (12m span) is recommended. The cost of the work is estimated at $240,000 for a cost benefit of 0.2 linear m/$1000 and 0.9$m^2$/$1000.

Conclusion

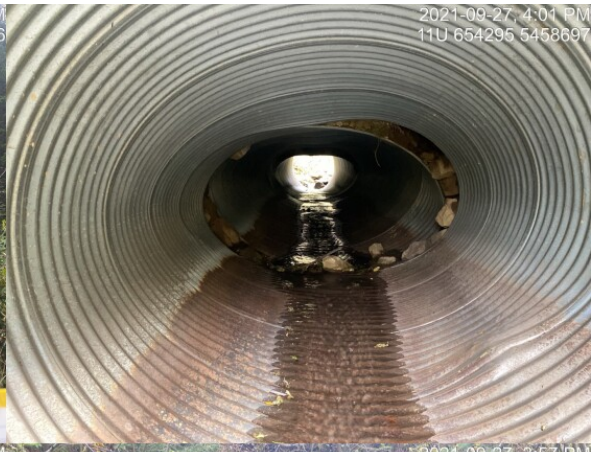
There was 197796 is 0.1km of habitat upstream of crossing rated as low value for salmonid rearing and spawning. Although unconfirmed, this road within the Wigwam Flats - Mt. Broadwood/Sportsmans Ridge access management area is likely the responsibility of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Rocky Mountain Forest District. Crossing 197796 was observed to have extensive damage within the structure and was ranked as a low priority for proceeding to design for replacement. The site could also be considered for removal and road deactivation once silviculture obligations have been met in the area.

Table 5.26: Summary of fish passage assessment for PSCIS crossing 197796.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2021-09-27	Crossing Sub Type	Round Culvert
PSCIS ID	197796	Diameter (m)	1.6
External ID	–	Length (m)	14
Crew	AI	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	654301.7	Resemble Channel	No
Northing	5458678	Backwatered	No
Stream	Tributary to Lodgepole Creek	Percent Backwatered	–
Road	Spur	Fill Depth (m)	2
Road Tenure	Unclassified	Outlet Drop (m)	0.6
Channel Width (m)	3.8	Outlet Pool Depth (m)	0.8
Stream Slope (%)	8.5	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	5
Habitat Value	Low	Valley Fill	Deep Fill
Final score	36	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Location and Stream Data	•	Crossing Characteristics	–

Comments: Gated access management area. Falls located ~60m upstream of the crossing. 15:45



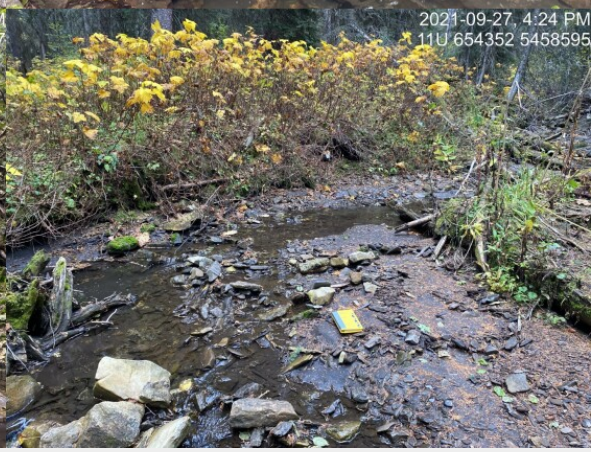


Table 5.27: Summary of habitat details for PSCIS crossing 197796.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197796	Upstream	110	3.8	1.9	0.6	8.5	–	low
197796	Downstream	125	4.1	1.8	0.4	7.0	–	low

Figure 5.15: Left: Typical habitat downstream of PSCIS crossing 197796. Right: Habitat downstream of crossing 197796.

Figure 5.16: Left: Habitat upstream of PSCIS crossing 197796. Right: 2.4m high rock falls located ~60m upstream of PSCIS crossing 197796.

Appendix - 197844 - Tributary to Bighorn Creek

Site Location

PSCIS crossing 197844 is located on a tributary to Bighorn Creek 2.5km west of Fernie on Cabin FSR. The crossing is located within the Mount Fernie Provincial Park Boundary and approximately 75m upstream from the confluence with Lizard Creek and the responsibility of the Ministry of Environment and Climate Change Strategy. The area is a popular recreational destination for hikers and mountain bikers.

Background

At crossing 197844, tributary to Bighorn Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 13.5km^2. The elevation of the east facing watershed ranges from a maximum of 2585m to 1316m at the crossing (Table 5.28). Upstream of Cabin FSR, no fish have previously been recorded (MoE 2020b). Downstream, Bighorn Creek supports westslope cutthroat trout, bull trout and mountain whitefish (MoE 2020b). 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). Strong and K. D. (2015) report that substrate core samples have been taken within Bighorn Creek at an index site ~700m upstream of the confluence with the Wigwam River between 2003 - 2008 and again in 2015 with an objective of analyzing stream substrate material/sediment levels to produce trend data valuable in monitoring suitability of stream reaches identified as critical for bull trout spawning.

Table 5.28: Summary of derived upstream watershed statistics for PSCIS crossing 197844.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Mean	Elev Median	Elev P60
197844	13.5	1316	1305	2585	1959	1976	1927

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

PSCIS crossing 197844 was surveyed with a phase 1 assessment opportunistically during field assessments in the area and was prioritized for follow up with a habitat confirmation as it was considered the crossing with the highest potential for remediation located within the Bighorn Creek watershed area. The site was noted as having a significantly sized outlet drop and good flow with a location very close to the mainstem of Bighorn Creek which contains confirmed spawning habitat for westslope cutthrout trout. Table 5.15 presents preliminary fish passage modelling data for crossing 197844 with linear length of spawning and rearing habitat estimated for westslope cutthrout trout at

0.1km and 0.3km respectively.. Additionally, 0.6km of habitat <8% gradient was modelled as located upstream. A map of the watershed is provided in map attachment 082G.108.

Table 5.29: 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.

† Modelled rearing habitat estimates do not currently include linear lengths of centrelines within lakes and wetlands.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Cabin FSR was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011b). The pipe was 1.2m in diameter with lengths of 12m, a culvert slope of 5%, a stream width ratio of 1.8 and an outlet drop of 1.2m (Table 5.30). Water temperature was 6°C, pH was 8.5 and conductivity was 273uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 95m to the confluence with Bighorn Creek (Figure 5.17). Total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as boulders (Table 5.31). The average channel width was 3.1m and the average gradient was 7.3%. The dominant substrate was cobbles with gravels subdominant. The stream was noted as going subsurface at ~40m downstream of the road then rewatering at ~80m downstream. There was evidence of high velocity/volume flows with a general lack of complexity. The habitat was rated as medium value for salmonid rearing and spawning due to dewatering, as well as a lack of deep pool and undercut bank cover.

Stream Characteristics Upstream

The stream was surveyed upstream from 197844 for approximately 840m to the location of a 1.1m high rock that likely presents a barrier to upstream fish passage (Figure 5.18). A ford (PSCIS

197801) was located on a spur road located upstream approximately 220m upstream of the FSR. Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, and undercut banks (Table 5.31). The average channel width was 3.3m, the average wetted width was 2.7m and the average gradient was 8.8%. The dominant substrate was gravels with cobbles subdominant. Occasional pools suitable for juvenile westslope cutthroat trout overwintering and frequent pockets of gravel present suitable for spawning were noted throughout. The fairly steep system had good flow with intermittent small woody debris drops between 0.5 and 1m in height. Habitat value was rated as medium with moderate potential for juvenile salmonid rearing.

Structure Remediation and Cost Estimate

Should restoration/maintenance activities proceed at the site, replacement of PSCIS crossing 197844 with a bridge (12m span) is recommended. The cost of the work is estimated at $240,000 for a cost benefit of 12.5 linear m/$1000 and 41.2$m^2$/$1000.

Conclusion

There was 3km of viable juvenile rearing habitat upstream of crossing 197844. Habitat in the areas surveyed upstream of the culvert were rated as medium value for salmonid rearing. Cabin FSR, at the crossing location, is located within the Mount Fernie Provincial Park Boundary and is the responsibility of the Ministry of Environment and Climate Change Strategy. As the crossing is located approximately 75m upstream from the confluence with Lizard Creek where westslope cutthrout trout spawning is known to occur, remediation of fish passage at the site could provide sdditional habitat for fry and juveniles migrating from the mainstem of Lizard Creek. Crossing 197844 was ranked as a moderate priority for proceeding to design for replacement.

Table 5.30: Summary of fish passage assessment for PSCIS crossing 197844.

Location and Stream Data	•	Crossing Characteristics	–
Date	2021-09-28	Crossing Sub Type	Round Culvert
PSCIS ID	197844	Diameter (m)	1.2
External ID	–	Length (m)	12
Crew	KP	Embedded	No
UTM Zone	11	Depth Embedded (m)	–
Easting	657919.7	Resemble Channel	No
Northing	5452802	Backwatered	No
Stream	Tributary to Bighorn Creek	Percent Backwatered	–
Road	Cabin FSR	Fill Depth (m)	1
Road Tenure	FLNR DRM 5466	Outlet Drop (m)	1.2
Channel Width (m)	2.2	Outlet Pool Depth (m)	0.93
Stream Slope (%)	5	Inlet Drop	No

Conclusion

Location and Stream Data	•	Crossing Characteristics	–
Beaver Activity	No	Slope (%)	5
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	36	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	12
Comments: Cobble substrate and abundant overhanging vegetation. Decent sized stream. 13:24			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Table 5.31: Summary of habitat details for PSCIS crossing 197844.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197844	Upstream	840	3.3	2.7	0.5	8.8	moderate	medium
197844	Downstream	95	3.1	2.1	0.4	7.3	moderate	medium

Figure 5.17: Left: Habitat downstream of crossing 197844. Right: Habitat downstream of crossing 197844.

Figure 5.18: Left: Habitat upstream of PSCIS crossing 197844. Right: Habitat upstream of PSCIS crossing 197844.

References

Allaire, JJ, Yihui Xie, Jonathan McPherson, Javier Luraschi, Kevin Ushey, Aron Atkins, Hadley Wickham, Joe Cheng, Winston Chang, and Richard Iannone. 2022. *Rmarkdown: Dynamic Documents for r.* https://CRAN.R-project.org/package=rmarkdown.

BC Species & Ecosystem Explorer. 2020a. “Oncorhynchus Clarkii Lewisi (Cutthroat Trout, Lewisi Subspecies).” 2020. https://a100.gov.bc.ca/pub/eswp/reports.do?elcode=AFCHA02088.

———. 2020b. “Salvelinus Confluentus (Bull Trout).” 2020. https://a100.gov.bc.ca/pub/eswp/reports.do?elcode=AFCHA05020.

Bell, M. C. 1991. “Fisheries Handbook of Engineering Requirements and Biological Criteria.”https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Bell_1991_Fisheries_handbook_of_engineering_requirements_and.pdf.

Blank, Matt D., Kevin M. Kappenman, Kathryn Plymesser, Katharine Banner, and Joel Cahoon. 2020. “Swimming Performance of Rainbow Trout and Westslope Cutthroat Trout in an Open-Channel Flume.”*Journal of Fish and Wildlife Management* 11 (1): 217–25. https://doi.org/10.3996/052019-JFWM-040.

Bourne, Christina, Dan Kehler, Yolanda Wiersma, and David Cote. 2011. “Barriers to Fish Passage and Barriers to Fish Passage Assessments: The Impact of Assessment Methods and Assumptions on Barrier Identification and Quantification of Watershed Connectivity.”*Aquatic Ecology* 45: 389–403. https://doi.org/10.1007/s10452-011-9362-z.

Boyer, Matthew C, Clint C Muhlfeld, and Fred W Allendorf. 2008. “Rainbow Trout (*Oncorhynchus Mykiss*) Invasion and the Spread of Hybridization with Native Westslope Cutthroat Trout (*Oncorhynchus Clarkii Lewisi*).”*Canadian Journal of Fisheries and Aquatic Sciences* 65 (4): 658–69. https://doi.org/10.1139/f08-001.

Bramblett, Robert, Mason Bryant, Brenda Wright, and Robert White. 2002. “Seasonal Use of Small Tributary and Main-Stem Habitats by Juvenile Steelhead, Coho Salmon, and Dolly Varden in a Southeastern Alaska Drainage Basin.”*Transactions of the American Fisheries Society* 131: 498–506. https://doi.org/10.1577/1548-8659(2002)131<0498:SUOSTA>2.0.CO;2.

Brown, Richard S., and William C. Mackay. 1995. “Spawning Ecology of Cutthroat Trout (*Oncorhynchus Clarki*) in the Ram River, Alberta.”*Canadian Journal of Fisheries and Aquatic Sciences* 52 (5): 983–92. https://doi.org/10.1139/f95-097.

Buchanan, S, Todd Hatfield, K Akaoka, and S Faulkner. 2017. “Dry Creek Fish Habitat Assessment Report.”

Burns, Michael, Donald Kidd, Daniel Principalli, and Peter W Morgan. 2021. “21463789 â€“Teck Line Creek Operations LCO Dry Creek C&S Project Early Works - CONSTRUCTION ENVIRONMENTAL MANAGEMENT PLAN,” 28.

Chapman, Jacqueline, and Todd Hatfield. 2021. “LCO Dry Creek Water Conveyance and Supplementation Project. Fish Habitat Assessment. DRAFT V1.”

Clarkin, K, A Connor, M Furniss, B Gubernick, M Love, K Moynan, and S WilsonMusser. 2005. “National Inventory and Assessment Procedure For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings.”United States Department of Agriculture, Forest Service, National Technology and Development Program. https://www.fs.fed.us/biology/nsaec/fishxing/publications/PDFs/NIAP.pdf.

Cope, R S, and K J Morris. 2001. “Wigwam River Juvenile Bull Trout and Fish Habitat Monitoring Program: 2000 Data Report.”https://digital.library.unt.edu/ark:/67531/metadc718003/m2/1/high_res_d/786475.pdf.

Cope, Scott. 2020. “Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019.”https://www.teck.com/media/UFR_WCT_Monitor_Final_Report_April_9_2020.pdf.
Cope, Scott, C. J Schwarz, and A Prince. 2017. “Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2017.”https://www.teck.com/media/Upper-Fording-River-Westslope-Cutthroat-Trout-Population-Monitoring-Project,-2012-2017-(December-2017).pdf.
Cote, David, P Frampton, M Langdon, and R Collier. 2005. *Fish Passage and Stream Habitat Restoration in Terra Nova National Park Highway Culverts*.
Davidson, A, H Tepper, J Bisset, K Anderson, P. J Tschaplinski, A Chirico, A Waterhouse, et al. 2018. “Aquatic Ecosystems Cumulative Effects Assessment Report.”https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/final_ev_cemf_aquatic_ecosystems_cea_report_24072018.pdf.
Diebel, M. W., M. Fedora, S. Cogswell, and J. R. O’Hanley. 2015. “Effects of Road Crossings on Habitat Connectivity for Stream-Resident Fish: STREAM-RESIDENT FISH HABITAT CONNECTIVITY.”*River Research and Applications* 31 (10): 1251–61. https://doi.org/10.1002/rra.2822.
Elk River Alliance. 2020. “Elk River Westslope Cutthroat Trout (WCT) Research Initiative: 2019 Report.”https://d3n8a8pro7vhmx.cloudfront.net/elkriveralliance/pages/240/attachments/original/1603756805/FRI_Phase_1_2019_Report_%28Report___Apps%29_compressed.pdf?1603756805.
Elk Valley Cumulative Effects Management Framework Working Group. 2018. “Elk Valley Cumulative Effects Assessment and Management Report.”https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/final_elk_valley_ceam_12122018.pdf.
Environment, and Climate Change Canada. 2020. “National Water Data Archive: HYDAT.” Service description. aem. 2020. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html.
Fish Passage Technical Working Group. 2011. “A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation Fo a Stream Crossing.”https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/checklist-for-fish-habitat-confirmation-201112.pdf.
———. 2014. “Fish Passage Strategic Approach: Protocl for Prioritizing Sites for Fish Passage Remediation.”https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fish-passage/strategic20approach20july202014.pdf.
FLNRORD. 2020a. “Digital Road Atlas (DRA) - Master Partially-Attributed Roads - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/digital-road-atlas-dra-master-partially-attributed-roads.
———. 2020b. “Digital Road Atlas (DRA) - Master Partially-Attributed Roads - Data Catalogue.” Published by Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2020. https://catalogue.data.gov.bc.ca/dataset/digital-road-atlas-dra-master-partially-attributed-roads.
———. 2020c. “Forest Tenure Road Section Lines - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-section-lines.
———. 2020d. “Forest Tenure Road Section Lines - Data Catalogue.” Published by Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). 2020. https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-section-lines.
———. 2021. “Freshwater Atlas Stream Network - Data Catalogue.” Published by Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2021. https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-stream-network.

Foster, S, and J Bachusky. 2005. “Ghost Towns of British Columbia - Coal Creek.” 2005. http://www.ghosttownpix.com/bc/coalcreek.html.
Grainger, Karen L. 2011. “2011 Fish Passage Culvert Assessments Within the Rocky Mountain Resource District.”
Hasek, Dave, and Katharina Batchelar. 2021. “2020 Line Creek Operations Local Aquatic Effects Monitoring Program (LAEMP) Report for Dry Creek.” 2021. https://www.teck.com/media/09_LCO_Dry_Creek_LAEMP_2020_Report_w_Cover_Page.pdf.
Hughes, Chad, and Beth Millions. 2020. “Coal Creek Cottonwood Project Pilot - Restoration Plan.”Elk River Alliance. https://d3n8a8pro7vhmx.cloudfront.net/elkriveralliance/pages/1334/attachments/original/1604619045/Restoration_Plan_Coal_Creek_Trial_Oct_2020.pdf?1604619045.
Irvine, A. 2016. “Columbia Basin Fish Passage Data Analysis.”http://a100.gov.bc.ca/pub/acat/documents/r50900/F-F16-24-FinalReport-Masse-FishPassage_1475094712285_5091517509.pdf.
———. 2021. “Upper Elk River and Flathead River Fish Passage Restoration Planning.”https://newgraphenvironment.github.io/fish_passage_elk_2020_reporting_cwf/.
Kemp, P. S., and J. R. O’Hanley. 2010. “Procedures for Evaluating and Prioritising the Removal of Fish Passage Barriers: A Synthesis: EVALUATION OF FISH PASSAGE BARRIERS.”*Fisheries Management and Ecology*, no–. https://doi.org/10.1111/j.1365-2400.2010.00751.x.
“Ktunaxa Nation.” 2020. 2020. https://www.ktunaxa.org/.
Lamson, Heather. 2020. “Evaluation of Current Westslope Cutthroat Trout Hybridization Levels in the Upper Kootenay Drainage.”http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=58888.
Mahlum, Shad, David Cote, Yolanda Wiersma, Dan Kehler, and K. Clarke. 2014. “Evaluating the Barrier Assessment Technique Derived from FishXing Software and the Upstream Movement of Brook Trout Through Road Culverts.”*Transactions of the American Fisheries Society* 143. https://doi.org/10.1080/00028487.2013.825641.
“Map Wigwam Flats Mt. Boadwood Sprotsmans Ridge.” 2021. https://www2.gov.bc.ca/assets/gov/sports-recreation-arts-and-culture/outdoor-recreation/motor-vehicle-prohibitions/region-4/motor-vehicle-closed-areas/mvpr_1_32_wigwam_flats_mt_broadwood_sportsman_ridge.pdf.
Masse Environmental Consultants Ltd. 2015. “Fish Habitat Confirmation Assessments East Kootenay Area Project Pd15tfe010.”https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=49504.
Ministry of Forests, Lands. 2020. “Elk Valley Cumulative Effects Management Framework - Province of British Columbia.”Province of British Columbia. 2020. https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/cumulative-effects-framework/regional-assessments/kootenay-boundary/elk-valley-cemf.
MoE. 2011a. “Field Assessment for Determining Fish Passage Status of Closed Bottom Structures.”BC Ministry of Environment (MoE). https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/field-assessment-for-determining-fish-passage-status-of-cbs.pdf.
———. 2011b. “Field Assessment for Determining Fish Passage Status of Closed Bottom Structures.”BC Ministry of Environment (MoE). https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/field-assessment-for-determining-fish-passage-status-of-cbs.pdf.
———. 2020a. “Known BC Fish Observations and BC Fish Distributions.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/known-bc-fish-observations-and-bc-fish-distributions.

———. 2020b. “Known BC Fish Observations and BC Fish Distributions.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/known-bc-fish-observations-and-bc-fish-distributions.
———. 2020c. “Provincial Obstacles to Fish Passage - Data Catalogue.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/provincial-obstacles-to-fish-passage.
———. 2020d. “Provincial Obstacles to Fish Passage - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/provincial-obstacles-to-fish-passage.
———. 2020e. “Stream Inventory Sample Sites.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/stream-inventory-sample-sites.
Norris, Simon. 2020. *Bcfishobs*. Hillcrest Geographics. https://github.com/smnorris/bcfishpass.
———. (2019) 2021. *Smnorris/Fwapg*. https://github.com/smnorris/fwapg.
———. (2016) 2021. *Smnorris/Bcdata*. https://github.com/smnorris/bcdata.
———. (2018) 2021. *Smnorris/Bcfishobs*. https://github.com/smnorris/bcfishobs.
———. (2020) 2021. *Smnorris/Bcfishpass*. https://github.com/smnorris/bcfishpass.
Northwest Hydraulic Consultants. 2014. “Coal Creek Floodplain Mapping,” 54.
QGIS Development Team. 2009. *QGIS Geographic Information System*. Open Source Geospatial Foundation. http://qgis.osgeo.org.
R Core Team. 2020. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.
Schmetterling, David. 2001. “Seasonal Movements of Fluvial Westslope Cutthroat Trout in the Blackfoot River Drainage, Montana.”*North American Journal of Fisheries Management* 21: 507–20. https://doi.org/10.1577/1548-8675(2001)021<0507:SMOFWC>2.0.CO;2.
Schweigert, J. F, John Robert Post, Canada, Environment, limate Change Canada, Canadian Wildlife Service, and Committee on the Status of Endangered Wildlife in Canada. 2017. *COSEWIC Assessment and Status Report on the Westslope Cutthroat Trout, Oncorhynchus Clarkii Lewisi, Saskatchewan-Nelson River Populations, Pacific Populations, in Canada.*Ottawa: Environment and Climate Change Canada. http://publications.gc.ca/collections/collection_2017/eccc/CW69-14-506-2017-eng.pdf.
Shaw, Edward A., Eckart Lange, James D. Shucksmith, and David N. Lerner. 2016. “Importance of Partial Barriers and Temporal Variation in Flow When Modelling Connectivity in Fragmented River Systems.”*Ecological Engineering* 91: 515–28. https://doi.org/10.1016/j.ecoleng.2016.01.030.
Slaney, P. A, Daiva O Zaldokas, and Watershed Restoration Program (B.C.). 1997. *Fish Habitat Rehabilitation Procedures*. Vancouver, B.C.: Watershed Restoration Program. https://www.for.gov.bc.ca/hfd/library/FFIP/Slaney_PA1997_A.pdf.
Strong, J. S., and Heidt K. D. 2015. “McNeil Substrate Sampling Program 2015 Summary Report.”https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=49787.
Swales, Stephen, and C. Levings. 1989. “Role of Off-Channel Ponds in the Life Cycle of Coho Salmon (Oncorhynchus Kisutch) and Other Juvenile Salmonids in the Coldwater River, British Columbia.”*Canadian Journal of Fisheries and Aquatic Sciences - CAN J FISHERIES AQUAT SCI* 46: 232–42. https://doi.org/10.1139/f89-032.
Teck Coal Limited. 2020. “Tributary Management Plan.”
Teck Coal Limited Line Creek Operations. 2009. “Line Creek Operations Phase LI Project Description.”http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs2013/529460/1254268211692_e13e225d8619af051b58f58b9c73dff23c2f53e6fa0f9f37bf2026f8dc4dc647.pdf.

Teck Resources Limited. 2014. “Elk Valley Water Quality Plan.”https://www.teck.com/media/2015-Water-elk_valley_water_quality_plan_T3.2.3.2.pdf.
Thompson, Richard. 2013. “Assessing Fish Passage at Culverts â€“ the Method, Its Metrics and Preliminary Findings from over 4,000 Assessments.”https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fish-passage/assessing_fish_passage_at_culverts.pdf.
Thorley, J. L., A. K. Kortello, and M. Robinson. 2021. “Upper Fording River Westslope Cutthroat Trout Population Monitoring 2020.” 2021. https://www.teck.com/media/14_UFR_WCT_Population_Monitoring_2020_Report_w_Cover_Page.pdf.
Tibballs, Scott. 2021. “PHOTOS: Aerial Perspective Captures Changes to Coal Creek Near Fernie.”Cranbrook Daily Townsman. 2021. https://www.cranbrooktownsman.com/news/photos-aerial-perspective-captures-changes-to-coal-creek-near-fernie/.
VAST Resource Solutions Inc. 2013. “2012 Fish Passage Assessments in BCTS Kootenay Business Area (Pd13tfe006).”http://a100.gov.bc.ca/appsdata/acat/documents/r43047/PD13TFE006_VAST_FinalReport_1405379598103_5374008940.pdf.
Washington Department of Fish & Wildlife. 2009. “Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual.”Washington Department of Fish and Wildlife. Olympia, Washington.https://wdfw.wa.gov/sites/default/files/publications/00061/wdfw00061.pdf.
Xie, Yihui. 2016. *Bookdown: Authoring Books and Technical Documents with R Markdown*. Boca Raton, Florida: Chapman; Hall/CRC. https://bookdown.org/yihui/bookdown.

Session Info

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R version 4.1.3 (2022-03-10)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows 10 x64 (build 22000), RStudio 1.4.1106

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  LC_TIME=English_Canada.1252

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bit64_4.0.5              bitops_1.0-7             blob_1.2.2
  bookdown_0.24            boot_1.3.28              brew_1.0-7
broom_0.7.12             bslib_0.3.1              cachem_1.0.6
  callr_3.7.0              cellranger_1.1.0         chk_0.8.0.9000
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crosstalk_1.2.0          crul_1.2.0               curl_4.3.2
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