SOCIETY FOR ECOSYSTEM RESTORATION
IN NORTHERN BRITISH COLUMBIA

Fish Passage Reporting Template

Prepared for
Habitat Conservation Trust Foundation - CAT23-6-288
BC Fish Passage Remediation Program
Ministry of Transportation and Infrastructure
Fish and Wildlife Compensation Program - Peace Region

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New Graph Environment Ltd.

|on behalf of | |Society for Ecosystem Restoration in Northern British Columbia

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new graph environment

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```
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Acknowledgement

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

1 Introduction

Since 2020, the Society for Ecosystem Restoration Northern British Columbia (SERNbc) has been actively involved in planning, coordinating, and conducting fish passage restoration efforts within the Bulkley River and Morice River watershed groups, which are sub-basins of the Skeena River watershed. In 2022, the study area was expanded to include the Zymoetz River watershed group and the Kispiox River watershed group, followed by an extension in 2023 to encompass sections of the Kitsumkalum River watershed group, particularly where Highway 16 intersects the watershed.

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

Although the main purpose of this report is to document 2023 field work data and results, it also builds on reporting from field activities conducted from 2020 to 2022. In addition to the numerous assessments at sites undocumented in past years of the project, field activities were also conducted at 10 sites where habitat confirmations were previously documented as per the report links below. The reports for these sites were edited and updated with 2023 data.

- Bulkley River and Morice River Watershed Groups Fish Passage Restoration Planning (2020)
- Bulkley River and Morice River Watershed Groups Fish Passage Restoration Planning 2021
- Bulkley River Watershed Fish Passage Restoration Planning 2022
- Skeena Watershed Fish Passage Restoration Planning 2022

Please note that at the time of reporting this document can be considered a living document. Version numbers are logged for each release with modifications, enhancements, and other changes tracked in the Changelog (page 51) with issues and proposed/planned enhancements tracked here.

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

Although remediation and replacement of stream crossing structures can have benefits to local fish populations, the costs of remedial works can be significant and the impacts of the work often complex to evaluate and quantify. Additionally, allocation of ecosystem restoration funding towards infrastructure upgrades on transportation right of ways are not always considered ethical under all circumstances from all perspectives. When funds are finite and invested groups are engaged in fund raising, cost benefits and the ethics of crossing replacements should be explored collaboratively alongside the cost benefits and ethics of alternative investment activities including transportation corridor relocation/deactivation, land procurement/covenant, cattle exclusion, riparian/floodplain restoration, habitat complexing, water conservation, commercial/recreational fishing management, salt water interventions and research.

2 Background

The Skeena study area includes the Bulkley River, Zymoetz River, Kispiox River, Morice River and Kitsumkalum River watershed groups (Figure 2.1) and is within the traditional territories of the Wet’suwet’en, Gitxsan and Tsimshian.

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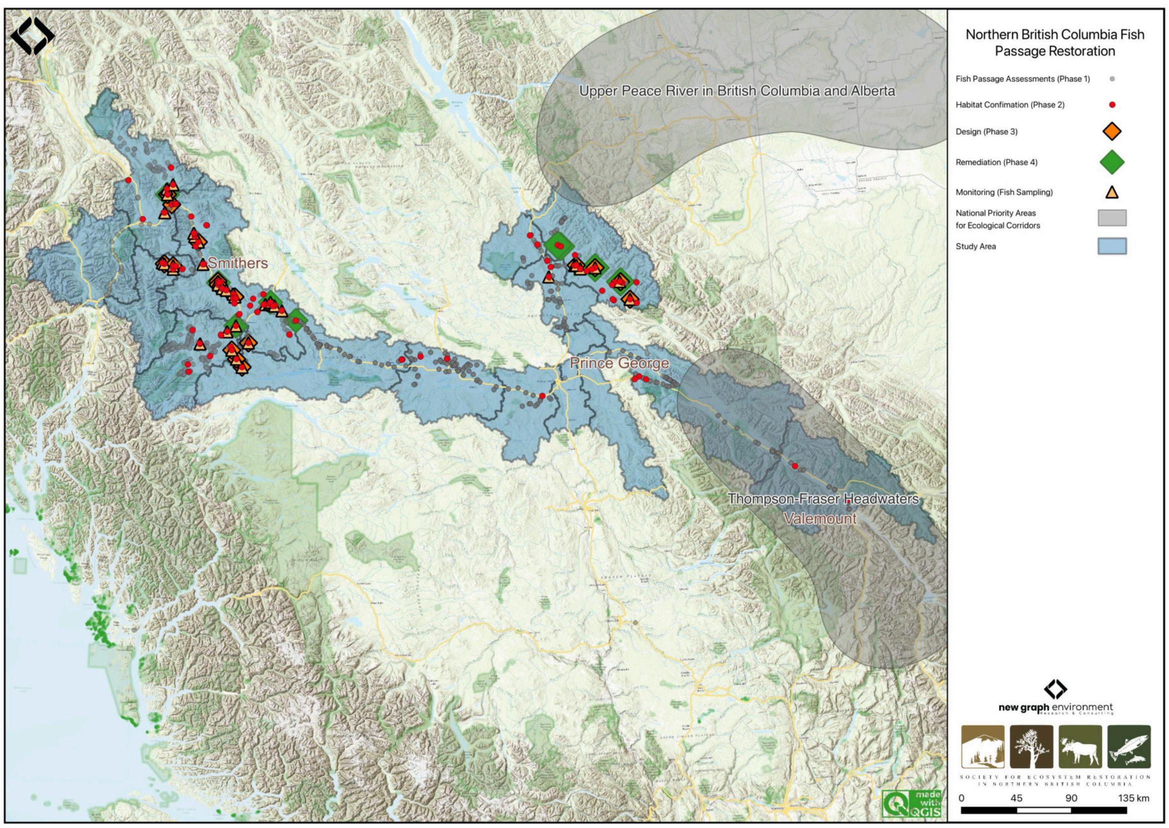

Figure 2.1: Overview map of Study Areas in the Skeena, Fraser and Mackenzie (FWCP Peace) watersheds

2.1 Wet’suwet’en

Wet’suwet’en hereditary territory covers an area of 22,000km^2 including the Bulkley River and Morice River watersheds and portions of the Nechako River watershed. The Wet’suwet’en people are a matrilineal society organized into the Gilseyhu (Big Frog), Laksilyu (Small Frog), Tsayu (Beaver clan), Gitdumden (Wolf/Bear) and Laksamshu (Fireweed) clans. Within each of the clans there are are a number of kin-based groups known as Yikhs or House groups. The Yikh is a partnership between the people and the territory. Thirteen Yikhs with Hereditary Chiefs manage a total of 38 distinct territories upon which they have jurisdiction. Within a clan, the head Chief is entrusted with the stewardship of the House territory to ensure the Land is managed in a sustainable manner. Inuk Nu’at’en (Wet’suwet’en law) governing the harvesting of fish within their lands are based on values founded on thousands of years of social, subsistence and environmental dynamics. The Yintahk (Land) is the centre of life as well as culture and it’s management is intended to provide security for sustaining salmon, wildlife, and natural foods to ensure the health and well-being of the Wet’suwet’en (Office of the Wet’suwet’en 2013; “Office of the Wet’suwet’en” 2021; FLNRORD 2017).

2.2 Gitxsan

Gitxsan means “People of the River Mist”. The Gitxsan Laxyip (traditional territories) covers an area of 33,000km^2 within the Skeena River and Nass River watersheds. The Laxyip is governed by 60 Simgiigyet (Hereditary Chiefs), within the traditional hereditary system made up of Wilps (House groups). Anaat are fisheries tenures found throughout the Laxyip. Traditional governance within a matrilineal society operates under the principles of Ayookw (Gitxsan law) (“Gitxsan Huwilp Government” n.d.). Many band members live in Hazelton, Kispiox and Glen Vowell (the Eastern Gitxsan) as well as within Kitwanga, Kitwankool and Kitsegukla (the Western Gitxsan) (Powell, Jensen, and Pedersen 2018).

```
# Salmon is considered the source of life and always treated with high
        regard.  It was brought by the Raven who also taught people
        how to fish and hunt.

 # The original Gitxsan economy depended heavily on the trade of fish
        and other natural resources with neighbouring First Nations
        along "grease trails," which are routes named so because they
        carried the refined oil of the oolichan, a fish that
        resembles a smelt that is common in some areas of British
        Columbia. They are also known for their range of traditional
        arts
```

2.3 Tsimshian

The Kitsumkalum community, part of the Tsimshian Nation, maintains a rich cultural heritage rooted in ancient traditions and values. Their society, governed by Tsimshian Law (ayaawx), emphasizes strong connections through marriages, adoptions, and resource sharing with other Tsimshian tribes. The community upholds its cultural and spiritual practices, including fishing, harvesting, and land stewardship, despite the impacts of colonization (Kitsumkalum Band n.d.).

Kitsumkalum's social structure is based on matrilineal kinship, with significant emphasis on family ties through the mother's lineage. Their cultural identity is expressed through crest groups (pteex), lineage houses (waap), and the importance of landed property (laxyuup), which ties them to their ancestral territories. The community combines traditional governance with modern administrative functions, reflecting their resilience and commitment to preserving their heritage (Kitsumkalum Band n.d.).

The Kitsumkalum River salmon populations have been an important part of their culture and economy (A. Gottesfeld and Rabnett 2007).

2.4 Bulkley River

The Bukley River is an 8th order stream that drains an area of 7,762km^2 in a generally northerly direction from Bulkley Lake on the Nechako Plateau to its confluence with the Skeena River at Hazleton. It has a mean annual discharge of 138.7 m^3/s at station 08EE004 located near Quick (~27km south of Telkwa) and 19 m^3/s at station 08EE003 located upstream near Houston. Flow patterns at Quick are heavily influenced by inflows from the Morice River (enters just downstream of Houston) resulting in flow patterns typical of high elevation watersheds which receive large amounts of precipitation as snow leading to peak levels of discharge during snowmelt, typically from May to July (Figure 2.2). The hydrograph peaks faster and generally earlier (May - June) for the Bulkley River upstream of Houston where the topography is of lower lower elevation (Figure 2.2).

Changes to the climate systems are causing impacts to natural and human systems on all continents with alterations to hydrological systems caused by changing precipitation or melting snow and ice increasing the frequency and magnitude of extreme events such as floods and droughts (Calvin et al. 2023; ECCC 2016). These changes are resulting in modifications to the quantity and quality of water resources throughout British Columbia and are likely to compound issues related to drought and flooding in the Bulkley River watershed where numerous water licenses are held with a potential over-allocation of flows identified during low flow periods (ILMB 2007).

The valley bottom has seen extensive settlement over the past hundred years with major population centers including the Village of Hazelton, the Town of Smithers, the Village of Telkwa and the District Municipality of Houston. As a major access corridor to northwestern British Columbia, Highway 16 and the Canadian National Railway are major linear developments that run along the Bulkley River within and adjacent to the floodplain with numerous crossing structures impeding fish access into and potentially out from important fish habitats. Additionally, as the valley bottom contains some of the most productive land in the area, there has been extensive conversion of riparian ecosystems to hayfields and pastures leading to alterations in flow regimes, increases in water temperatures, reduced streambank stability, loss of overstream cover and channelization (ILMB 2007; Wilson and Rabnett 2007).

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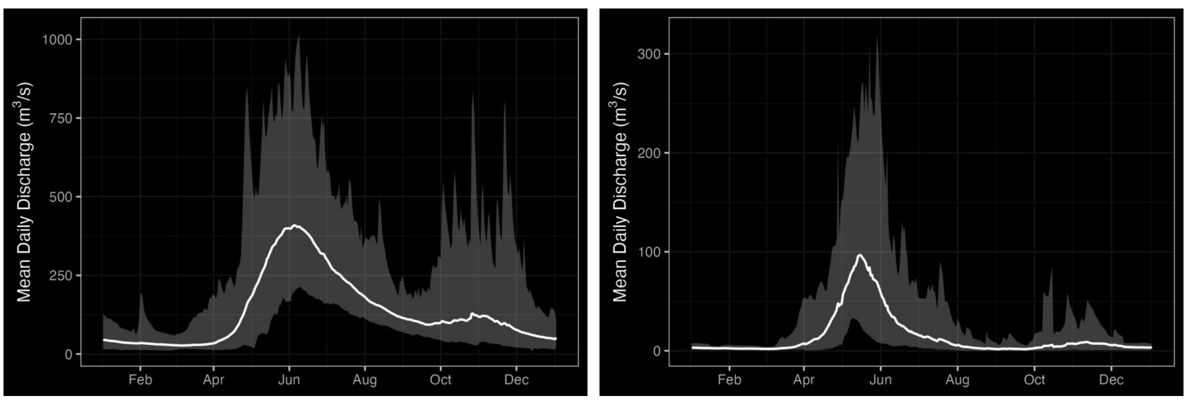

Figure 2.2: Hydrograph for Bulkley River at Quick (Station #08EE004) and near Houston (Station #08EE003).

2.5 Morice River

The Morice River watershed drains 4,379km^2 of Coast Mountains and Interior Plateau in a generally south-eastern direction. The Morice River is an 8th order stream that flows approximatley 80km from Morice Lake to the confluence with the upper Bulkley River just north of Houston. Major tributaries include the Nanika River, the Atna River, Gosnell Creek and the Thautil River. There area numerous large lakes situated on the south side of the watershed including Morice Lake, McBride Lake, Stepp Lake, Nanika Lake, Kid Price Lake, Owen Lake and others. There is one active hydrometric station on the mainstem of the Morice River near the outlet of Morice Lake and one historic station that was located at the mouth of the river near Houston that gathered data in 1971 only (Canada 2024). An estimate of mean annual discharge for the one year of data available for the Morice near it's confluence with the Bulkley River is 113 m^3/s. Mean annual discharge is estimated at 75 m^3/s at station 08ED002 located near the outlet of Morice Lake. Flow patterns are typical of high elevation watersheds influenced by coastal weather patterns which receive large amounts of winter precipitation as snow in the winter and large precipitation events in the fall. This leads to peak levels of discharge during snowmelt, typically from May to July with isolated high flows related to rain and rain on snow events common in the fall (Figure 2.3).

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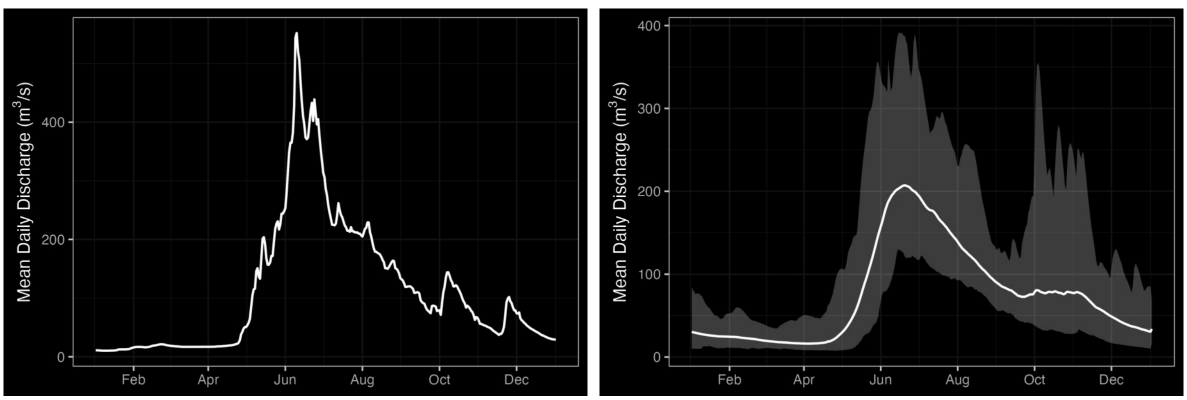

Figure 2.3: Left: Hydrograph for Morice River near Houston (Station #08ED003 - 1971 data only). Right: Hydrograph for Morice River near outlet of Morice Lake (Station #08ED002).

2.6 Zymoetz River

The Zymoetz River (known locally as the Copper River) watershed is an eighth order stream that drains an area of 3026km^2 in a generally westerly direction. It is considered a major tributary of the Skeena River, as it contributes approximately 10% of the flow. The headwater lakes are located approximately 20km southwest of Smithers, and they include Aldrich, Dennis and McDonell Lakes. The upper and lower portions of the watershed are accessed via logging roads off of Highway 16 from Smithers and Terrace, respectively. Access to the middle watershed is difficult due to road wash out. The Zymoetz River flows roughly 120km, starting just west of Hudson Bay mountain near Smithers and ending at the confluence of the Skeena River, approximately 8km north-east of Terrace. Elevations in the watershed range from 120m at the confluence, to 2740m in the Howson Range. The Duthie mine operated on the south-west slope of Hudson Bay Mountain during the 1930’s and 1950’s, and reports have documented contaminated streams and lakes in the surrounding area (Allen Gottesfeld, Rabnett, and Hall 2002). The lower end of the Zymoetz watershed has seen a significant reduction in riparian habitat due to fires, forest development practices, pipe line and road construction (Allen Gottesfeld, Rabnett, and Hall 2002). Snowmelt plays a big role in controlling the stream hydrology, with a mean annual discharge estimated at 106 m^3/s at station 08EF005 located near Smithers. Peak discharge happens in May to early June, which is typical of a high elevation watershed like this (Figure 2.4).

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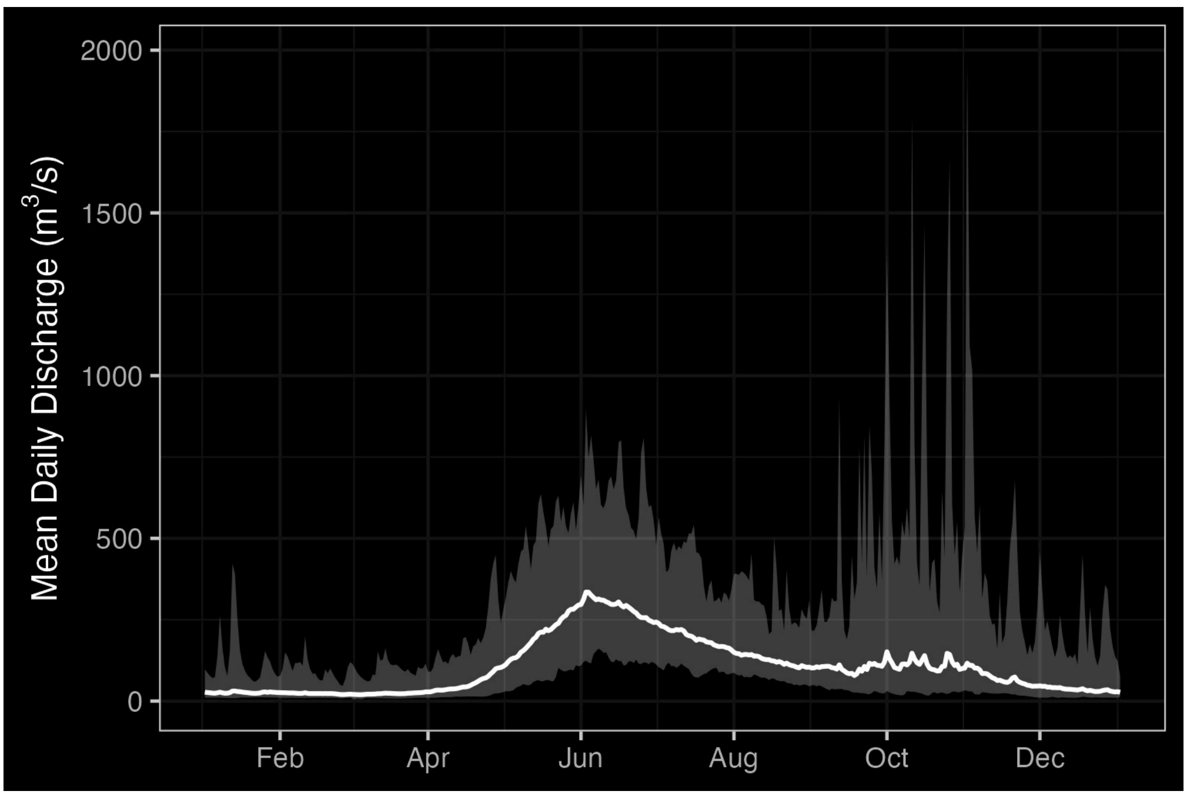

Figure 2.4: Zymoetz River Above O.k. Creek (Station #08EF005 - Lat 54.49363 Lon -128.32466). Available mean daily discharge data from 1963 to 2021.

2.6.1 Kispiox River

The Kispiox River watershed is a seventh order stream that drains an area of 2100km^2 in a south east direction. It is a large tributary of the Skeena River, contributing approximately 9% of its flow. It flows 140km to the confluence of the Skeena River, near Kispiox Village. Elevations in the watershed range from 200m at the mouth to as high as 2090m on Kispiox Mountain. The mainstream of the Kispiox is fed mainly by glacier melt and high elevation snow melt. Swan and Stephens Lakes (located in the upper watershed) are important sockeye systems. Swan Lake drains via Club Lake into Stephens Lake which in turn flows via Stephens Creek into the mainstem of the Kispiox River. Some of the biggest threats to aquatic ecosystems in the Kispiox valley are reported as erosion, obstructions, sedimentation, and altered water yield. The upper third of the Kispiox watershed (upstream of the Nangeese River) is well protected from development by the Swan Lake Kispiox River Provincial Park and because it contains few roads with little forestry development (Allen Gottesfeld, Rabnett, and Hall 2002). The Kispiox River has a mean annual discharge estimated at 45 m^3/s at station 08EB004 located near Hazelton. Peak discharge happens in May and June as a result of the spring snowmelt (Figure 2.5).

```
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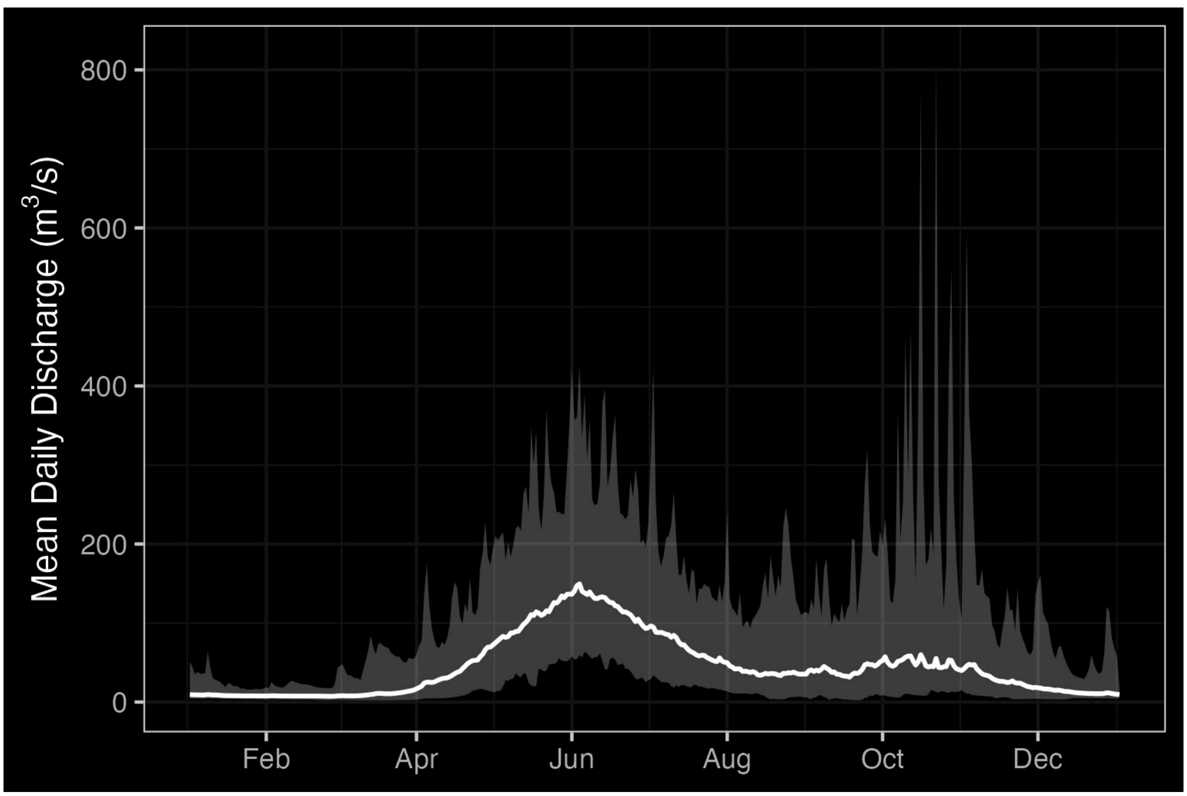

Figure 2.5: Kispiox River Near Hazelton (Station #08EB004 - Lat 55.43385 Lon -127.71616). Available mean daily discharge data from 1963 to 2022.

2.7 Kitsumkalum River

The Kitsumkalum River is a sixth order stream that flows east from the Coast Mountains to Kitsumkalum lake then south to Terrace where it joins the Skeena River, draining an area of 2289km^2. Major tributaries to the Kitsumkalum River include the Cedar River, Nelson River, Mayo Creek, Goat Creek, Lean-To Creek and Deep Creek (McElhanney 2022). Peak flows occur in May-June from snow melt with subsequent peaks the fall from rain events (McElhanney 2022). There is one hydrometric station below Kitsumkalum lake which has been active since 2018, and has a mean annual discharge of 123 m^3/s (Figure 2.6). From 1929-1954, there was a hydrometric station near Terrace, which estimated the mean annual discharge to be 138m^3/s.

The Kitsumkalum River watershed has been highly impacted by logging. Many of the tributaries to the Kitsumkalum River have altered channel morphology, increased bedload movement, bank failures, sediment loading, and debris accumulation (A. Gottesfeld and Rabnett 2007).

There has been a significant amount of work done to enhance salmon populations within the watershed. The SkeenaWild Conservation Trust is conducting riparian restoration surveys on several tributaries to the Kitsumkalum River, including Willow Creek, Spring Creek, Lean-To Creek, and Deep Creek (Healthy Watersheds Initiative 2021). The Deep Creek Hatchery, operated by the Terrace Salmonid Enhancement Society, has been supporting Kitsumkalum River chinook populations since 1984 (A. Gottesfeld and Rabnett 2007). Additionally, there is a small groundwater facility for the incubation and rearing coho and chum, run by the Kitsumkalum First Nation (A. Gottesfeld and Rabnett 2007). In 2000 The Clear Creek Eastern Side Channel was constructed to enhance juvenile rearing habitat and adult spawning habitat for coho salmon on Clear Creek, a tributary to the Kitsumkalum River, however the site has not been maintained and beaver activity has obstructed fish accessibility to much of the channel (Elmer 2021).

```
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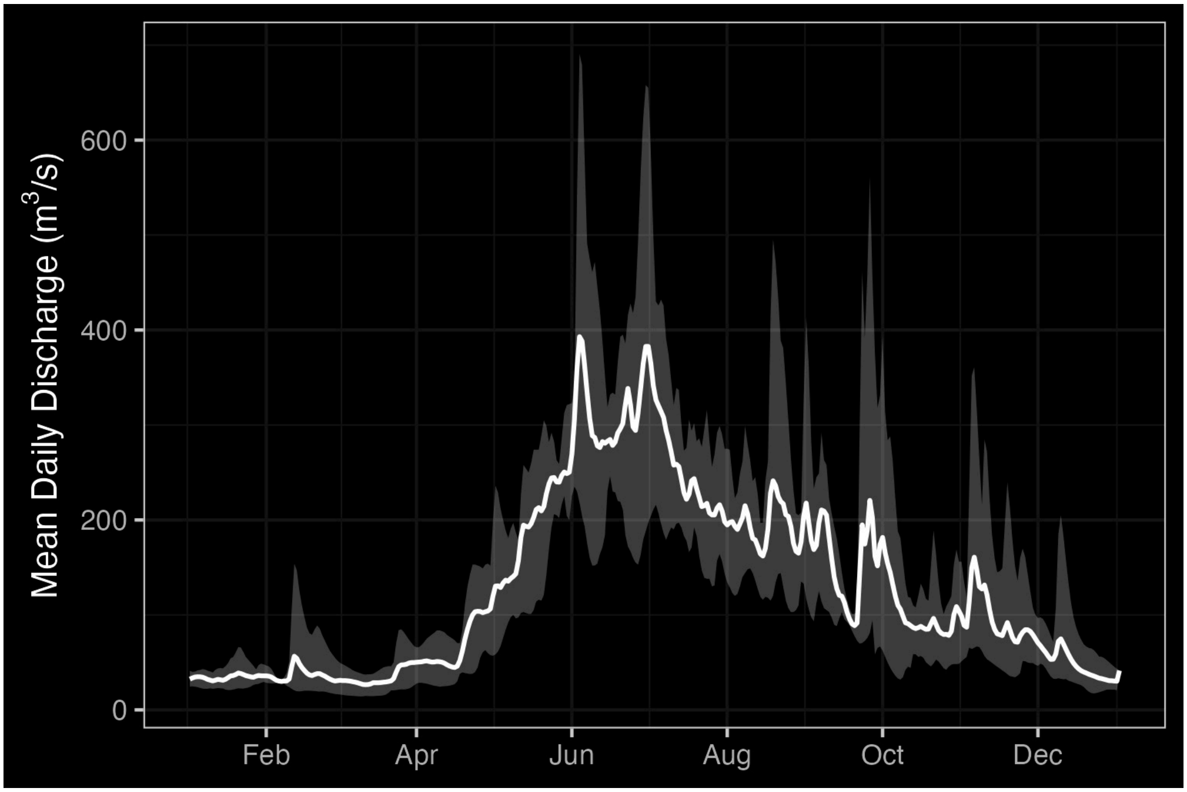

Figure 2.6: Kitsumkalum River Below Alice Creek (Station #08EG019 - Lat 54.6793 Lon -128.74396). Available mean daily discharge data from 2018 to 2022.

2.8 Fisheries

In 2004, IBM Business Consulting Services (2006) estimated the value of Skeena Fisheries at an annual average of $110 million dollars. The Bulkley-Morice watershed is an integral part of the salmon production in the Skeena drainage and supports an internationally renown steelhead, chinook and coho sport fishery (Tamblyn 2005).

2.8.1 Bulkley River

Traditionally, the salmon stocks passing through and spawning in the greater Bulkley River were the principal food source for the Gitxsan and Wet'suwet'en people living there (Wilson and Rabnett 2007). Anadromous lamprey passing through and spawning in the upper Bulkley River were traditionally also an important food source for the Wet'suwet'en (A. Gottesfeld and Rabnett (2007); pers comm. Mike Ridsdale, Environmental Assessment Coordinator, Office of the Wet'suwet'en). A. Gottesfeld and Rabnett (2007) report sourceing information from Department of Fisheries and Oceans (1991) that principal spawning areas for chinook in the Neexdzii Kwah include the mainstem above and below Buck and McQuarrie Creeks, between Cesford and Watson Creeks, and the reaches upstream and downstream of Bulkley Falls.

Renowned as a world class recreational steelhead and coho fishery, the greater Bulkley River receives some of the heaviest angling pressure in the province. In response to longstanding angler concerns with respect to overcrowding, quality of experience and conflict amongst anglers, an Angling Management Plan was drafted for the river following the initiation of the Skeena Quality Waters Strategy process in 2006 and an extensive multi-year consultation process. The plan introduces a number of regulatory measures with the intent to provide Canadian resident anglers with quality steelhead fishing opportunities. Regulatory measures introduced with the Angling Management Plan include prohibited angling for non-guided non-resident aliens on Saturdays and Sundays, Sept 1 - Oct 31 within the Bulkley River, angling prohibited for non-guided non-resident aliens on Saturdays and Sundays, all year within the Suskwa River and angling prohibited for non-guided non-resident aliens Sept 1 - Oct 31 in the Telkwa River. The Neexdzii Kwah is considered Class II water and there is no fshing permitted upstream of the Morice/Bulkley River Confluence (FLNRO 2013a, 2013b; FLNRORD 2019).

2.8.1.1 Upper Bulkley Falls

A detailed field assessment and write up regarding the upper Bulkley falls was conducted as part of fish passage restoration in the watershed - is presented in Irvine (2021) with a condensed summary here. The site was assessed on October 28, 2021 by Nallas Nikal, B.i.T, and Chad Lewis, Environmental Technician. The top of the falls is located at 11U.678269.6038266 at an elevation of 697m approximatley 11.3km downstream of Bulkley Lake and upstream of Ailport Creek. Within the Bulkley River immediately below the 12 - 15m high bedrock falls, the channel width was 17.4m and the wetted width was 15.6m. Two channels comprised the falls. The primary channel was 20m long, had a channel/wetted width of 8.5m, a 16% grade and water depths ranging from 35 - 63cm. The secondary channel was 25m long, with channel/wetted widths of 7.5m, a grade of 12% and water depths ranging from 3 - 13cm (Irvine 2021).

Dyson (1949) and Stokes (1956) report substantial use of habitat above Bulkley Falls by steelhead, chinook, coho and sockeye utilization in the past (pre-1950) based on spawning reports. Both authors concluded that the Bulkley Falls pose a partial obstruction to migrating fish based on flow levels. Chinook, which migrate early in the summer when water levels are high, have been noted as able to ascend the falls in normal to high water years and in high water years it was thought that coho and steelhead could ascend. A. Gottesfeld and Rabnett (2007) report that the falls are almost completely impassable to all salmon during low water flows. Stokes (1956) reports that there was high value spawning habitat located within the first 3km of the Neexdzii Kwah from the outlet of Bulkley Lake.

Wilson and Rabnett (2007) reported that approximately 11.3 km downstream of the Bulkley Lake outlet and just upstream of Watson Creek, the upper Bulkley falls is an approximately 4m high narrow rock sill that crosses the Neexdzii Kwah, producing a steep cascade section. This obstacle to fish passage is recorded as an almost complete barrier to fish passage for salmon during low water flows. Wilson and Rabnett (2007) also reported that coho have not been observed beyond the falls since 1972.

```
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2.8.2 Morice River

Detailed reviews of Morice River watershed fisheries can be found in Bustard and Schell (2002), Allen Gottesfeld, Rabnett, and Hall (2002), Schell (2003), A. Gottesfeld and Rabnett (2007), and ILMB (2007) with a comprehensive review of water quality by Oliver (2018) Overall, the Morice watershed contains high fisheries values as a major producer of chinook, pink, sockeye, coho and steelhead.

2.8.3 Zymoetz River

Within the Zymoetz Watershed, there are many areas with high fishery values. Steelhead are the most extensively documented fish species in the Zymoetz River watershed. Adults enter the river from July to November and then go on to spawn the following year in late spring to early summer. The Zymoetz River is a relatively steep system. Two canyons are located 6.4 and 19.6 kilometers upstream of the Skeena River confluence. These canyons make access to the Zymoetz difficult for pink and chum salmon (Allen Gottesfeld, Rabnett, and Hall 2002). The Zymoetz River is renowned for its aggressive steelhead that have been known to take flies or lures. There is a 50km stretch upstream of Limonite Creek that's very remote and offers high quality fishing opportunities for anglers (FLNRORD 2013).

Traditional First Nations use of the upper Zymoetz River watershed by the Gitxsan and Wet'suwet'en people differed between community sites, residences, and fish houses, and was large and diverse. From the upper to lower Zymoetz River and to the Skeena River, a significant ancient grease trail connected, with a branch track forking through Limonite Creek and flowing down the Telkwa River. The fishery used a weir at the mouth of McDonell Lake and spears at Six Mile Flats, near Dennis Lake. There is no information on native fisheries on the lower Zymoetz River. The Zymoetz is considered to be one of the top ten steelhead rivers in BC (Allen Gottesfeld, Rabnett, and Hall 2002).

2.8.4 Kispiox River

Kispiox River salmon are a important food source and cultural symbol for the Gitxsan people with sockeye and coho historically the two most significant species. Gitangwalk and Lax Didax, two significant villages that were both abandoned in the early 1900s, were situated on the Kispiox in such a way as to block the sockeye and coho salmon's upstream migration to the Upper Kispiox River spawning grounds providing opportunities to gather and preserve a significant amount of high-quality food over relatively short time periods (Allen Gottesfeld, Rabnett, and Hall 2002). The 100 km of mainstem and 300km of tributary streams in the Kispiox River Watershed are considering high value fish habitat supporting migration, spawning and rearing for many fish species. The Kispiox fisheries supports both recreational and commercial fishing while also enhancing the ecology, nutrient regime, and structural diversity of the drainage. Since 1992, sockeye and coho escapements from the Kispiox Watershed have been documented by the Gitxsan Watershed Authorities as they creates strong cultural, economic, and symbolic ties for the local communities (Allen Gottesfeld, Rabnett, and Hall 2002).

2.8.5 Kitsumkalum River

The Kitsumkalum River is an important waterway for all species of salmon. It is one of the three main chinook producing rivers in the Skeena watershed and supports all five species of pacific salmon, steelhead, and other resident trout and char species (McElhanney 2022). Most notably, the Kitsumkalum River has consistently produced the largest-bodied chinook in the Skeena Watershed, as well as on most of the Pacific coast (A. Gottesfeld and Rabnett 2007). The watershed supports strong recreational coho, steelhead, and chinook fishing. Kitsumkalum salmon also play an important role in the culture and economy of the Kitsumkalum Band (A. Gottesfeld and Rabnett 2007).

2.8.6 Salmon Stock Assessment Data

Fisheries and Oceans Canada stock assessment data was accessed via the NuSEDS-New Salmon Escapement Database System through the Open Government Portal. A brief memo on the data extraction process is available here.

2.8.7 Fish Species

Fish species recorded in the Morice, Bulkley, Zymoetz, Kispiox, and Kitsumkalum Rivers watershed groups are detailed in Table 2.1 (MoE 2019a). Coastal cutthrout trout and bull trout are considered of special concern (blue-listed) provincially. Summaries of some of the Skeena fish species life history, biology, stock status, and traditional use are documented in Schell (2003), Wilson and Rabnett (2007), Allen Gottesfeld, Rabnett, and Hall (2002) and Office of the Wet'suwet'en (2013). Wilson and Rabnett (2007) discuss chinook, pink, sockeye, coho, steelhead and indigenous freshwater Bulkley River fish stocks within the context of key lower and upper Bulkley River habitats such as the Suskwa River, Station Creek, Harold Price Creek, Telkwa River and Buck Creek. Key areas within the upper Bulkley River watershed with high fishery values, documented in Schell (2003), are the upper Bulkley mainstem, Buck Creek, Dungate Creek, Barren Creek, McQuarrie Creek, Byman Creek, Richfield Creek, Johnny David Creek, Aitken Creek and Emerson Creek.

Some key areas of high fisheries values for chinook, sockeye and coho are noted in Bustard and Schell (2002) as McBride Lake, Nanika Lake, and Morice Lake watersheds. A draft gantt chart for select species in the Morice River and Bulkley River watersheds was derived from reviews of the aforementioned references and is included as Figure 2.7. The data is considered in draft form and will be refined over the spring and summer of 2021 with local fisheries technicians and knowledge holders during the collaboratory assessment planning and fieldwork activities planned.

In the 1990's the Morice River watershed, A. Gottesfeld and Rabnett (2007) estimated that chinook comprised 30% of the total Skeena system chinook escapements. It is estimated that Morice River coho comprise approximatley 4% of the Skeena escapement with a declining trend noted since the 1950 in A. Gottesfeld and Rabnett (2007). Coho spawn in major tributaries and small streams ideally at locations where downstream dispersal can result in seeding of prime off channel habitats including warm productive sloughs and side channels. Of all the salmon species, coho rely on small tributaries the most (Bustard and Schell 2002). Bustard and Schell (2002) report that much of the distribution of coho into non-natal tributaries occurs during high flow periods of May - early July with road culverts blocking migration into these habitats.

```
##### Chinook
#  In the 1990's Morice River watershed,
        @gottesfeld_rabnett2007SkeenaFish estimated that chinook
        comprised 30% of the total Skeena system chinook escapements.
        @buckwalter_kirsch2012Fishinventory have recorded juvenile
        chinook rearing in small non natal streams.

# @buckwalter_kirsch2012Fishinventory have uvenile chinook have been
        recorded rearing in small non natal streams


#It is estimated that Morice River coho comprise approximatley 4% of
        the Skeena escapement with a declining trend noted since the
        1950 in @gottesfeld_rabnett2007SkeenaFish.  Coho spawn in
        major tributaries and small streams ideally at locations
        where downstream dispersal can result in seeding of prime off
        channel habitats including warm productive sloughs and side
        channels.  Of all the salmon species, coho rely on small
        tributaries the most [@bustard_schell2002ConservingMorice].
        @bustard_schell2002ConservingMorice report that much of the
        distribution of coho into non-natal tributaries occurs during
        high flow periods of May - early July with road culverts
        blocking migration into these habitats.
```

Summaries of historical fish observations in the Bulkley River and Morice River watershed groups (n=4033), graphed by remotely sensed average gradient as well as measured or modelled channel width categories for their associated stream segments where calculated with `bcfishpass` and `bcfishobs` and are provided in Figures 2.8 - 2.9.

```
fiss_species_table <-
        readr::read_csv('data/inputs_extracted/fiss_species_table.csv')

fiss_species_table %>%
  fpr::fpr_kable(caption_text = 'Fish species recorded in the Morice
        River, Bulkley River, Zymoetz River, Kispiox River, and
        Kitsumkalum River watershed groups.',
                 footnote_text = 'COSEWIC abbreviations :
                 SC - Special concern
                 DD - Data deficient
                 NAR - Not at risk
                 E - Endangered
                 T - Threatened

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

Table 2.1: Fish species recorded in the Morice River, Bulkley River, Zymoetz River, Kispiox River, and Kitsumkalum River watershed groups.

Scientific Name	Species Name	BC List	COSEWIC	Bulkley	Kispiox	Kalum	Morice	Zymoetz
Catostomus catostomus	Longnose Sucker	Yellow	–	Yes	Yes	–	Yes	Yes
Catostomus commersonii	White Sucker	Yellow	–	Yes	Yes	Yes	Yes	–
Catostomus macrocheilus	Largescale Sucker	Yellow	–	Yes	Yes	Yes	Yes	Yes
Chrosomus eos	Northern Redbelly Dace	Yellow	–	Yes	–	–	–	–
Coregonus clupeaformis	Lake Whitefish	Yellow	–	Yes	Yes	–	Yes	–
Coregonus sardinella	Least Cisco	Blue	–	–	–	Yes	–	–
Cottus aleuticus	Coastrange Sculpin (formerly Aleutian Sculpin)	Yellow	–	Yes	Yes	Yes	Yes	–
Cottus asper	Prickly Sculpin	Yellow	–	Yes	Yes	Yes	Yes	Yes
Cottus cognatus	Slimy Sculpin	Yellow	–	–	Yes	Yes	–	–
Couesius	Lake Chub	Yellow	DD	Yes	Yes	Yes	Yes	–

```
gantt_raw <-
        read_csv("data/inputs_raw/fish_species_life_history_gantt.csv")


##start with just the morice to keep it simple
# ungroup()
##start with just the morice to keep it simple
gantt <- gantt_raw %>%
  dplyr::select(Species,
         life_stage,
         morice_start2,
         morice_end2) %>%
  dplyr::filter(
    life_stage != 'Rearing' &
      life_stage != 'Upstream fry migration' &
```

```
    !is.na(life_stage),    !is.na(morice_start2)  )%>%
dplyr::mutate(    morice_start2 = lubridate::as_date(morice_start2),
  morice_end2 = lubridate::as_date(morice_end2),
  life_stage = factor(life_stage, levels =
                      c('Migration', 'Overwintering', 'Spawning',
      'Incubation', 'Emergence', 'Outmigration')),
  life_stage = forcats::fct_rev(life_stage) ##last line was upside
      down!
) %>%   dplyr::filter(life_stage != 'Overwintering')
      ##make a plotggplot(gantt, aes(xmin = morice_start2,
                xmax = morice_end2,                     y = life_stage,
                color = life_stage)) +  geom_linerange(size = 2) +
labs(x=NULL, y=NULL)+  # theme_bw()+
ggdark::dark_theme_bw(base_size = 11)+
theme(legend.position = "none")+  scale_x_date(date_labels = "%B")+
facet_wrap(~Species, ncol = 1)
```

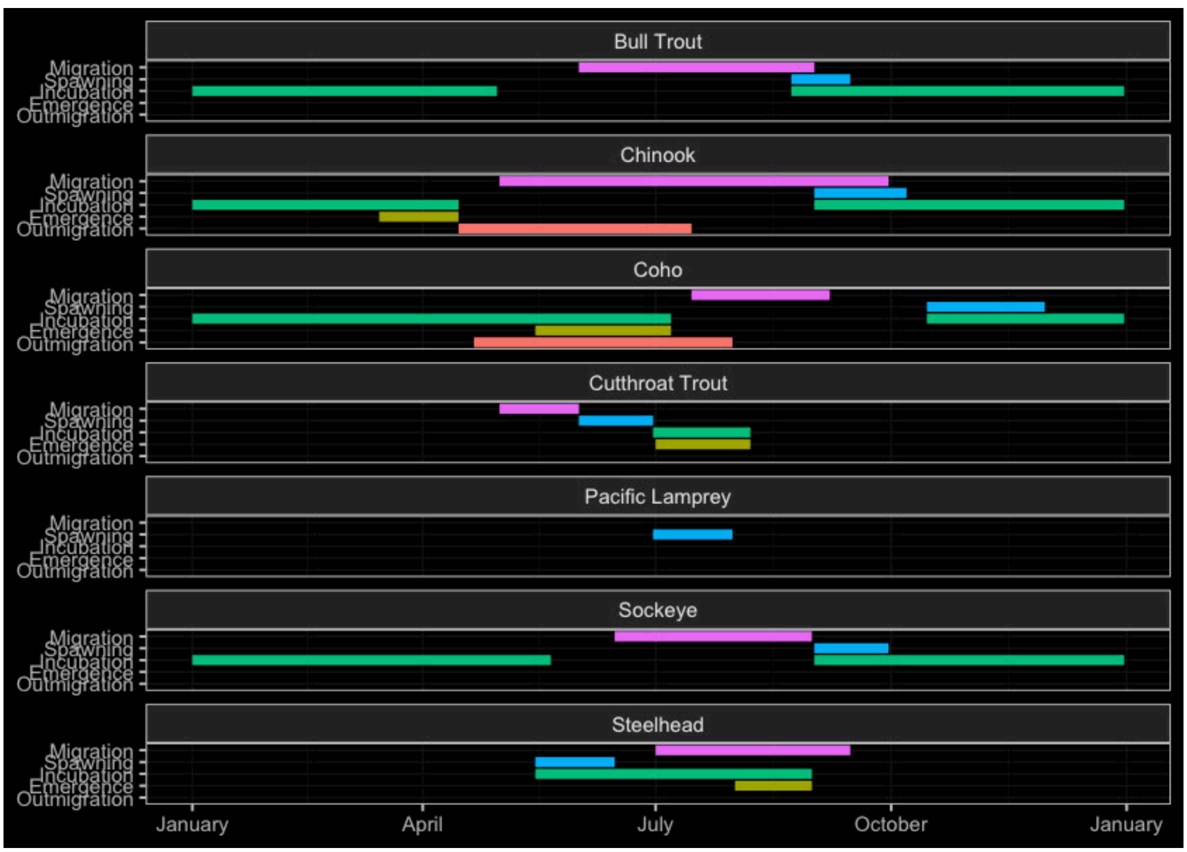

Figure 2.7: Gantt chart for select species in the Morice River and Bulkley River watersheds. To be updated in consultation with local fisheries techicians and knowledge holders.

```
# fiss_sum <- readr::read_csv(file = paste0(getwd(),
        '/data/extracted_inputs/fiss_sum.csv'))
fiss_sum_grad <- readr::read_csv(file =
        'data/inputs_extracted/fiss_sum_grad.csv')
fiss_sum_width <- readr::read_csv(file =
        'data/inputs_extracted/fiss_sum_width.csv')

# A summary of historical westslope cutthrout trout observations in
        the Elk River watershed group by average gradient category of
        associated stream segment is provided in Figure
        \@ref(fig:fish-wct-bar). Of `r wct_elkr_grad %>%
        filter(gradient_id == 3) %>% pull(total)` observations, `r
        wct_elkr_grad %>% filter(gradient_id == 3) %>% pull(Percent)
        + wct_elkr_grad %>% filter(gradient_id == 5) %>%
        pull(Percent) + wct_elkr_grad %>% filter(gradient_id == 8)
        %>% pull(Percent)`% were within stream segments with average
        gradients ranging from 0 - 8%.  A total of `r wct_elkr_grad
        %>% filter(gradient_id == 3) %>% pull(Percent)`% of historic
        observations were within stream segments with gradients
        between 0 - 3%, `r wct_elkr_grad %>% filter(gradient_id == 5)
        %>% pull(Percent)`% were within stream segments with
        gradients ranging from 3 - 5% and `r wct_elkr_grad %>%
        filter(gradient_id == 5) %>% pull(Percent)`% were within
        stream segments with gradients between 5 - 8%
        [@data_fish_obs; @norris2020bcfishobs].
```

```
##bar graph
plot_grad <- fiss_sum_grad %>%
  dplyr::filter(gradient_id != 99) %>%
  ggplot(aes(x = Gradient, y = Percent)) +
  geom_bar(stat = "identity")+
  facet_wrap(~species_code, ncol = 2)+
  ggdark::dark_theme_bw(base_size = 11)+
  labs(x = "Average Stream Gradient", y = "Occurrences (%)")
plot_grad
```

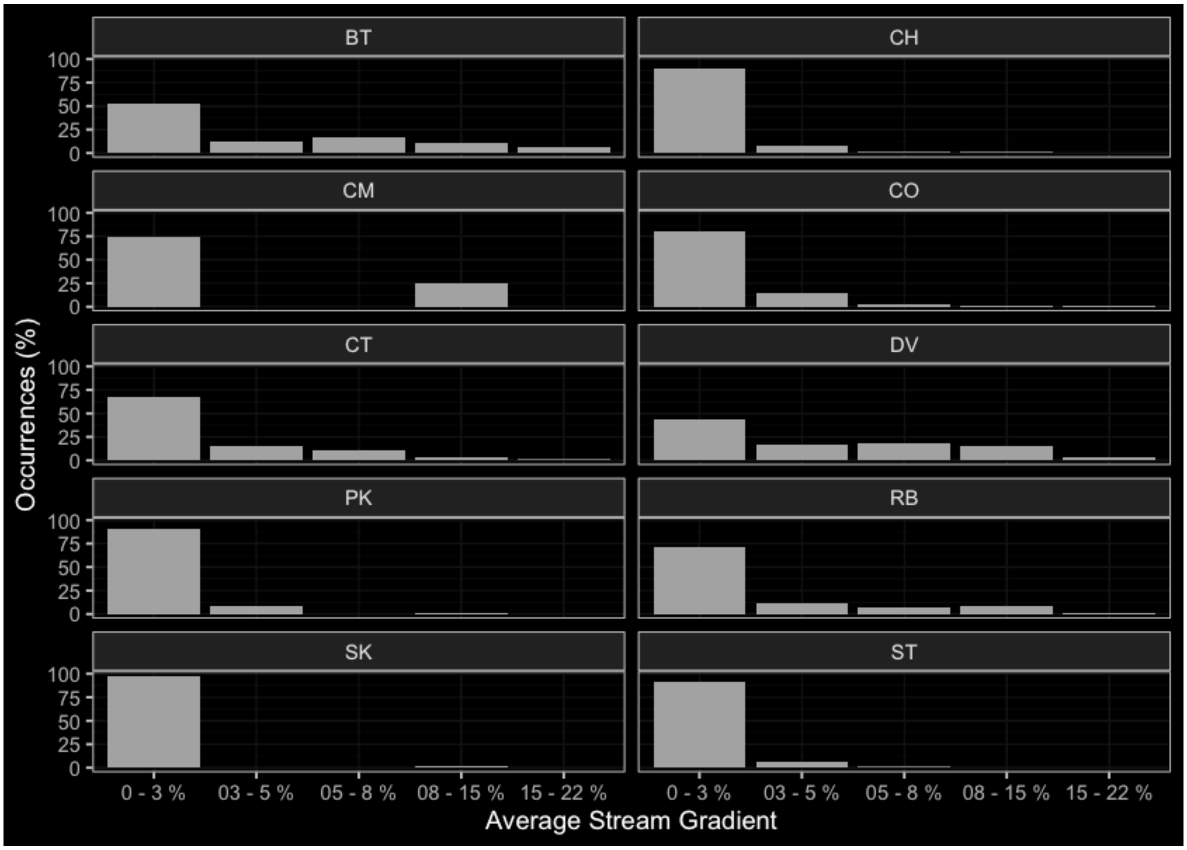

Figure 2.8: Summary of historic salmonid observations vs. stream gradient category for the Bulkley River watershed group.

```r
##bar graph
plot_width <- fiss_sum_width %>%
  dplyr::filter(!is.na(width_id)) %>%
  ggplot(aes(x = Width, y = Percent)) +
  geom_bar(stat = "identity")+
  facet_wrap(~species_code, ncol = 2)+
  ggdark::dark_theme_bw(base_size = 11)+
  labs(x = "Channel Width", y = "Occurrences (%)")
plot_width
```

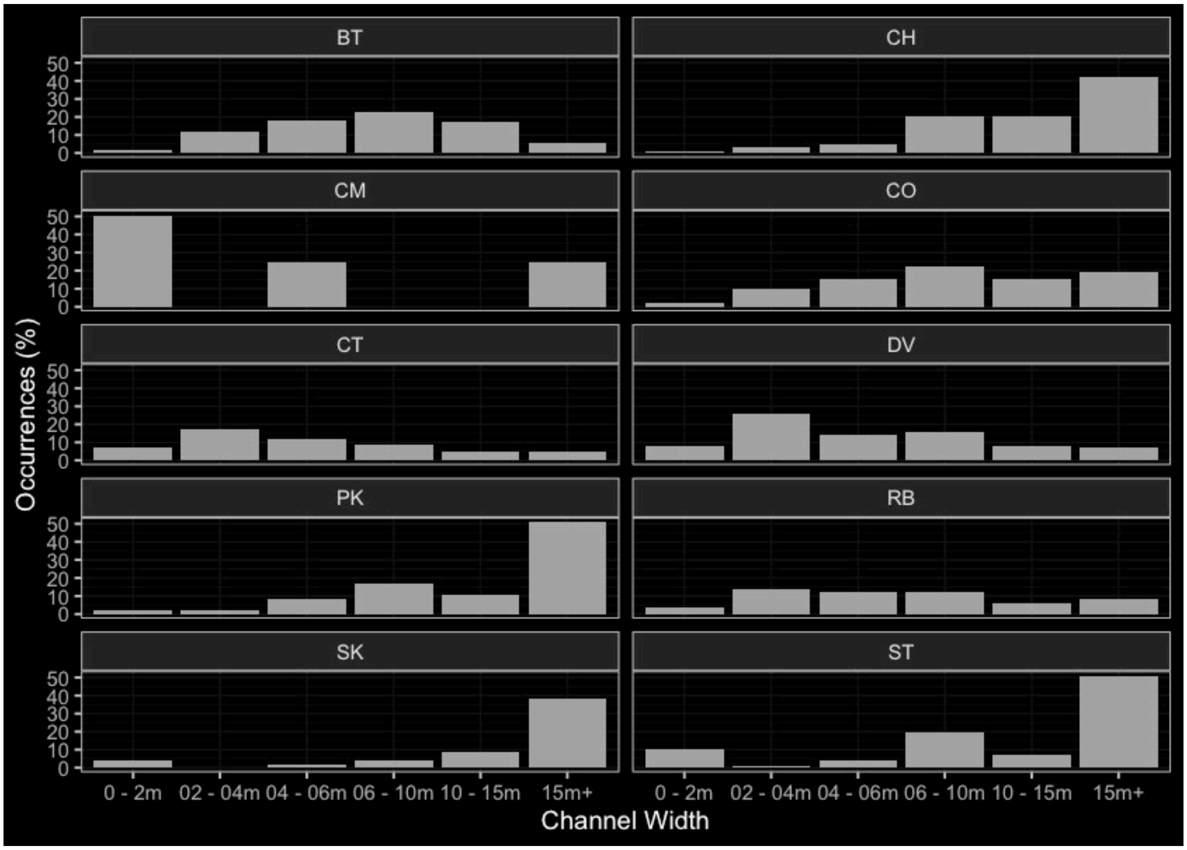

Figure 2.9: Summary of historic salmonid observations vs. channel width category for the Bulkley River watershed group.

```
##bar graph
fiss_sum_wshed_filter <- fiss_sum %>%
  dplyr::filter(upstream_area_ha < 5000) %>%
  mutate(upstream_area_km = upstream_area_ha/100)

bin_1 <- 0
# bin_1 <- floor(min(fiss_sum_wshed_filter$upstream_area_ha, na.rm =
        TRUE)/5)*5
bin_n <- ceiling(max(fiss_sum_wshed_filter$upstream_area_km, na.rm =
        TRUE)/5)*5
bins <- seq(bin_1,bin_n, by = 5)

plot_wshed_hist <- ggplot(fiss_sum_wshed_filter,
        aes(x=upstream_area_km
                                            # fill=alias_local_name
                                            # color = alias_local_name
)) +
```

```
  geom_histogram(breaks = bins,
                 position="identity", size = 0.75)+
  labs(x = "Upstream Watershed Area (km)", y = "Count Fish (#)") +
  facet_wrap(~species_code, ncol = 2)+  # scale_color_grey() +
  # scale_fill_grey() +  ggdark::dark_theme_bw(base_size = 11)+
  scale_x_continuous(breaks = bins[seq(1, length(bins), by = 2)])+
  # scale_color_manual(values=c("grey90", "grey60", "grey30",
        "grey0"))+
  # theme(axis.text.x = element_text(angle = 45, hjust = 1))+
  geom_histogram(aes(y=..density..), breaks = bins, alpha=0.5,
                 position="identity", size = 0.75)plot_wshed_hist
```

```
## Fish Passage Restoration Planning and Implementation

# 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
        @fishpassagetechnicalworkinggroupFishPassageStrategic2014 :
#
# -   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 -- Re-connection of isolated habitats
        through replacement, rehabilitation or removal of prioritized
        crossing structure barriers.
```

```
##`r pscis_historic_phase1 %>% dplyr::filter(watershed_group_code
        %ilike% 'BULK' & assessment_date < '2020-01-01') %>% nrow()`
### Bulkley River
```

```
# There is a rich history of fish passage restoration planning in the
        Bulkley River watershed group with not all the work documented
        in the PSCIS system. A non-exhaustive list of historic fish
        passage reports for the watershed includes
        @wilson_rabnett2007FishPassage,
        @mccarthy_fernando20152015Inventory,@smith2018AssessingBarriers
        @casselman_stanley2010BulkleyFulton and
        @irvine2018AnalysisPriority.
#       # <br>  #
# Review of the PSCIS database indicated that prior to 2021, 1665
        assessments for fish passage (Phase 1) at crossing structures
        within the Bulkley River watershed group have been recorded
        in the PSCIS database [@moe2021PSCISAssessments]. No habitat
        confirmations are recorded in the PSCIS database
        [@moe2021PSCISHabitat]. Within the Bulkley River watershed
        group, a number of remediation projects have been completed
        over the years with backwatering works conducted on Toboggan
        Creek, Coffin Creek, Moan Creek, Johnny David Creek and
        potentially others. Three culvert replacements (with open
        bottom structures) in the watershed group have been tracked
        in PSCIS and include works on Barren Creek as well as two
        tributaries to Harold Prince Creek
        [@moe2021PSCISRemediation]. McDowell Creek at Highway 16 was
        replaced with a horizontally drilled baffled structure in
        2017 and a design is currently being drafted for the Highway
        16 crossing over Taman Creek (pers. comm. Kathryn Graham,
        Regional Manager Environmental Services - Ministry of
        Transportation and Infrastructure).
#       # ## Morice river#
# Within the Morice River watershed group prior to 2021, 21 fish
        passage assessments (Phase 1) had been recorded in the PSCIS
        database [@moe2021PSCISAssessments]. At the time of
        reporting, no habitat confirmations had been recorded
        [@moe2021PSCISHabitat]. Two culvert replacements (with open
        bottom structures) in the watershed group have been tracked
        in PSCIS in the and include works on a tributary to the
        Morice River located at km 39.2 of the Morice River FSR and
        on bridge installation at km 4 of McBride Road on a tributary
        to McBride Lake [@moe2021PSCISRemediation].
```

```
##`r pscis_historic_phase1 %>% dplyr::filter(watershed_group_code
        %ilike% 'MORR' & assessment_date < '2020-01-01') %>% nrow()`
```

3 Methods

```
fish_col_permit_num <- "PG23-813101"
```

3.1 Communicate Connectivity Issues

3.1.1 Engage Partners

Engaging partners for ecosystem restoration initiatives is critical as it allows us to utilize available resources, tap into different areas of expertise, and benefit from diverse perspectives through collaboration that leads to successful outcomes. Engagement actions have included video conference calls, meetings, emails, presentations and phone calls.

3.1.2 Collaborative GIS Environment

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

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

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

- Download and clip user specified layers from the BC Data Catalogue as well as data layers stored in custom Amazon Web Services buckets for an area of interest defined by a list of watershed groups and load to a geopackage called `background_layers.gpkg` stored in the main directory of the project.

- A project directory is created to hold the spatial data and `QGIS` project information (ie. layer symbology and naming conventions, metadata, etc.).
- Metadata for individual project spatial layers is kept in the `rfp_tracking` table within the `background_layers.gpkg` along with tables related to user supplied stream width/gradient inputs to `bcfishpass` to model potentially high value habitat that is accessible to fish species of interest.

3.1.3 Issue Tracking

"Issues" logged on the online github platform are effective ways to track tasks, enhancements, and bugs related to project components. They can be referenced with the scripts, text and actions used to address them by linking documentation to the issues with text comments or programatically through `git` commit messages. Issues for this project are kept here.

3.1.4 Mapping

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

3.2 Planning

3.2.1 Habitat Modelling

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

- `bcfishpass` background information
- Access model
- Linear spawning/rearing habitat model

The access model identifies natural barriers (ex. steep gradients for extended distances) and hydroelectric dams to classify the accessibility of streams for fish (Norris [2020] 2021). On potentially accessible streams, scripts identify known barriers (ex. waterfalls >5m high) and additional anthropogenic features which are primarily road/railway stream crossings (i.e. culverts) that are potentially barriers. To prioritize these features for assessment or remediation, scripts report on how much modelled potentially accessible aquatic habitat the barriers may obstruct. The model can be refined with numerous parameters including known fish observations upstream of identified barriers and for each crossing location, the area of lake and wetland habitat upstream, species documented upstream/downstream, and an estimate of watershed area (on 2nd order and higher streams). Furthermore, mean annual precipitation weighted to upstream watershed area, stream discharge, and channel width can be collated using `bcfishpass`, `fwapg` and `bcfishobs`. This information can be used to provide an indication of the potential quantity and quality of habitat potentially gained should fish passage be restored, by comparing to user defined thresholds for the aforementioned parameters.

The linear spawning and rearing habitat model uses species-specific thresholds for stream gradient (Table 3.1), channel width or discharge, network connectivity, and habitat type to assess the intrinsic potential of streams to support spawning and rearing. It also incorporates documented spawning locations and literature-derived parameters to refine habitat suitability estimates. This model helps guide field assessments and prioritize locations for fish passage restoration.

Regarding gradients, `bcfishpass` calculates the average gradient of BC Freshwater Atlas stream network lines at minimum 100m long intervals starting from the downstream end of the streamline segment and working upstream. The network lines are broken into max gradient categories with new segments created if and when the average slope of the stream line segment exceeds user provided thresholds. For this phase of the project, the user provided gradient thresholds used to delineate “potentially accessible habitat” were based on estimated max gradients that rainbow trout (20%) and bull trout (25%) are likely to be capable of ascending.

Gradient, channel size and stream discharge are key determinants of channel morphology and subsequently fish distribution. High value rearing, overwintering, and spawning habitat preferred by numerous species/life stages of fish are often located within channel types that have relatively low gradients and large channel widths (also quantified by the amount of flow in the stream).

Following delineation of “potentially accessible habitat”, the average gradient of each stream segment within habitat classified as below the 20% and 25% thresholds was calculated and summed within species and life stage specific gradient categories. Average gradient of stream line segments can be calculated from elevations contained in the provincial freshwater atlas streamline dataset.

To obtain estimates of channel width upstream of crossing locations, where available, `bcfishpass` was utilized to pull average channel gradients from Fisheries Information Summary System (FISS) site assessment data (MoE 2019b) or PSCIS assessment data (MoE 2021) and associate with stream segment lines. When both FISS and PSCIS values were associated with a particular stream segment, or multiple FISS channel widths are available a mean of the average channel widths was used. To model channel width for 2nd order and above stream segments without associated FISS or PSCIS sites, first `fwapg` was used to estimate the drainage area upstream of the segment. Then, rasters from ClimateBC (Wang et al. 2012) were downloaded to a `postgresql` database, sampled for upstream watershed areas associated with each stream segment and a mean annual precipitation weighted by upstream watershed area was calculated. In early 2021, Bayesian statistical methods were developed to predict channel width in all provincial freshwater atlas stream segments where width measurements had not previously been measured in the field. The model was based on the relationship between watershed area and mean annual precipitation weighted by upstream watershed area (Thorley and Irvine 2021). In December of 2021, Thorley and Irvine (2021) methods were updated using a power model derived by Finnegan et al. (2005) which relates stream discharge to watershed area and mean annual precipitation. Data (n = 24849) on watershed size, mean annual precipitation and measured channel width was extracted from the provincial freshwater atlas (FLNRORD 2021; GeoBC 2022), the BC Data Catalogue fisheries datasets (MoE 2024, 2021) and Wang et al. (2012) utilizing `bcfishpass`(Norris [2020] 2021) and `fwapg`(Norris [2019] 2021). Details of this analysis and subsequent outputs can be reviewed here(Thorley, Norris, and Irvine 2021).

`bcfishpass` and associated tools have been designed to be flexible in analysis, accepting user defined gradient, channel width and stream discharge categories (MoE 2019b). Although currently in draft form, and subject to development revisions, gradient and channel width thresholds for habitat with the highest intrinsic value for a number of fish species in the Parsnip River watershed group have been specified and applied to model habitat upstream of stream crossing locations with the highest potential intrinsic value (Table 3.1). Definitions of modelling outputs for bull trout are presented in Table 3.3. Modelling of habitat for Arctic grayling, in the Peace region are planned for 2024-2025 with the work leveraging multiple other initiatives underway by SERNbc and others throughout British Columbia including work related to Arctic grayling habitat use and preference conducted by UNBC and others [Hagen and Stamford (2023); Bottoms et al. (2023).

```
#`r if(identical(gitbook_on, FALSE)){knitr::asis_output("<br><br>
        <br>")}`

species <- c('BT','GR')

text_footnote <- ""
  #"Models for RB, GR and KO are under a process of development and
        have not yet been released.  All models parameters are
        preliminary and subject to collaborative development."


bcfishpass_spawn_rear_model |>
  dplyr::filter(species_code %in% species) |>
  mutate(Species = fishbc::fbc_common_name(species_code),
         spawn_gradient_max = round(spawn_gradient_max * 100 ,1),
         rear_gradient_max = round(rear_gradient_max * 100 ,1)) |>
  select(Species,
         `Spawning Gradient  Max (%)`= spawn_gradient_max,
         `Spawning Width Min (m)` = spawn_channel_width_min,
         `Rearing Width Min (m)` = rear_channel_width_min,
```

```
         # `Spawning Width Max (m)` = spawn_channel_width_max,
         # `Spawning MAD Min (m3/s)` = spawn_mad_min,
         # `Spawning MAD Max (m3/s)` = spawn_mad_max,
         `Rearing Gradient Max (%)` = rear_gradient_max) |>
         # `Rearing MAD Min (m3/s)` = rear_mad_min,
         # `Rearing MAD Max (m3/s)` = rear_mad_max,
         # `Rearing Wetland Multiplier` = rear_wetland_multiplier,
         # `Rearing Lake Multiplier` = rear_lake_multiplier) |>
  t() |>  as_tibble(rownames = "row_names") |>
  janitor::row_to_names(row_number = 1) |>
  rename(Variable = Species) |>
  fpr::fpr_kable(caption_text = 'Stream gradient and channel width
        thresholds used to model potentially highest value fish
        habitat.',
                 footnote_text = text_footnote,
                 scroll = F,
                 scroll_box_height = '300px')
```

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

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

*

```
# bcfishpass_spawn_rear_model_references <- readr::read_csv(file =
        'data/width_modelling/model_spawning_rearing_habitat.csv')
bcfishpass_spawn_rear_model_references <- readr::read_csv(file =
        'data/inputs_raw/bcfishpass_spawn_rear_model_ref.csv')
  # select(species_code, contains('ref'), -
        contains(c('multiplier','mad')))

bcfishpass_spawn_rear_model_references |>
  mutate(Species = fishbc::fbc_common_name(species_code)) |>
  select(Species,
         `Spawning Gradient  Max (%)`= spawn_gradient_max,
         `Spawning Width Min (m)` = spawn_channel_width_min,
         # `Spawning Width Max (m)` = spawn_channel_width_max_ref,
```

```
          # `Spawning MAD Min (m3/s)` = spawn_mad_min,
          # `Spawning MAD Max (m3/s)` = spawn_mad_max,
          `Rearing Gradient Max (%)` = rear_gradient_max) |>
          # `Rearing Wetland Multiplier` = rear_wetland_multiplier,
          # `Rearing Lake Multiplier` = rear_lake_multiplier) |>
          # `Rearing MAD Min (m3/s)` = rear_mad_min,
          # `Rearing MAD Max (m3/s)` = rear_mad_max) |>  t() |>
  as_tibble(rownames = "row_names") |>
  janitor::row_to_names(row_number = 1) |>
  rename(Variable = Species) |>
  fpr::fpr_kable(caption_text = 'References considered for stream
        gradient and channel width thresholds used to model
        potentially highest value fish habitat. Preliminary and
        subject to revisions.',
                 # footnote_text = 'The maximum gradient for steelhead
        rearing has been adjusted to 8.5% based on professional
        judgment, although references indicate 7.49%',
                 scroll = F)
```

Table 3.2: References considered for stream gradient and channel width thresholds used to model potentially highest value fish habitat. Preliminary and subject to revisions.

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

```
fpr::fpr_xref_crossings |>
  dplyr::filter(id_side == 1) |>
  arrange(id_join) |>
  select(Attribute = report, Definition = column_comment) |>
  fpr::fpr_kable(caption_text = 'bcfishpass outputs and associated
        definitions',
```

```
                footnote_text = 'Bull trout model uses a gradient
        threshold of maximum 25% to determine if access if likely
        possible',
                scroll = gitbook_on)
```

Table 3.3: bcfishpass outputs and associated definitions

Attribute	Definition
ST Network (km)	Steelhead model, total length of stream network potentially accessible upstream of point
ST Lake Reservoir (ha)	Steelhead model, total area lakes and reservoirs potentially accessible upstream of point
ST Wetland (ha)	Steelhead model, total area wetlands potentially accessible upstream of point
ST Slopeclass03 Waterbodies (km)	Steelhead model, length of stream connectors (in waterbodies) potentially accessible upstream of point with slope 0-3%
ST Slopeclass03 (km)	Steelhead model, length of stream potentially accessible upstream of point with slope 0-3%
ST Slopeclass05 (km)	Steelhead model, length of stream potentially accessible upstream of point with slope 3-5%
ST Slopeclass08 (km)	Steelhead model, length of stream potentially accessible upstream of point with slope 5-8%
ST Spawning (km)	Length of stream upstream of point modelled as potential Steelhead spawning habitat
ST Rearing (km)	Length of stream upstream of point modelled as potential Steelhead rearing habitat
CH Spawning (km)	Length of stream upstream of point modelled as potential Chinook spawning habitat
CH Rearing (km)	Length of stream upstream of point modelled as potential Chinook rearing habitat
CO Spawning (km)	Length of stream upstream of point modelled as potential Coho spawning habitat
CO Rearing (km)	Length of stream upstream of point modelled as potential Coho rearing habitat

```
#to quantify upstream habitat potentially available for salmonids and
        facilitate stream line symbology based on stream morphology.

# while high gradient sections typically  present  upstream  migration
        barriers  and  less  available  habitat.  Additionally, the
        size of the stream (indicated by channel width) is an
        important determinant for habitat suitability for different
        species as well as specific life stages of those species.

# `bcfishpass` was used to categorize and sum potentially accessible
        stream segments in the study area watersheds within gradient
        and width categories for each stream segment.
```

```
# (0 - 3%, 3 - 5%, 5 - 8%, 8 - 15%, 15 - 20%) with these outputs
        further amalgamated to summarize and symbolize potential
        upstream habitat in three categories: riffle/cascade (0 -
        5%), step-pool (5 - 15%) and step-pool very steep (15-20%)
        (Table \@ref(tab:tablethreshaverage)).
                #threshold and average gradient table
table_thresh_average <- tibble::tibble(`Gradient` = c('0 - 5%', '5 -
        15%', '15 - 20%', '>20%'),
                                        `Channel Type` = c('Riffle and
        cascade pool', 'Step pool', 'Step pool - very steep', 'Non
        fish habitat'))
        table_thresh_average |>
    fpr::fpr_kable(caption_text = 'Stream gradient categories
        (threshold and average) and associated channel type.')
```

3.3 Fish Passage Assessments

In the field, crossings prioritized for follow-up were first assessed for fish passage following the procedures outlined in "Field Assessment for Determining Fish Passage Status of Closed Bottomed Structures" (MoE 2011). The reader is referred to (MoE 2011) for detailed methodology. Crossings surveyed included closed bottom structures (CBS), open bottom structures (OBS) and crossings considered "other" (i.e. fords). Photos were taken at surveyed crossings and when possible included images of the road, crossing inlet, crossing outlet, crossing barrel, channel downstream and channel upstream of the crossing and any other relevant features. The following information was recorded for all surveyed crossings: date of inspection, crossing reference, crew member initials, Universal Transverse Mercator (UTM) coordinates, stream name, road name and kilometer, road tenure information, crossing type, crossing subtype, culvert diameter or span for OBS, culvert length or width for OBS. A more detailed "full assessment" was completed for all closed bottom structures and included the following parameters: presence/absence of continuous culvert embedment (yes/no), average depth of embedment, whether or not the culvert bed resembled the native stream bed, presence of and percentage backwatering, road fill depth, outlet drop, outlet pool depth, inlet drop, culvert slope, average downstream channel width, stream slope, presence/absence of beaver activity, presence/absence of fish at time of survey, type of valley fill, and a habitat value rating. Habitat value ratings were based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), fish migration patterns, the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation (Table 3.4).

```
fpr_table_habvalue |>
  knitr::kable(caption = 'Habitat value criteria (Fish Passage
        Technical Working Group, 2011).', booktabs = T, label = NA)
        |>
```

```
    kableExtra::column_spec(column = 1, width_min = '1.5in') |>
    kableExtra::kable_styling(c("condensed"), full_width = T,
        font_size = font_set)
```

Table 3.4: Habitat value criteria (Fish Passage Technical Working Group, 2011).

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

Fish passage potential was determined for each stream crossing identified as a closed bottom structure as per MoE (2011). The combined scores from five criteria: depth and degree to which the structure is embedded, outlet drop, stream width ratio, culvert slope, and culvert length were used to screen whether each culvert was a likely barrier to some fish species and life stages (Table 3.5, 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). For crossings determined to be potential barriers or barriers based on the data, a culvert fix and recommended diameter/span was proposed.

```
tab <- as_tibble(t(fpr_table_barrier_scoring)) |>
  mutate(V4 = names(fpr_table_barrier_scoring)) |>
  select(V4, everything()) |>
  janitor::row_to_names(1) |>  ##turn the table sideways
  mutate(Risk = case_when(Risk == 'Value' ~ '  Value',
                          T ~ Risk))

tab |>
  fpr::fpr_kable(caption_text = 'Fish Barrier Risk Assessment (MoE
      2011).', scroll = F)
```

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

```
fpr_table_barrier_result |>
  fpr::fpr_kable(caption_text = 'Fish Barrier Scoring Results (MoE
        2011).', scroll = F)
```

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

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

Habitat gain indexes are the quantity of modelled habitat upstream of the subject crossing and represents an estimate of habitat gained with remediation of fish passage at the crossing. For this project, a gradient threshold between accessible and non-accessible habitat was set at 25% (for a minimimum length of 100m) and intended to represent the maximum gradient of which the strongest swimmers of anadromous species (bull trout) are likely to be able to migrate upstream. This is the amount of habitat upstream of each crossing less than 25% gradient before a falls of height >5m - as recorded in MoE (2020) or documented in other `bcfishpass` online documentation. For Phase 2 - habitat confirmation sites, conservative estimates of the linear quantity of habitat to be potentially gained by fish passage restoration, bull trout rearing maximum gradient threshold (10.5%) was used. To generate estimates for area of habitat upstream (m^2), the estimated linear length was multiplied by half the downstream channel width measured (overall triangular channel shape) as part of the fish passage assessment protocol. Although these estimates are not generally conservative, have low accuracy and do not account for upstream stream crossing structures they allow a rough idea of the best candidates for follow up.

Potential options to remediate fish passage were selected from MoE (2011) and included:

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

3.3.1 Cost Estimates

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

Base costs for installation of bridges on forest service roads and permit roads with surfaces specified in provincial GIS road layers as rough and loose was estimated at $25000/linear m and assumed that the road could be closed during construction and a minimum bridge span of 15m. For streams with channel widths <2m, embedded culverts were reported as an effective solution with total installation costs estimated at $50k/crossing (pers. comm. Phil MacDonald, Steve Page then adjusted for inflation). For larger streams (>6m), estimated span width increased proportionally to the size of the stream. For crossings with large amounts of fill (>3m), the replacement bridge span was increased by an additional 3m for each 1m of fill >3m to account for cutslopes to the stream at a 1.5:1 ratio. To account for road type, a multiplier table was generated to estimate incremental cost increases with costs estimated for structure replacement on paved surfaces, railways and arterial/highways costing up to 20 times more than forest service roads due to expenses associate 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.

```
sfpr_xref_road_cost() |>
  mutate(cost_m_1000s_bridge = formatC(cost_m_1000s_bridge * 15000,
         format="d", big.mark=",")) |>
  mutate(cost_embed_cv = formatC(cost_embed_cv * 1000, format="d",
         big.mark=",")) |>
  rename(
    Class = my_road_class,
    Surface = my_road_surface,
    `Class Multiplier` = road_class_mult,
    `Surface Multiplier` = road_surface_mult,
    `Bridge $/15m` = cost_m_1000s_bridge,
    `Streambed Simulation $` = cost_embed_cv
  ) |>
  dplyr::filter(!is.na(Class)) |>
  mutate(Class =case_when(
    Class == 'fsr' ~ str_to_upper(Class),
    TRUE ~ stringr::str_to_title(Class)),
    Surface = stringr::str_to_title(Surface)
  ) |>
  # dplyr::filter(Class != 'FSR' & Surface != 'Paved') |>
  fpr::fpr_kable(caption_text = 'Cost multiplier table based on road
        class and surface type.', scroll = F)
```

Table 3.7: Cost multiplier table based on road class and surface type.

Class	Surface	Class Multiplier	Surface Multiplier	Bridge $/15m	Streambed Simulation $
FSR	Rough	1	1	450,000	100,000
FSR	Loose	1	1	450,000	100,000
Resource	Loose	1	1	450,000	100,000
Resource	Rough	1	1	450,000	100,000
Permit	Unknown	1	1	450,000	100,000
Permit	Loose	1	1	450,000	100,000
Permit	Rough	1	1	450,000	100,000
Unclassified	Loose	1	1	450,000	100,000

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

3.4 Designs

Engineering designs were conducted by consultants hired by forest licensees with tenure over the roads and/or timber harvest planned on the roads where work was conducted. Completed designs are loaded to the PSCIS data portal.

3.5 Habitat Confirmation Assessments

Following fish passage assessments, habitat confirmations were completed in accordance with procedures outlined in the document “A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation of a Stream Crossing” (Fish Passage Technical Working Group 2011). The main objective of the field surveys was to document upstream habitat quantity and quality and to determine if any other obstructions exist above or below the crossing. Habitat value was assessed based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation. Criteria used to rank habitat value was based on guidelines in Fish Passage Technical Working Group (2011) (Table 3.4).

During habitat confirmations, to standardize data collected and facilitate submission of the data to provincial databases, information was collected on “Site Cards”. Habitat characteristics recorded included channel widths, wetted widths, residual pool depths, gradients, bankfull depths, stage, temperature, conductivity, pH, cover by type, substrate and channel morphology (among others). When possible, the crew surveyed downstream of the crossing to a minimum distance 300m and upstream to a minimum distance of 500 - 600m. Any potential obstacles to fish passage were inventoried with photos, physical descriptions and locations recorded on site cards. Surveyed routes were recorded with time-signatures on handheld GPS units.

3.6 Fish Sampling

3.6.1 Electrofishing

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

3.6.2 Fish Handling and Processing

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

3.6.3 Pit Tagging

Fish with a fork length greater than 60 mm and belonging to species approved under the scientific fish collection permit PG23-813101 were tagged with Passive Integrated Transponders (PIT tags) using the Abdominal Cavity method outlined by Biomark. To anesthetize fish prior to pit tagging, we used a solution of approximately 0.1 mL of clove oil per 1 L of water (1:10,000). This concentration was selected for its efficiency in providing effective sedation with minimal residual effects, making it ideal for studies in which fish are released back into their natural habitats (Fernandes et al. 2017). The clove oil solution was prepared in advance by dissolving pure clove oil in ethyl alcohol in a 1:9 ratio (clove oil: ethyl alcohol) to enhance solubility, then mixed into the water bucket (Fernandes et al. 2017). Fish were immersed in this solution until they reached an appropriate level of anesthesia for handling and then were tagged. To maintain needle sharpness and minimize injury risk, needles were replaced approximately every 10 fish. Each tagged fish was scanned with the PIT reader, and both the PIT tag ID and row ID were recorded. Once tagged, fish were placed into a bucket of fresh water and allowed to recover before being released back into the stream. Fish information and habitat data will be submitted to the province under scientific fish collection permit PG23-813101.

3.7 Remediations

Structure replacement was conducted by contractors hired by Sinclar (forest licensee). As-built drawings were completed and loaded to the PSCIS data portal.

3.8 Climate Change Risk Assessment

In collaboration with the Ministry of Transportation and Infrastructure (MoTi), a new climate change replacement program aims to prioritize vulnerable culverts for replacement (pers. comm Sean Wong, 2022) based on data collected and ranked related to three categories - culvert condition, vulnerability and priority. Within the "condition" risk category - data was collected and crossings were ranked based on erosion, embankment and blockage issues. The "climate" risk category included ranked assessments of the likelihood of both a flood event affecting the culvert as well as the consequence of a flood event affecting the culvert. Within the "priority" category the following factors were ranked - traffic volume, community access, cost, constructability, fish bearing status and environmental impacts (Table 3.8). This project is still in its early stages with methodology changes going forward.

```
# This line can be removed once Table.R is run. Just a work around for
        now.
xref_moti_climate_names <- sfpr_xref_moti_climate_names()

xref_moti_climate_names  %>%
  slice(7:nrow(.)) |>
  select(spdsht, report) |>
  rename(Parameter = spdsht, Description = report) |>
  fpr::fpr_kable(caption_text = 'Climate change data collected at MoTi
        culvert sites', scroll = gitbook_on)
```

Table 3.8: Climate change data collected at MoTi culvert sites

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

4 Results

```
sites_all <- fpr::fpr_db_query(
  query = "SELECT * FROM working.fp_sites_tracking"
)
```

```
# unique(sites_all$watershed_group_name)
#
# # here is a list of SERN wtershed groups
# wsg_skeena <- c("Bulkley River",
#                 "Zymoetz River",
#                 "Kispiox River",
#                 "Kalum River",
#                 "Morice River",
#                 "Parsnip River",
#                 "Carp Lake",
#                 "Crooked River")

# wsg_peace <- c(
#                 "Parsnip River",
#                 "Carp Lake",
#                 "Crooked River"
#                 )

# more straight forward is new graph only watersheds
wsg_ng <- "Elk River"

# here is a summary with Elk watershed group removed
sites_all_summary <- sites_all |>
  # make a flag column for uav flights
  dplyr::mutate(
    uav = dplyr::case_when(
      !is.na(link_uav1) ~ "yes",
      T ~ NA_character_
    )) |>
  # remove the elk counts
  dplyr::filter(!watershed_group %in% wsg_ng) |>
  dplyr::group_by(watershed_group) |>
  dplyr::summarise(
    dplyr::across(assessment:fish_sampling, ~ sum(!is.na(.x))),
    uav = sum(!is.na(uav))
  ) |>
  sf::st_drop_geometry() |>
  # make pretty names
```

```
  dplyr::rename_with(~ stringr::str_replace_all(., "_", " ") |>
                       stringr::str_to_title()) |>
  # annoying special case  dplyr::rename(
    `Drone Imagery` = Uav) |>   janitor::adorn_totals()
```

```
my_caption = "Summary of fish passage assessment procedures conducted
        in northern British Columbia through SERNbc."
my_tab_caption()
```

Table 4.1: Summary of fish passage assessment procedures conducted in northern British Columbia through SERNbc. **NOTE: To view all columns in the table - please click on one of the sort arrows within column headers before scrolling to the right.**

```
sites_all_summary |>
  dplyr::mutate(dplyr::across(everything(), as.character)) |>
  my_dt_table(
    page_length = 20,
```

```
    cols_freeze_left = 0              )
```

```
my_caption = "Details of fish passage assessment procedures conducted
        in northern British Columbia through SERNbc."
my_tab_caption(tip_flag = FALSE)
```

Table 4.2: Details of fish passage assessment procedures conducted in northern British Columbia through SERNbc.

```
sites_all |>
  sf::st_drop_geometry() |>
  dplyr::mutate(dplyr::across(everything(), as.character)) |>
  dplyr::relocate(watershed_group, .after = my_crossing_reference) |>
  dplyr::select(-idx) |>
  # make pretty names
  dplyr::rename_with(~ . |>
                       stringr::str_replace_all("_", " ") |>
                       stringr::str_replace_all("repo", "Report") |>
                       stringr::str_replace_all("uav", "Drone") |>
                       stringr::str_to_title()) |>
  # dplyr::arrange(desc(stream_crossing_id)) |>

  my_dt_table(
    cols_freeze_left = 1,
    escape = FALSE
  )
```

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

Changelog

fish_passage_reporting_template 0.0.1

- *2025-02-13*
    - Added 2025 data process scripts (01_prep_inputs).
    - Added of 2025 reporting scripts (02_reporting).
    - Added 2024 Peace data so report builds
    - Updated script readmes

Session Info

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

```
if(gitbook_on){
  devtools::session_info(to_file = 'session_info.csv')
} else {
  devtools::session_info()
}
```

Attachment 1 - Maps

All georeferenced field maps are presented at:

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

Maps are also available zipped for bulk download at:

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

Attachment 2 - Phase 1 Data and Photos

Data and photos for all Phase 1 (fish passage assessments) are provided online at https://www.newgraphenvironment.com/fish_passage_peace_2024_reporting/appendix---phase-1-fish-passage-assessment-data-and-photos.html - with a pdf version at https://github.com/NewGraphEnvironment/fish_passage_peace_2024_reporting/raw/main/docs/Attachment_2.pdf

Attachment 2 - Habitat Assessment and Fish Sampling Data

All field data collected is available here.

Habitat assessment data (including fish sampling and PIT tagging information) is available for download here.

Raw fish data is available for download here.