Co-development of framework for prioritizing culvert remediation; a case study from Simpcw Territory in the North Thompson watershed, B.C.

Violaine Pemberton-Renaud, Jeremy Sterling, Tina Donald, Sean Naman, and Emma Hodgson

North Thompson Salmon Ecosystems Research Program
Freshwater Ecosystems Section
Fisheries and Oceans Canada
Pacific Region
4222 Columbia Valley Hwy
Cultus Lake, BC, V2R 5B6

2024

Canadian Technical Report of Fisheries and Aquatic Sciences 3588

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 3588

2024

Co-development of framework for prioritizing culvert remediation; a case study from Simpcw Territory in the North Thompson watershed, B.C.

by

Violaine Pemberton-Renaud[1], Jeremy Sterling[2], Tina Donald[3], Sean Naman[1], and Emma Hodgson[1]

[1]North Thompson Salmon Ecosystems Research Program
Freshwater Ecosystems Section
Fisheries and Oceans Canada, Pacific Region
4222 Columbia Valley Hwy, Cultus Lake, BC, V2R 5B6

[2]Secwepemc Fisheries Commission
680 Athabasca St W, Kamloops, BC V2H 1C4

[3]Natural Resources Department
Simpcw
7555 Dunn Lake Road, Chu Chua, BC, V0E 1E0

Cat. No. Fs 97-6/3588E-PDF ISBN 978-0-660-69848-9 ISSN 1488-5379

Correct citation for this publication:

Pemberton-Renaud, V., Sterling, J., Donald, T., Naman, S., Hodgson, E. 2024. Co-development of framework for prioritizing culvert remediation; a case study from Simpcw Territory in the North Thompson watershed, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 3588: iv + 38 p.

TABLE OF CONTENTS

ABSTRACT

Pemberton-Renaud, V., Sterling, J., Donald, T., Naman, S., Hodgson, E. 2024. Co-development of framework for prioritizing culvert remediation; a case study from Simpcw Territory in the North Thompson watershed, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 3588: iv + 38 p.

Culverts that are associated with linear development (the building of roads and rail lines) passing over streams can pose barriers to fish passage. The resulting habitat fragmentation is a key threat to migratory fishes, including Pacific salmon. Restoring habitat connectivity through remediation of barrier culverts has been shown to be an effective management tool; however, high numbers of culverts combined with program and financial constraints necessitates strategic prioritization of culverts for remediation. While various approaches to prioritization exist, there is increasing recognition of the value of Indigenous knowledge in decision making processes, and the importance of working with the Nations in whose territory the work is being conducted. These are crucial components of a more ethical approach to research. Here, we describe a collaborative process where a prioritization framework was co-developed between DFO Science and First Nations partners and applied to culverts in the North Thompson watershed, British Columbia. Through this process, we iteratively refined a list of 19,417 modelled stream crossings into 12 priority barrier crossings. Key metrics incorporated into prioritization included culvert barrier status, number of downstream barrier culverts, length of potential habitat upstream, and presence of a known salmon spawning population in the tributary watershed.

RÉSUMÉ

Pemberton-Renaud, V., Sterling, J., Donald, T., Naman, S., Hodgson, E. 2024. Co-development of framework for prioritizing culvert remediation; a case study from Simpcw Territory in the North Thompson watershed, B.C. Can. Tech. Rep. Fish. Aquat. Sci. 3588: iv + 38 p.

Les ponceaux associés aux projets linéaires (construction de routes et de lignes ferroviaires) qui passent au-dessus des cours d’eau peuvent constituer des obstacles au passage des poissons. La fragmentation de l’habitat qui en résulte constitue une menace majeure pour les poissons migrateurs, notamment le saumon du Pacifique. Le rétablissement de la connectivité de l’habitat par la modification des ponceaux constituant un obstacle s’est avéré être un outil de gestion efficace; cependant, le nombre élevé de ponceaux, combiné aux contraintes financières et de programme, nécessite une priorisation stratégique des ponceaux à modifier. Bien qu’il existe divers méthodes de priorisation, on reconnaît de plus en plus la valeur du savoir autochtone dans les processus de prise de décision et l’importance de travailler avec les nations sur le territoire desquelles les travaux sont menés. Il s’agit là de composantes essentielles d’une approche plus éthique de la recherche. Nous décrivons ici un processus de collaboration dans le cadre duquel un cadre de priorisation a été élaboré conjointement par le secteur des sciences du MPO et des partenaires des Premières Nations, et appliqué aux ponceaux du bassin versant de la rivière Thompson Nord, en Colombie-Britannique. Ce processus nous a permis d’affiner de manière itérative une liste de 19 417 franchissements de cours d’eau modélisés et de déterminer 12 ponceaux prioritaires. Les paramètres clés intégrés dans l’établissement des priorités comprenaient l’état des ponceaux, le nombre de ponceaux constituant un barrière en aval, la longueur de l’habitat potentiel en amont et la présence dans le bassin d’une population de saumons reproductrice connue.

INTRODUCTION

British Columbia's Southern Interior salmon populations have been in decline for decades, with associated social and economic consequences (Irvine and Bradford 2000; Interior Fraser Coho Recovery Team 2006; Weir et al. 2022; Atlas et al. 2023). In the Thompson-Shuswap watershed, in Secwepemcúl'ecw territory, threatened Interior-Fraser coho (*Oncorhynchus kisutch*) (COSEWIC 2016), endangered Interior-Fraser steelhead (*O. mykiss*) (COSEWIC 2020), and endangered spring and summer run Chinook (*O. tshawytscha*) (Weir et al. 2022) have declined substantially; for example, coho returns declined up to 50% from 1988-1997 (Irvine and Bradford 2000). These populations are subject to cumulative anthropogenic pressures from land use change, in particular linear development and forestry (Bradford and Irvine 2000). Furthermore, such anthropogenic pressures are being exacerbated by climate change (Walters et al. 2013; Moore and Schindler 2022; Weller et al. 2023), with forecasts suggesting elevated stream temperatures and altered hydrology (e.g., higher peak flows and reduced baseflows) (Poff et al. 2002; Moore et al. 2009; DeBano et al. 2016; Weller et al. 2023). These existing and forecasted impacts will pose substantial cumulative pressure on freshwater habitat, which is crucial for anadromous salmonids.

The 2019 Recovery Potential Assessment for Interior Fraser Coho (DFO 2019) identified "*the three highest ranked anthropogenic threats to Interior Fraser Coho [as] modifications to catchment surfaces, linear development, and agricultural and forestry effluents*," all of which impact both freshwater habitat quality and quantity. Linear development, the building of connecting infrastructure such as roads and railroads, leads to the construction of stream crossings, often in the form of culverts (tunnels carrying the stream under the road or railway). When improperly constructed, installed, or maintained (see example in Figure 1), culverts may pose barriers to fish passage (Warren and Pardew 1998; Park et al. 2008; Miller 2012). The widespread presence of such culverts has led to extensive stream fragmentation, which is a major threat to freshwater systems (Fuller et al., 2015). In British Columbia there are estimated to be over 440,000 culverts (Thompson 2013), and previous reports suggest that between 50 and 90% of culverts are likely barriers to fish passage (Langill and Zamora 2002; Park et al. 2008; Miller 2012). Such stream fragmentation is especially detrimental to migratory fish that require access to diverse habitats to complete their life cycle; for example, stream-type anadromous Pacific salmon populations that have long juvenile rearing periods in freshwater before migrating to the ocean (Quinn 2018).

Figure 1. Example of barrier culvert on Chuck Creek, BC.

It is widely recognized by those who live and work within Secwepemcúl'ecw that both the quality and quantity of freshwater salmon habitat has decreased (Karakatsoulis et al. 2005; Cirque Resources and B Extension Services 2013; Ecoscape Environmental Consultants Ltd. 2020, 2022; SFC 2021), highlighting the need for restoration. Remediating barrier-forming culverts is an increasingly common restoration action and has been shown to effectively increase watershed connectivity and the availability of rearing and spawning habitat for salmon (Roni et al. 2002, 2008; Erkinaro et al. 2017; Wood et al. 2018; Clark et al. 2020). Yet, while the costs of culvert assessment and remediation are lower than many other larger-scale restoration actions (e.g., large-scale floodplain reconnection), the large number of problem culverts in many watersheds often greatly exceeds available funding and program capacity. Thus, effectively prioritizing culverts to focus remediation efforts is critical in order to maximize the benefits of this action (Mount et al. 2011; Beechie et al. 2012).

While there are numerous methods for prioritizing restoration projects (Roni et al. 2002; O'Hanley and Tomberlin 2005; Beechie et al. 2008; Kemp and O'Hanley 2010), it is increasingly recognized that local community values, and specifically, Indigenous knowledge and leadership, are integral to effective landscape and river restoration (Ens et al. 2012; Fox et al. 2017; Dickson-Hoyle et al. 2022; Salmond et al. 2022; Wickham et al. 2022). Furthermore, researchers trained in western science are moving toward more ethical approaches to research (Turner and Berkes 2006; Polfus et al. 2016; Artelle et al. 2018; Ban et al. 2018; Hovel et al. 2020; Wong et al. 2020; Atlas et al. 2021). In this paradigm, researchers co-develop projects with the communities and Nations in whose territories they conduct research (Bull 2010; Forbes et al. 2020; Breton-Honeyman et al. 2021; Dimayuga et al. 2023), which was our intention with this work. Here, we describe a restoration prioritization process developed collaboratively between Fisheries and Oceans Canada (DFO) scientists and First Nations partners, and applied to culverts in the North Thompson watershed, Simpcw territory, interior BC. This collaboration is between DFO, the Secwepemc Fisheries Commission (SFC), and Simpcw Natural Resources Department, with support from the Simpcw Resources Group Ltd. This work resulted from ongoing conversations and research on salmon populations in the North Thompson watershed within the Simpcw and Tk'emlúps te Secwepemc traditional territory.

BACKGROUND

The North Thompson watershed is located north of Kamloops, BC (Figure 2), and drains an area of approximately 20,676 km^2 (Harding et al. 1994). The North Thompson has headwaters in the Cariboo Mountains and flows south into the Thompson River, the longest tributary of the Fraser River, at Kamloops. The watershed is predominantly on the territory of Simpcw, one of the 17 Secwepemc bands, who have lived in the Thompson River Valley since time immemorial. It is also home to four anadromous Pacific salmon species: Chinook, coho, sockeye (*O. nerka*), and pink (*O. gorbuscha*). These are populations of high cultural, ecological, and economic value, several of which have been assessed as being of special concern or threatened (COSEWIC 2016, 2017; DFO 2019; Weir et al. 2022).

The region has extensive linear development (road density ranging from 0.3-3.2km km^{-2} for 28 local salmon-bearing watersheds withing the region), largely associated with forestry operations (Cunningham et al. 2023). Given the recognition of the impacts of linear development on threatened salmon populations in the region (Interior Fraser Coho Recovery Team 2006; DFO 2019), improving connectivity through culvert remediation has the potential to increase accessibility of important habitat. Therefore, identifying which crossings may limit habitat for salmon stocks and then creating a framework for prioritization to be used throughout Secwepemc territory has been identified as a useful process. This co-developed framework is intended for future use in other watersheds within Secwepemcúl’ecw, to maximize fish habitat for multiple salmon species and potentially improve passage for freshwater resident species.

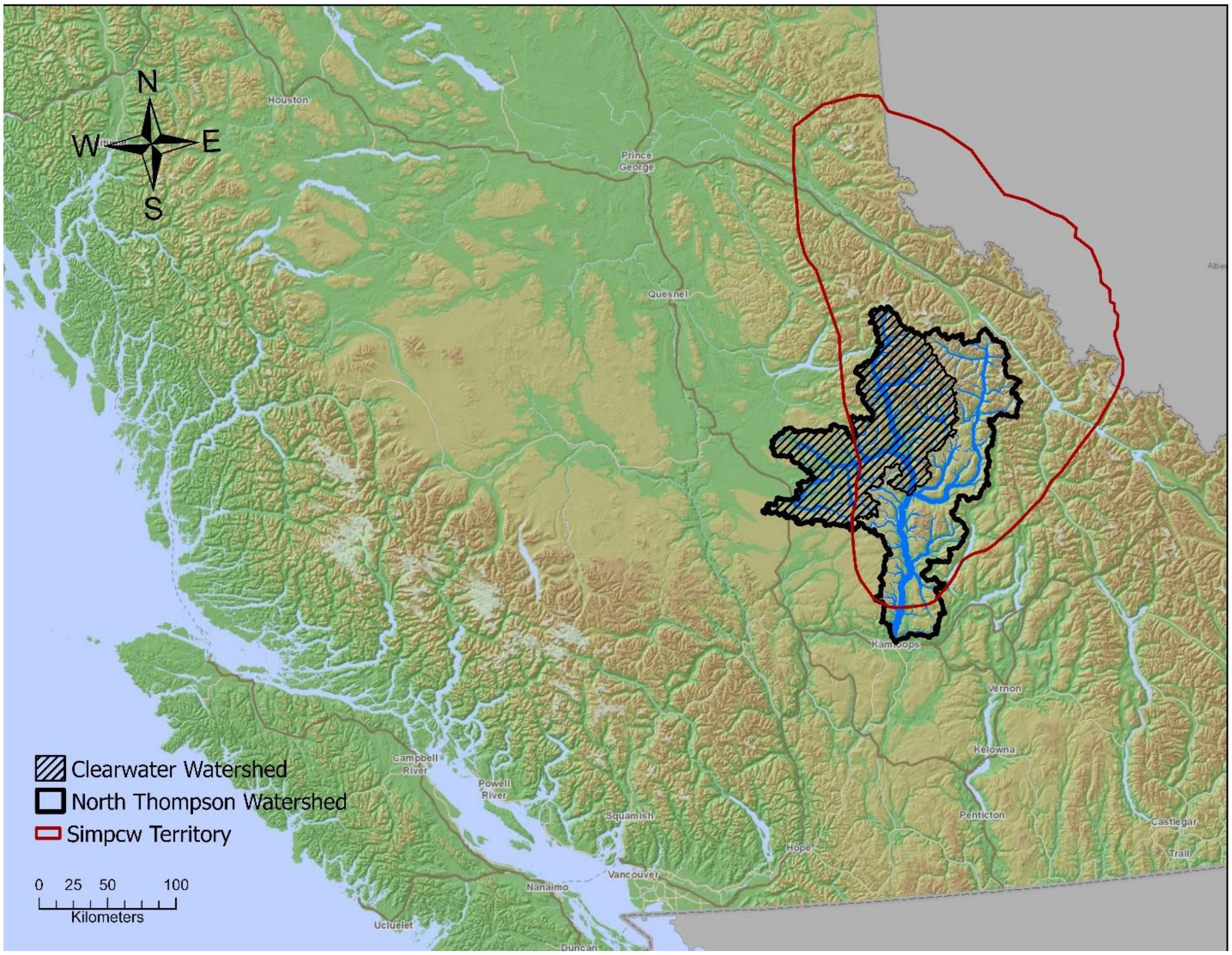


Figure 2: Location of study area, the North Thompson watershed, within British Columbia, Canada. The extent of the Simpcw territory is shown, and the Clearwater watershed (the largest tributary watershed within the North Thompson) is delineated as the vast majority of this region is not used by anadromous salmon and was not included in this project.

This work was developed as a collaboration between DFO, SFC, and the Simpcw Natural Resources Department, with support from Simpcw Resources Group Ltd. We are a collaborative group of non-Indigenous and Indigenous partners working to highlight the importance of Indigenous voices within restoration prioritization processes. Report authors (initials) VPR, EH, and SN work for DFO in the Freshwater Ecosystems Section in the Science Branch, Pacific Region. EH and SN, along with another research scientist, run the North Thompson Salmon Ecosystems Research Program that focuses on coho salmon in the North

Thompson watershed. JS works for SFC, whose mission is to support the work of the Secwepemc communities to provide stewardship for the fisheries in their territories and to assert their traditional fisheries rights within a co-management framework. TD works for the Simpcw Natural Resources Department in partnership with Simpcw Administration and Council, and is responsible for monitoring any activity or project that could impact the multitude of resources found in Simpcw Territory. A full list of team members who collaborated on the co-development of this prioritization framework is presented in Appendix A; however, we wish to highlight Caroline Feischl due to her extensive involvement in this collaboration. CF, who works closely with TD, is a biologist with Simpcw Resources Group Ltd., an environmental consulting company whose purpose is to generate income and employment for Simpcw members and focuses on using sustainable and environmentally responsible methods while respecting the culture of the nation.

APPROACH AND RESULTS

This project was carried out in three distinct phases (Figure 3): Phase 1 – Site selection and field assessments, Phase 2 – Culvert prioritization, and Phase 3 – Wrap-up and next steps. However, prior to Phase 1, in order to determine if there was interest in the work and whether it was a priority for communities in the region, there was a series of informal and formal discussions. To begin, there were informal conversations between DFO, Simpcw, and SFC; these included phone calls and discussion of the project idea at an annual update meeting held between DFO and SFC. When it became clear that this was a priority and related to work already underway (SFC had done a local culvert remediation in the year before this project began), a more formal community engagement process was initiated. This involved the distribution of a one-page project summary to all Secwepemc communities (written by DFO and distributed by SFC) and a presentation at an open forum to give interested community members a chance to learn more and ask questions. As the results of this again highlighted interest in the work and no major concerns, the research portion was initiated. In Phase 1, modelled stream crossings were refined down to a list of sites to field assess, field assessments were conducted, and barrier status was determined. In Phase 2, a series of meetings were convened to develop a prioritization framework for selecting barrier culverts on which to carry out in-depth upstream habitat confirmations for subsequent remediation. Necessary data layers were identified and collated for all barrier (and potential barrier) stream crossings, and a priority list of culverts was generated. Finally, in Phase 3, the team convened to debrief this collaborative process and discuss next steps to be undertaken.

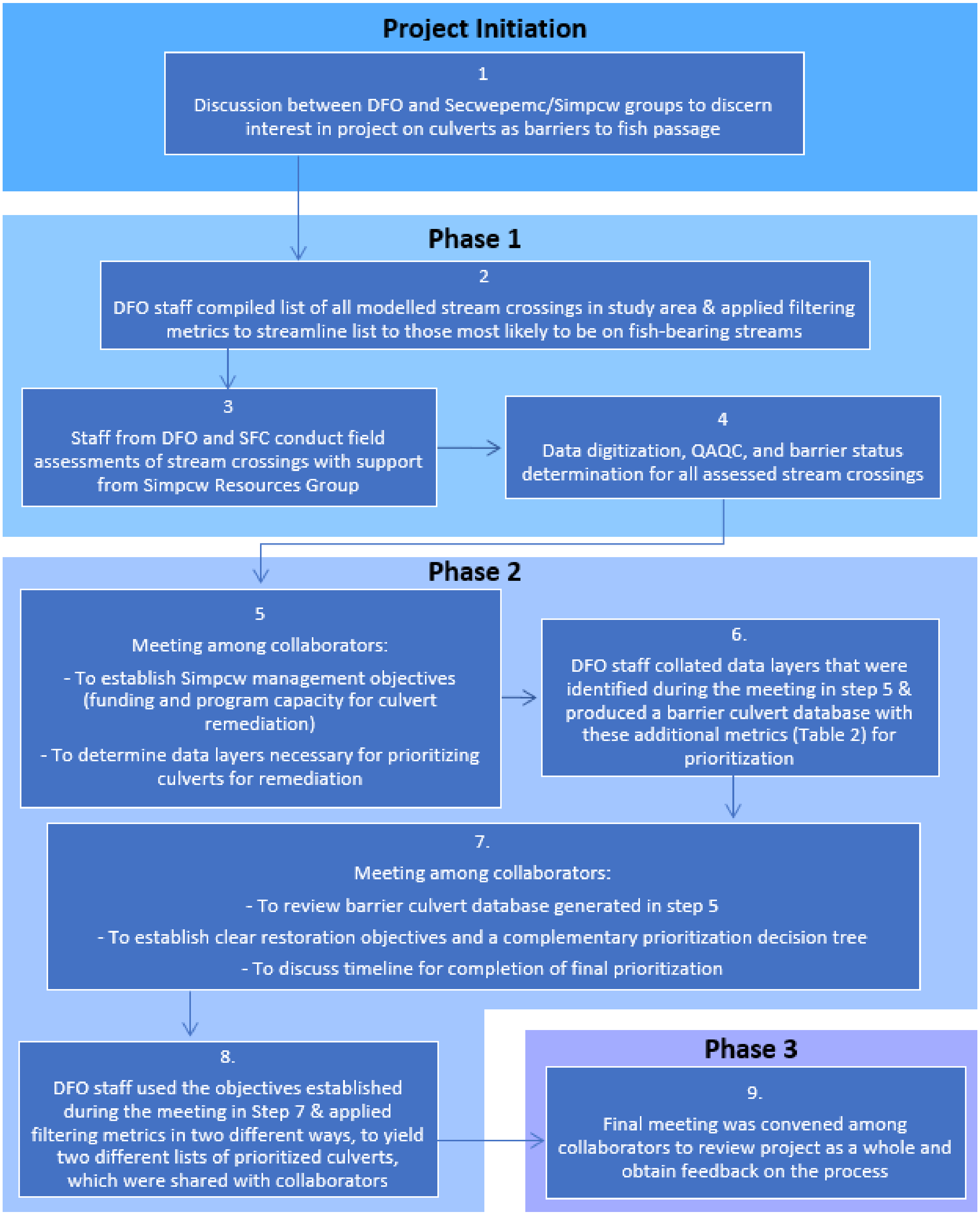


Figure 3: Flow chart summarizing steps taken throughout co-development of prioritization framework as applied to culverts in the North Thompson watershed.

Phase 1: Site Selection & Field Assessments

A series of steps were undertaken to: (a) identify culverts to assess, (b) conduct field assessments, and (c) input data into a database to determine which culverts pose as potential barriers to fish passage (Figure 3). We first collected and refined provincial data layers to determine where culverts were present in the watershed and to select which of those culverts would be assessed. We used the provincial stream crossings model (Mount et al. 2011) to obtain the locations of potential stream crossings in the North Thompson watershed. The model included all possible stream crossings (n = 19,417, Figure 4A), identified by layering provincial roads and rail layers with the stream network. We then applied a suite of six metrics (Table 1) to refine the list and remove crossings that were bridges or on stream segments unlikely to be salmon-bearing. These six metrics reduced the number of potential culverts to n = 403. As a final step, these 403 potential culverts were checked in Google Maps Satellite Imagery (Google Maps accessed August 2021) by two separate individuals and sites were eliminated from our list of crossings to field-assess if there was consensus that they were clearly bridges, cross-ditches, or that no stream crossing existed (see Appendix B for examples). Any crossings that were challenging to visually assess in Google Maps or for which the two individuals did not reach a consensus were retained in our list. The final list of stream crossings to field-assess contained 353 sites, ranging in location from Kamloops at the confluence with the South Thompson to the head waters of the North Thompson River (Figure 4B).

Table 1: Metrics from provincial stream crossings model (Mount et al. 2011) used to narrow down list of crossings and reasoning for their application.

Filtering Metric	Eliminated Data	Details and Reasoning
Watershed	• Crossings in Clearwater watershed	• Anadromous salmon populations are not known to spawn in the vast majority of this watershed (DFO 2019)
Crossing type	• Open-bottomed structures	• Sites known or modelled to be bridges, derived from data such as aerial surveys, size of river, etc. • Model assigned this status very conservatively • These were largely on streams of stream order 6+
Stream order	• Crossings on stream orders 1 & 2	• Lowest order streams are less likely to be important salmon spawning and rearing habitat (Reiser and Bjornn 1979; unpublished data on coho rearing habitats in the North Thompson, DFO) • Low order streams are more likely to be further from the mainstem and thus likely to have numerous culverts downstream of them
Habitat	• Crossings on stream reaches listed as non-fish habitat	• Stream reaches above known natural or anthropogenic barriers to fish passage (dams, large waterfalls, etc.)
Gradient	• Crossings on stream reaches with gradient > 15% downstream	• High gradient is a natural barrier to salmon migration
PSCIS status	• All crossings already present in PSCIS database	• These are crossings that have already been field-assessed and for which barrier status has been determined

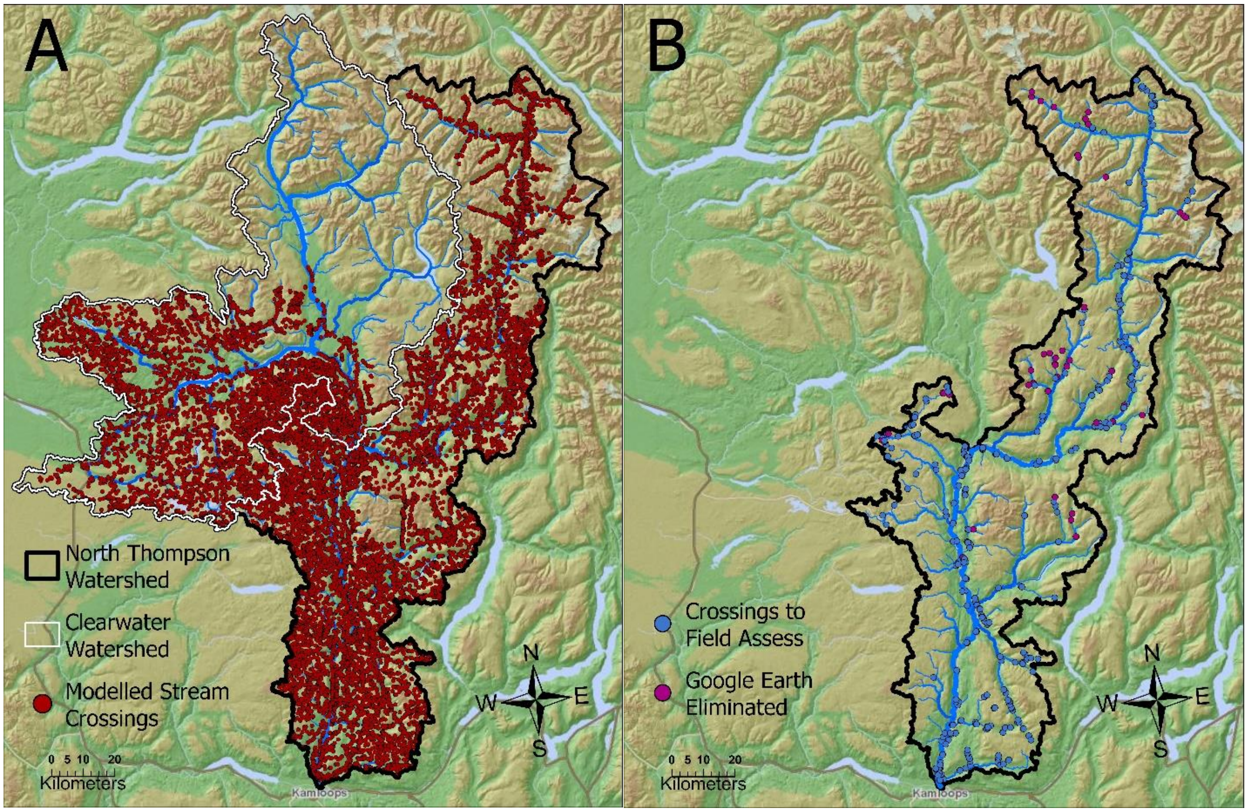


Figure 4: Maps of North Thompson watershed showing A) Clearwater watershed delineated with a white boundary and location of all modelled crossings in North Thompson watershed, and B) Clearwater watershed removed and location of modelled crossings selected for assessment after the application of filtering metrics shown in Table 1, with pink symbols denoting crossings that were subsequently eliminated after checking in Google Maps (2019).

Crews from Fisheries and Oceans Canada (DFO) and the Secwepemc Fisheries Commision (SFC) conducted field assessments of the identified 353 potential culverts in August and September 2021, and in August 2022. For one of the weeks that DFO crews were in the field in 2021, staff from Simpcw Resources Group Ltd. provided support. These assessments followed the protocol specified in the B.C. Ministry of Environment document *Field Assessment for Determining Fish Passage Status of Closed Bottom Structures* (B.C. Ministry of Environment 2011), with the addition of a few extra measurements (Appendix C), and involved the collection of a suite of data from each field site, including:

- GPS coordinates and access notes
- Stream channel width and gradient
- Culvert diameter, length, and slope
- Embedment of the culvert in the substrate (presence, depth)
- Height of outlet drop and depth of outlet pool

- Subjective measure of habitat quality immediately above and below the culvert (e.g. higher quality based on presence of deep pools, gravel of a size suitable for spawning, undercut banks, stable debris, etc.)

Field visits revealed additional cases where modelled culverts were bridges (n = 58), did not have any stream crossing structures (n = 101), or were inaccessible (n = 44). Modelled culverts that did not have any stream crossing structure were due to several possible reasons, with most falling into two categories: (1) no road crossing or (2) no stream. For those in the first category, there were instances where the road had been decommissioned and the culvert removed, leaving a cross-ditch. There were also instances where the road had never been built or had been built in such a way as to not cross the stream, as the provincial stream crossings model uses GIS layers that include all road permits. For the second category, there were instances where streams did not appear to exist, or where “streams” were drainage ditches or seasonal marshes and thus no formal stream crossing was built. These occurred generally in instances where the modelled streams were small (lowest stream magnitudes of stream order 3). Finally, some sites were not safely accessible by field crews (n = 44); for the most part these were higher in the drainage on poor quality logging roads. Collectively, this reduced the final number of assessed culverts and other possible barrier structures (e.g. concrete boxes and pipe arches) to 157 (Fig 5A).

After field data was collected and digitized, barrier scores and status were computed for each crossing using the approach developed by the Province of B.C. (B.C. Ministry of Environment 2011). This method uses several primary fish passage criteria in order to assign a barrier score from which a status of either passable, potential barrier, or barrier is assigned. These fish passage criteria include:

- Culvert length
- Culvert slope
- Outlet drop
- Stream width ratio (downstream channel width relative to culvert diameter)
- Embedment score (based on depth of embedment relative to culvert diameter)

These criteria highlight the main factors that make culverts impassable: high velocities and turbulence inside the culvert, and large drops at the culvert outlet. These methods are a coarse assessment of culvert passability, and not specific to an individual species (see Bourne et al. 2011 for other methods).

While the provincial method for culvert assessments classifies pipe arches as Open-Bottom Structures (OBS), in the same category as bridges, we completed full crossing assessments on pipe arches and, based on the above described barrier status determination, four pipe arches were determined to be barriers and two were classed as potential barriers (see Appendix D for details). As such, they were included in subsequent barrier stream crossing prioritization and are considered Closed-Bottom Structures (CBS) for the purpose of this report. In total we completed 157 full crossing assessments. Of those, 108 were determined to be barriers, 22 were determined to be potential barriers, and 22 were determined to be passable. There were also 5 CBS for which no barrier status could be determined as there were elements of the site that prevented field crews from obtaining certain measurements and thus the barrier score metric was incomplete (Figure 5B).

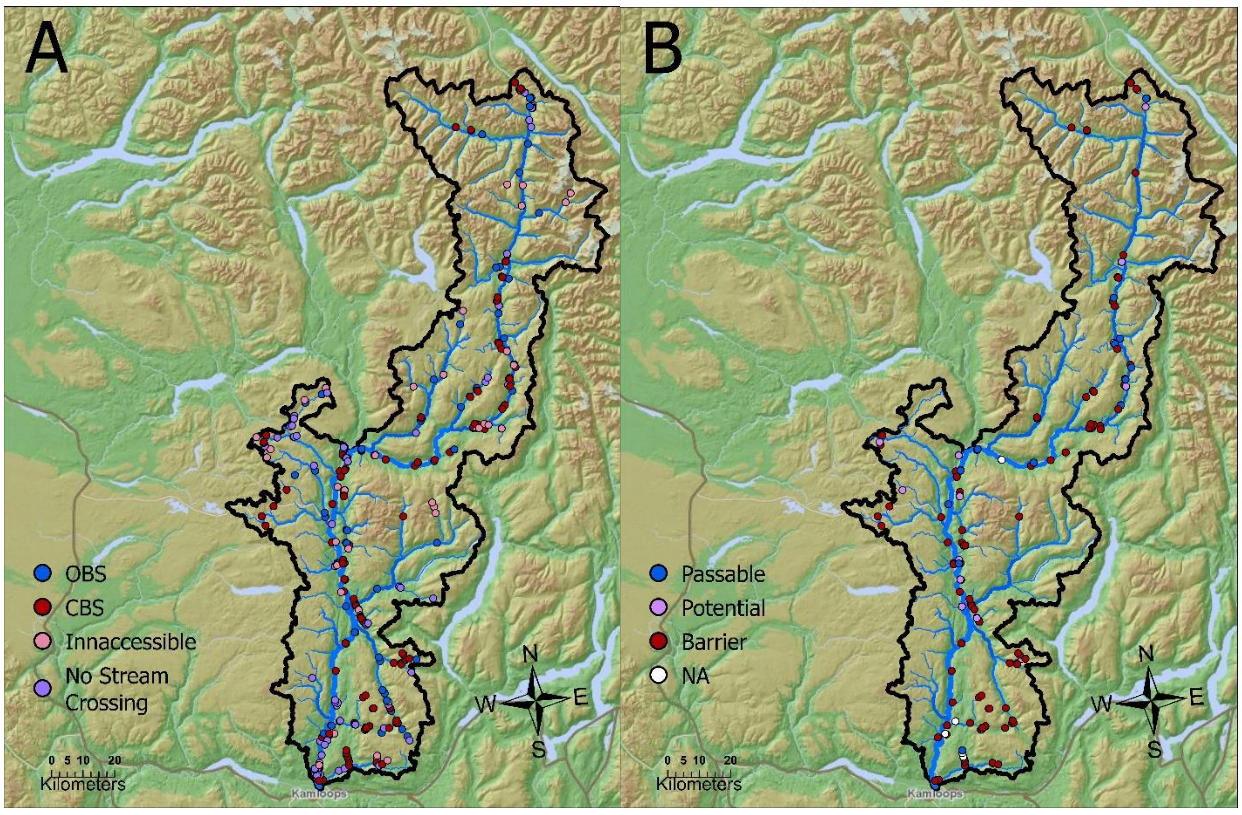


Figure 5: Map of study area (North Thompson watershed with Clearwater watershed removed) showing location and A) crossing type for all modelled crossings selected for field assessment, demarcated by symbol colour, B) barrier status of all Close-Bottomed Structures (CBS), demarcated by symbol colour. Note that we use the term culvert to encompass all types of potential barrier crossings, including culverts, concrete boxes, and pipe arches.

Phase 2: Culvert Prioritization

Following the completion of Phase 1, there was interest and program capacity within SFC and Simpcw Resources Group Ltd. to proceed with remediating several stream crossings. This raised the question – how best to proceed in prioritizing barrier (or potential barrier) stream crossings for remediation? The provincial culvert assessment protocol suggests a standard series of steps following the initial assessment of a culvert and determination of it being a likely barrier to fish passage: (1) a more in-depth upstream habitat confirmation, (2) commission of a site plan and remediation design including engineering plans and cost estimates, and (3) carrying out construction of the design from (2) to remediate the stream crossing (Fish Passage Technical Working Group 2014). The first step (1), an in-depth upstream habitat assessment, is conducted to verify the quality and accessibility of upstream habitat beyond the immediate vicinity of the stream crossing, i.e., to confirm there are no unknown natural or anthropogenic barriers nearby. This is an important step to complete prior to moving forward with costly restoration projects. However, even this step requires effective site prioritization and a refined list of culverts as it involves time-intensive fieldwork. Thus, the collaborative group (Appendix A) convened a series of meetings. The first meeting focused on identifying prioritization goals and a list of metrics that would feed into prioritizing culverts for remediation. Then, the second meeting focused on decision trees to narrow down the list of barrier or potential barrier crossings after data layers had been collated. This section will detail these two meetings and the associated data collation. A final meeting (Phase 3) was held to review the project and gain feedback, and will be discussed in the next section of this report. For ease we will refer to barrier stream crossings as culverts; however, as noted at the end of Phase 1, the barrier crossing database does include six pipe arches and one concrete box.

The first meeting listed above was held to discuss group goals and identify the layers of information needed for prioritization. During this meeting it was agreed upon that the broad goal was to identify sites that would maximize salmon habitat increases if remediated, and more specifically to develop an effective and repeatable process for prioritizing culverts for habitat confirmations. The final suite of metrics collated were identified through an iterative process. At this meeting, data layers were discussed and a comprehensive list of potential metrics was compiled. However, as data collation proceeded, some metrics were determined to be unnecessary or beyond the scope of this stage of the process (Appendix E), additional metrics were identified to be important, and some metrics were adjusted to match information currently available. Two metrics, remediation cost and cultural importance, were flagged as important considerations in prioritizing culverts but beyond the scope of this step of the process. Remediation cost involves cost-benefit analysis that requires engineering and financial expertise beyond that of this group, and cultural importance should be determined solely by Simpcw. These metrics were therefore left out of the final database, resulting in a suite of 25 metrics (Table 2).

DFO co-authors then compiled all data layers for each barrier or potential barrier culvert in the database. Previously assessed barrier and potential barrier crossings from the Provincial Stream Crossing Information System (PSCIS) were added to our crossing database so that all known barrier and potential barrier crossings in the study area were included. Crossing data (coordinates, crossing type, and barrier status) as well as upstream habitat quality were obtained from our field assessments and barrier status determination (Phase 1) or from PSCIS data. Local watershed and tributary watershed data was obtained from the publicly available Freshwater Atlas Named Watersheds data layer (BC data catalogue). Presence of a spawning population, species of spawning populations, and 10-year mean escapement estimates were obtained from the Chinook and Coho Fraser and Interior Stock Assessment and the Sockeye Fraser and Interior Stock Assessment groups within DFO. Data for number of at-risk conservation units by watershed was provided by SFC, and upstream gradient data and land owner information (if available) was obtained from the stream crossings model (Mount et al. 2011). ArcGIS Pro 2.8 was used for all spatial data visualization and analyses.

Table 2: Final database columns and notes on the data or data source, showing the 25 metrics that were compiled into a database for all barrier and potential barrier stream crossings in the study area.

Final Database Columns	Notes on Final Database Columns
Year	Year of assessment
Crossing ID	
Longitude	
Latitude	
Crossing Type	OBS or CBS
Crossing Subtype	e.g. Round culvert, concrete box, etc.
Barrier Status	Potential barrier or Barrier
Local watershed	Watershed of stream where crossing is located
Tributary watershed	Watershed of tributary to North Thompson (often larger than local watershed and encompasses local watershed)
Known spawning population	Does the tributary watershed have a known spawning population (Y/N)
Salmon species	Species of known spawning populations in local watershed
Sockeye escapement	• 10-year mean

	• Data from Fraser and Interior Stock Assessment (DFO)
Coho escapement	• 10-year mean • Data from Fraser and Interior Stock Assessment (DFO)
Chinook escapement	• 10-year mean • Data from Fraser and Interior Stock Assessment (DFO)
Number of downstream barrier culverts	Calculated in ArcGIS
Number of upstream barrier culverts	Calculated in ArcGIS
Distance to the closest upstream barrier culvert (km)	Calculated in ArcGIS
Number of at-risk conservation units (CU) in tributary watershed	Provided by the Secwepemc Fisheries Commission
Upstream length (km) of 0-3% gradient habitat until 15% gradient barrier	Obtained from the provincial stream crossings model
Upstream length (km) of 3-5% gradient habitat until 15% gradient barrier	Obtained from the provincial stream crossings model
Upstream length (km) of 5-8% gradient habitat until 15% gradient barrier	Obtained from the provincial stream crossings model
Upstream length (km) of 8-15% gradient habitat until 15% gradient barrier	Obtained from the provincial stream crossings model
Upstream length (km) of 0-5% gradient habitat until a culvert or gradient barrier	The upstream length of 0-5% habitat until a barrier culvert or a 15% gradient barrier Calculated from: • Distance to closest upstream culvert barrier • Upstream length of 0-3% habitat until a 15% gradient barrier • Upstream length of 3-5% habitat until a 15% gradient barrier
Upstream habitat quality (Low, Med, High)	Collected during the culvert assessment – subjective measure of habitat immediately upstream of culvert
Land owner (if known, e.g. CN rail)	Obtained from the provincial stream crossings model

Following the completion of the database, the second meeting was convened to identify a prioritization decision tree that would best fit management objectives. While the clear objective among all parties was increasing access to salmon habitat, different projects and funding sources might necessitate different priorities; for example, some funding sources may require targeting watersheds with more than one at-risk Conservation Units (CU). Thus, a single consensus was difficult to achieve. From these discussions, it was agreed upon that DFO co-authors would develop several prioritization schemes based on different objectives. This would allow future decision-making to be dynamic and adjust to variable funding and community priorities. Three universal filtering metrics were agreed upon and ranked. The top-ranked filter was number of downstream barrier culverts, which would also have to be remediated for anadromous connectivity to be restored. While this was a crucial first metric, we did not immediately remove all crossings with downstream barrier culverts, as we considered the possibility that remediation of multiple culverts in succession on a stream might be worthwhile if all other metrics indicated an extremely high quality and quantity of upstream habitat. The second filter was upstream distance (km) of potential spawning and/or rearing habitat (0-5% gradient; combining columns 0-3 and 3-5% gradient) until reaching a barrier (either a >15% gradient barrier or another barrier culvert). The third filter was presence of a known salmon spawning population in the tributary watershed (e.g., at the scale of Lemieux Creek watershed or Albreda River watershed). These filters were selected because restoring access to potential salmon habitat was identified as the main priority for restoration efforts. Prioritizing barriers over potential barriers in the database was discussed, but ultimately we did not filter out potential barriers given that they still could be a barrier to certain life stages or at certain times of the year, and if located on a very high-value stream segment might be of higher priority for remediation than other barriers. Other filters discussed included salmon escapement estimates and the number of at-risk conservation units in the watershed. It is also important to note that cultural importance, which had been flagged in an earlier meeting as a critical consideration for prioritization, was further discussed in this meeting. It was reiterated that this would be an independent process for Simpcw and thus would be applied after the short list was supplied by DFO.

The final filtering steps were determined iteratively and ultimately only included the three top-ranked filtering metrics. First, a cutoff of maximum two downstream blocked culverts paired with minimum two kilometers of potential upstream salmon habitat was established. This resulted in the list of 130 culverts being narrowed down to only 17. A third filter was then applied, removing culverts in tributary watersheds with no known salmon spawning population, which yielded a list of 12 (Figure 6). Interestingly, the 12 culverts that were selected by applying these filters were all in watersheds with at least one at-risk CU (another prioritization priority), thus rendering that filter redundant. As the final number of 12 sites was deemed feasible for field habitat confirmations, it was determined that there was no need to add other metrics and further refine the list. DFO co-authors then shared with collaborators the list of twelve priority culverts, along with details of the metrics and cutoffs that had been used to generate them. The complete barrier culvert database was also shared with collaborators, should any group wish to apply different prioritization metrics in the future.

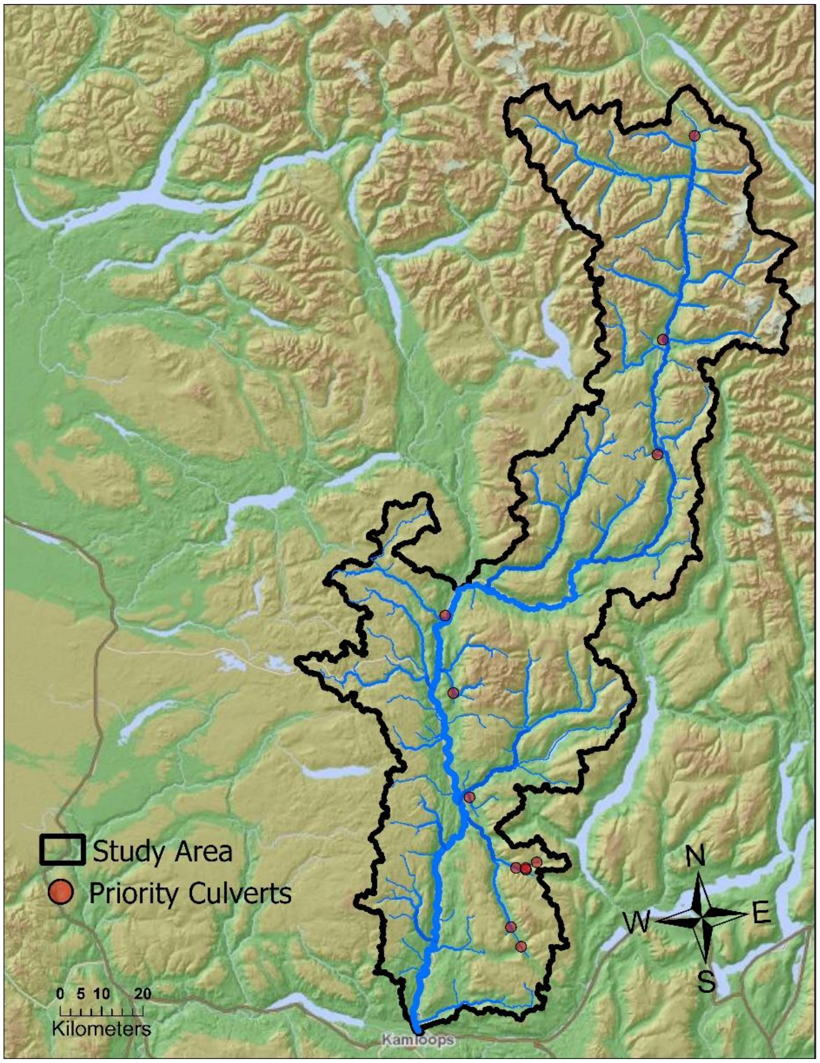


Figure 6: Location of priority stream crossings (n=12) selected by the prioritization framework described above.

Phase 3: Project Wrap-up & Next Steps

Feedback from collaborators and team members was very positive. All parties noted that communication among groups was effective, that the needs of each group were met, and that the process was meaningfully collaborative. However, with any collaborative process there are learnings and areas to improve. In this case, we identified four areas that could be approached differently. First, the provincial Fish Passage Technical Working group have a great wealth of knowledge on culvert remediation, and they were consulted at the beginning of Phase 1, and midway through Phase 2. Consultation earlier in Phase 2 would have allowed for greater efficiency. Second, we used the B.C. Ministry of Environment's stream crossing assessment method (B.C. Ministry of Environment 2011), which is a fairly coarse protocol and may be overly conservative in determining barrier status compared to other methods (Bourne et al. 2011). Future processes could benefit from a refined stream crossing assessment protocol, particularly if a specific target species is the focus rather than all life stages of all salmonids in the region as was the case in this project. Third, increased communication with SFC during Stage 1 to ensure consistency in data format and details between crews from both groups would have streamlined subsequent data entry and analysis. Finally, Indigenous Knowledge could potentially be included in earlier stages (e.g. in Step 2 of Table 2). This was out of the scope of this project, and of course working with Indigenous Knowledge would require its own ethical responsibilities and approval processes.

Follow-up work has been undertaken by Simpcw and Secwepemc partners on this project, including the incorporation of cultural values to the prioritization framework, and follow-up habitat confirmations. The Simpcw Natural Resources Department has six directives that dictate their work, one of these being Séwllkwe (water), with seven priority rivers and one of the priority actions being enhancement of fish habitat (Appendix F). These directives are used to inform Simpcw work and are sent to all collaborators or companies that want to undertake work in the territory, whether government, scientific, or industry. The Simpcw also have cultural knowledge that is held in their Knowledge Keeper app, a spatially-explicit software that holds Simpcw knowledge regarding elements such as wildlife use areas and traditional and contemporary fishing, hunting, and gathering sites. These layers of information, the six directives and the Knowledge Keeper app, were used in conjunction with knowledge from individual knowledge holders, to inform a cultural layer and further prioritize streams. It is beyond the scope of this report to include any cultural knowledge information in our reporting; moreover, it would not meet our ethical obligations for the treatment of Indigenous data. However, we wanted to highlight the elements that went into the cultural layer, and the importance of cultural knowledge being used to inform restoration prioritization.

Follow-up habitat confirmations have been undertaken on five priority culverts in the North Thompson. As noted previously, these habitat confirmations are used to verify habitat quality and quantity upstream of priority culverts as proposed by the provincial method (Fish Passage

Technical Working Group 2014). Simpcw Resources Group, with support from SFC, conducted five of these in fall of 2022 (further sites were not accessible due to an early freeze in the watershed). First Nations partners are now moving forward with restoration engineering plans for two sites: Louis Creek (NT-072) and McTaggart Creek (NT-128).

DISCUSSION

As a collaborative group involving Fisheries and Oceans Canada (DFO), Simpcw, and the Secwepemc Fisheries Commission (SFC), we developed a restoration prioritization framework, and applied it to culverts as potential barriers to passage of Pacific salmon in the North Thompson watershed. This work highlights how widespread barrier culverts are within an important salmon-bearing watershed in British Columbia. Such data are valuable as barrier culverts and the resulting habitat fragmentation is recognized as a major threat to freshwater systems (Fuller et al. 2015; DFO 2019); a threat to which anadromous Pacific salmon are particularly sensitive (Quinn 2018). Moreover, this study provides a comprehensive prioritization framework for culvert restoration. The framework we developed utilized a broad database and is repeatable, making it applicable to other restoration priorities and for use in other watersheds. It also incorporated both extensive field assessments to determine barrier status as well as a desktop GIS exercise to prioritize barrier culverts for in-depth upstream habitat confirmations, setting it apart from another recently developed culvert restoration prioritization framework (Mazany-Wright et al. 2021). Finally, this work highlights the importance of working in collaboration with Nations in restoration processes and of ongoing relationship building between researchers trained in Western science and Indigenous partners. Such collaboration is not only ethical (Bull 2010; Dimayuga et al. 2023) but also integral for effective habitat management and restoration (Breton-Honeyman et al. 2021; Dickson-Hoyle et al. 2022; Fish and Fish Habitat Protection Program and DFO 2022).

In Phase 1 of this work, we conducted field assessments and subsequent barrier status determination of 157 culverts following the provincial method (B.C. Ministry of Environment 2011; Mount et al. 2011; Fish Passage Technical Working Group 2014), with results in line with prior estimates from the literature. We found that 72% of assessed culverts were barriers to fish passage, with an additional 15% being potential barriers. Previous studies and models estimate that between 50% to 90% of culverts are likely barriers to fish passage (Langill and Zamora 2002; Park et al. 2008; Miller 2012). This places our results in the mid to upper range of previous estimates, supporting claims that barrier culverts are widespread and a major cause of stream fragmentation and reduced watershed connectivity (Langill and Zamora 2002; Fuller et al. 2015; Finn et al. 2021).

Despite the high proportion of barrier culverts that we found in Phase 1, and the associated biotic and abiotic impacts on the watershed, the location of these barriers suggests that their impacts may not be as severe for Pacific salmon habitat. Many of the stream reaches found to have problem culverts were small low order streams with naturally low average flow or other poor habitat characteristics, making them unlikely to be salmon-bearing stream reaches. Moreover, observationally stream crossings on known important salmon bearing stream reaches were often bridges or well-constructed passable culverts (pipe arches). However, even these well-constructed culverts may still pose habitat fragmentation challenges for other fish species. Culverts can impact resident fish community structure and population diversity (Torterotot et al. 2014; Evans et al. 2015), and abiotic characteristics such as sediment transport which can negatively impact downstream habitat quality (Cocchiglia et al. 2012; Pépino et al. 2012; Frankiewicz et al. 2021). These results for the North Thompson watershed suggest that while barrier culverts are indeed a concern and a likely source of widespread stream fragmentation, they may not be quite as detrimental to Pacific salmon habitat.

Collectively, it is important to consider our approach to culvert prioritization relative to other prioritization methods. In particular, differences in workload among prioritization processes strongly influence their relative utility. Here, we conducted a brief desktop exercise (Figure 3, Step 2) to refine the list of potential stream crossings to those most likely to be closed bottom structures on salmon bearing streams, and then moved directly to fairly extensive field assessments (visiting 353 sites), after which a more in-depth desktop exercise was performed with the data from the field assessments. Follow-up habitat confirmations were then conducted by collaborators. In contrast, the Canadian Wildlife Federation (CWF) recently created their own process for culvert prioritization (Mazany-Wright et al. 2021), that involved a much more in-depth and detailed desktop exercise. Field assessments for confirmation of barrier status were only completed on a select few high priority sites and habitat confirmation was conducted at the same time as the initial assessment, since only a few were undertaken. The merits of the CWF approach are apparent in light of our results, where many culverts that we included in our field assessments were on stream reaches that were ultimately deemed low-priority for salmon habitat restoration (e.g. no known spawning population in tributary watershed, proximal high gradient natural barriers upstream, etc.). An exercise focused more heavily on the desktop analysis before conducting field assessments limits the expense and time needed for the latter. However, while this may be more efficient with regards to focused habitat remediation prioritization, there are numerous benefits to the approach that we employed in this process. Assessing barrier status of culverts throughout the watershed provides data on how widespread culvert barriers are within the area and insight into fragmentation at a watershed level. This watershed-scale fragmentation data feeds into larger-scale restoration and planning exercises occurring in the region, as well as supporting a broad goal of determining the extent of culvert barrier issues in B.C. Towards the latter, the data collected during our extensive field assessments of stream crossings is publicly available in the PSCIS database (Miller 2012; Fish Passage Technical Working Group 2014) and also provides data for refinement of the PSCIS model, which is utilized province-wide (Mount et al. 2011). Finally, as highlighted by collaborators at SFC, there is immeasurable value in physically visiting sites, to observe both the watershed more broadly and also specific locations. This can inform an understanding of the system, and may allow for observation of specific problem-locations that would not otherwise be detected. Therefore, either method (or a combination of the two) may be beneficial depending on the goals of the project.

During our process, a principal challenge we encountered in developing the metrics for prioritization (Fig 3, steps 5 & 6) was the level of detail to include. There were many data layers that were considered potentially relevant, with increasing levels of detail (for example, distance from a culvert to a known salmon spawning site, distance from a culvert to adult coho migration corridors, etc.). Ultimately, we determined that it was preferable to remain lower resolution in the metrics incorporated into the database. The reasoning for this was twofold. First, if simpler methods were sufficient to address prioritization goals (i.e. prioritize culverts on potential salmon habitat and yield a number of priority culverts on which completing habitat confirmations was feasible within program capacity), they were preferred as it reduces staff time and program resources. Second, our goal was for a database that was easy to use and replicable for other areas, so remaining at a higher level was deemed both sufficient and preferable for our specific scope. We do note though, that validation was not undertaken and is a potential area for improvement. Our methods for prioritization in this process were semi-quantitative, and a potential improvement and method of validation would be to incorporate further quantitative methods such as a calculation of the dendritic connectivity index (DCI) (Cote et al. 2009) as a final step in the prioritization process. Additionally, although beyond the scope of this project, we wish to highlight the importance of monitoring following culvert remediation, to ensure effectiveness of restoration efforts and to inform future restoration planning (Ogren and Huckins 2015; Erkinaro et al. 2017; Mahlum et al. 2018).

This prioritization process as applied to culverts in the North Thompson highlights the value and importance of ethical collaboration with Indigenous groups, as well as the practical benefits of co-development. Though obvious, it is important to highlight that unlike Western scientists who are often trained and live elsewhere, representatives from Simpcw and SFC have local knowledge of the watershed, and Simpcw community members hold extensive knowledge of their territory beyond anything a researcher can learn. For example, the sharing of high fishery value streams holds profound cultural and ecological importance. These waterways serve as essential components of both traditional practices and ecological composition. Moreover, Simpcw organizations have the ability to take the work a step beyond that of DFO, by applying cultural knowledge to the restoration prioritization process. This lends support to a growing body of work documenting how co-development is integral to effective prioritization and a crucial component to ethical research and reconciliation (Dickson-Hoyle et al. 2022; Wickham et al. 2022). Furthermore, the collaborative approach allowed us to benefit from capacity on all fronts. DFO co-authors with the North Thompson Salmon Ecosystems Research Program had program capacity to conduct initial GIS culvert site selection and in-the-field culvert barrier assessments throughout the watershed, while SFC and Simpcw had capacity for subsequent habitat confirmations and funding to move forward with culvert restoration for select high priority barrier sites.

The groups involved in this project have extensive research programs in the North Thompson watershed and the project itself arose out of existing relationships between the North Thompson Salmon Ecosystems Research Program, Simpcw, and SFC. Ongoing relationships between researchers and Nations are vital to successful collaborations, allowing for those involved to work together as research programs expand and community needs evolve (Bull 2010; Hovel et al. 2020). Currently, DFO's North Thompson Salmon Ecosystems Research Program has numerous projects in the area including research focused on coho salmon habitat productivity, coho salmon habitat use, and environmental monitoring. Similarly, SFC has many other programs in the North Thompson Watershed. These programs include leading sensitive habitat inventory mapping (SHIM) and thermal drone imagery assessments on several North Thompson tributaries, with plans for subsequent salmon habitat restoration activities. As well, in conjunction with Simpcw Resources Group Ltd., they are undertaking ongoing water quality and flow monitoring of two major tributaries of the North Thompson. Thus, we explored culverts as barriers in the context of widespread research programs and highlighted the importance of ongoing relationships in collaborative work between Western science and First Nations partners.

Finally, while the co-developed prioritization process described here was developed for the North Thompson, this process was undertaken with the intention that it could serve as a model to be applied to other watersheds and utilized by other groups. SFC has already applied this process to culverts in the Bessette watershed, resulting in two priority culverts for remediation, and intends to move forward with this process in other watersheds within the Secwepemc territory.

ACKNOWLEDGMENTS

We thank our three collaborative team members, Aaron Gillespie, Caroline Feischl, and Ceryne Staples, who were integral to the process. We would also like to express our gratitude to Pat Matthew, Craig Mount, Simon Norris, Murray Ross, and Bill Rublee for their contributions to meetings and discussions of various pieces of this project, and to everyone who assisted in the field culvert assessments: Jillian Atkinson, Jessie Chestnut, Jacob Guerin, Jordan Motruk, Amanda Celesta, Kirsten Bradford, Brittany Milner, and Lida Nguyen-Dang. Finally, we would also like to acknowledge those who provided DFO peer-review, David Cote and Colin Gallagher, whose reviews and comments strengthened this report.

REFERENCES

Artelle, K.A., Stephenson, J., Bragg, C., Housty, J.A., Housty, W.G., Kawharu, M., and Turner, N.J. 2018. Values-led management: the guidance of place-based values in environmental relationships of the past, present, and future. Ecol. Soc. **23**(3): 35. doi:10.5751/ES-10357-230335.

Atlas, W.I., Ban, N.C., Moore, J.W., Tuohy, A.M., Greening, S., Reid, A.J., Morven, N., White, E., Housty, W.G., Housty, J.A., Service, C.N., Greba, L., Harrison, S., Sharpe, C., Butts, K.I.R., Shepert, W.M., Sweeney-Bergen, E., Macintyre, D., Sloat, M.R., and Connors, K. 2021. Indigenous Systems of Management for Culturally and Ecologically Resilient Pacific Salmon (Oncorhynchus spp.) Fisheries. Bioscience **71**(2): 186–204. doi:10.1093/biosci/biaa144.

Atlas, W.I., Sloat, M.R., Satterthwaite, W.H., Buehrens, T.W., Parken, C.K., Moore, J.W., Mantua, N.J., Hart, J., and Potapova, A. 2023. Trends in Chinook salmon spawner abundance and total run size highlight linkages between life history, geography and decline. Fish Fish. **24**: 595–617. doi:10.1111/faf.12750.

B.C. Ministry of Environment. 2011. Field Assessment for Determining Fish Passage Status Of Closed Bottom Structures. Available from http://www.for.gov.bc.ca/ftp/hcp/external/!publish/web/fia/Field-Assessment-forDetermining-Fish-Passage-Status-of-CBS.pdf.

Ban, N.C., Frid, A., Reid, M., Edgar, B., Shaw, D., and Siwallace, P. 2018. Incorporate Indigenous perspectives for impactful research and effective management. Nat. Ecol. Evol. **2**(11): 1680–1683. doi:10.1038/s41559-018-0706-0.

Beechie, T., Pess, G., Roni, P., and Giannico, G. 2008. Setting River Restoration Priorities: A Review of Approaches and a General Protocol for Identifying and Prioritizing Actions. North Am. J. Fish. Manag. **28**(3): 891–905. doi:10.1577/M06-174.1.

Beechie, T., Roni, P., and Beechie, T. 2012. Prioritization of Watersheds and Restoration Projects. *In* Stream and Watershed Restoration. *Edited by* P. Roni and T. Beechie. John Wiley & Sons, Incorporated, United Kingdom. pp. 189–214. doi:10.1002/9781118406618.ch6.

Bourne, C.M., Kehler, D.G., Wiersma, Y.F., and Cote, D. 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. Aquat. Ecol. **45**: 389-403. doi:10.1007/s10452-011-9362-z .

Bradford, M.J., and Irvine, J.R. 2000. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. Can. J. Fish. Aquat. Sci. **57**(1): 13–16. doi:10.1139/f99-283.

Breton-Honeyman, K., Huntington, H.P., Basterfield, M., Campbell, K., Dicker, J., Gray, T., Jakobsen, A.E.R., Jean-Gagnon, F., Lee, D., Laing, R., Loseto, L., McCarney, P., Noksana Jr, J., Palliser, T., Ruben, L., Tartak, C., Townley, J., and Zdor, E. 2021. Beluga whale stewardship and collaborative research practices among Indigenous peoples in the Arctic. Polar Res. **40**. doi:10.33265/polar.v40.5522.

Bull, J.R. 2010. Research with Aboriginal Peoples: Authentic Relationships as a Precursor to Ethical Research. J. Empir. Res. Hum. Res. Ethics **5**(4): 13–22. doi:10.1525/jer.2010.5.4.13.

Cirque Resources and B Extension Services. 2013. Skeetchestn Land and Resource Management Plan Deadman Watershed. Available from https://skeetchestnnr.ca/wp-content/uploads/2016/11/SkeetchestnFinal-LUP-September-2013.pdf.

Clark, C., Roni, P., Keeton, J., and Pess, G. 2020. Evaluation of the removal of impassable barriers on anadromous salmon and steelhead in the Columbia River Basin. Fish. Manag. Ecol. **27**(1): 102–110. doi:10.1111/fme.12410.

Cocchiglia, L., Purcell, P.J., and Kelly-Quinn, M. 2012. A Critical Review of the Effects of Motorway River-Crossing Construction on the Aquatic Environment. Freshw. Rev. **5**(2): 141–168. doi:10.1608/FRJ-5.2.489.

COSEWIC. 2016. COSEWIC assessment and status report on the Coho salmon, Oncorhynchus kisutch, interior Fraser population, in Canada. COSEWIC, Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. Available from https://go.exlibris.link/S6gfC51M.

COSEWIC. 2017. COSEWIC assessment and status report on the sockeye salmon, Oncorhynchus nerka, 24 designatable units in the Fraser River drainage basin, in Canada. COSEWIC, Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. Available from https://go.exlibris.link/MhmhdvnB.

COSEWIC. 2020. COSEWIC assessment and status report on the Steelhead Trout Oncorhynchus mykiss (Thompson River and Chilcotin River populations) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. xvi + 104 pp. (https://www.canada.ca/en/environment-climatechange/services/species-risk-public-registry.html).

Cote, D., Kehler, D.G., Bourne, C., and Wiersma, Y.F. 2009. A new measure of longitudinal connectivity for stream networks. Landsc. Ecol. **24**: 101-113 doi:10.1007/s10980-008-9283-y .

Cunningham, D.S., Braun, D.C., Moore, J.W., and Martens, A.M. 2023. Forestry influences on salmonid habitat in the North Thompson River watershed, British Columbia. Can. J. Fish. Aquat. Sci. **80**: 1053-1070. doi:10.1139/cjfas-2022-0255.

DeBano, S.J., Wooster, D.E., Walker, J.R., McMullen, L.E., and Horneck, D.A. 2016. Interactive influences of climate change and agriculture on aquatic habitat in a Pacific Northwestern watershed. Ecosphere **7**(6). doi:10.1002/ecs2.1357.

DFO. 2019. Recovery Potential Assessment - Interior Fraser Coho (Oncorhynchus kisutch). DFO Can. Sci. Advis. Secr. Sci. Advis. Rep. 2019/043.

Dickson-Hoyle, S., Ignace, R.E., Ignace, M.B., Hagerman, S.M., Daniels, L.D., and Copes-Gerbitz, K. 2022. Walking on two legs: a pathway of Indigenous restoration and reconciliation in fire-adapted landscapes. Restor. Ecol. **30**(4). doi:10.1111/rec.13566.

Dimayuga, P., Sur, S., Choi, A., Greenwood, H.L., Galloway, T., and Bilton, A.M. 2023. A review of collaborative research practices with Indigenous Peoples in engineering, energy, and infrastructure development in Canada. Energy. Sustain. Soc. **13**(1): 3–15. doi:10.1186/s13705-023-00382-8.

Ecoscape Environmental Consultants Ltd. 2020. Bonaparte River Sensitive Habitat Inventory and Mapping and Aquatic Habitat Index. Prepared for Secwepemc Fisheries Commission.Available from https://cmnbc.ca/wp-content/uploads/2020/06/Bonaparte-River.pdf.

Ecoscape Environmental Consultants Ltd. 2022. Salmon River Sensitive Habitat Inventory and Mapping and Aquatic Habitat Index. Prepared for Yucwmenlucwu; Splatsin Development Corporation.

Ens, E.J., Finlayson, M., Preuss, K., Jackson, S., and Holcombe, S. 2012. Australian approaches for managing “country” using Indigenous and non-Indigenous knowledge. Ecol. Manag. Restor. **13**(1): 100–107. doi:10.1111/j.1442-8903.2011.00634.x.

Erkinaro, J., Erkinaro, H., and Niemelä, E. 2017. Road culvert restoration expands the habitat connectivity and production area of juvenile Atlantic salmon in a large subarctic river system. Fish. Manag. Ecol. **24**(1): 73–81. doi:10.1111/fme.12203.

Evans, N.T., Riley, C.W., and Lamberti, G.A. 2015. Culvert Replacement Enhances

Connectivity of Stream Fish Communities in a Michigan Drainage Network. Trans. Am. Fish. Soc. **144**(5): 967–976. doi:10.1080/00028487.2015.1054519.

Finn, R.J.R., Chalifour, L., Gergel, S.E., Hinch, S.G., Scott, D.C., and Martin, T.G. 2021. Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River Freshw. Ecol. **12**(7). doi:10.1002/ecs2.3646.

Fish and Fish Habitat Protection Program, and DFO. 2022. Framework to Identify Fish Habitat Restoration Priorities. Ottawa. Available from https://nwac.ca/assets-documents/Framework-to-Identify-Fish-Habitat-Restoration-priorities.pdf.

Fish Passage Technical Working Group. 2014. Fish passage strategic approach: protocol for prioritizing sites for fish passage remediation. Available from https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/fish-passage/strategic_approach_july_2014.pdf.

Forbes, A., Ritchie, S., Walker, J., and Young, N. 2020. Applications of Two-Eyed Seeing in Primary Research Focused on Indigenous Health: A Scoping Review. Int. J. Qual. methods **19**. doi:10.1177/1609406920929110.

Fox, C.A., Reo, N.J., Turner, D.A., Cook, J., Dituri, F., Fessell, B., Jenkins, J., Johnson, A., Rakena, T.M., Riley, C., Turner, A., Williams, J., and Wilson, M. 2017. "The river is us; the river is in our veins": re-defining river restoration in three Indigenous communities. Sustain. Sci. **12**(4): 521–533. doi:10.1007/s11625-016-0421-1.

Frankiewicz, P., Radecki-Pawlik, A., Wałęga, A., Łapińska, M., and Wojtal-Frankiewicz, A. 2021. Small hydraulic structures, big environmental problems: is it possible to mitigate the negative impacts of culverts on stream biota? Environ. Rev. **29**(4): 510–528. doi:10.1139/er-2020-0126.

Fuller, M.R., Doyle, M.W., and Strayer, D.L. 2015. Causes and consequences of habitat fragmentation in river networks: River fragmentation. Ann. N. Y. Acad. Sci. **1355**(1): 31–51. doi:10.1111/nyas.12853.

Harding, T., Jaremovic, L., and Kosakoski, G. 1994. Strategic review of fisheries resources North Thompson habitat management area. Department of Fisheries and Oceans, Vancouver, B.C. Available from https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/168123.pdf.

Hovel, R.A., Brammer, J.R., Hodgson, E.E., Amos, A., Lantz, T.C., Turner, C., Proverbs, T.A., and Lord, S. 2020. The importance of continuous dialogue in community-based wildlife monitoring: case studies of dzan and luk dagaii in the Gwich'in Settlement Area. Arct. Sci. **6**(3): 154–172. doi:10.1139/as-2019-0012.

Interior Fraser Coho Recovery Team. 2006. Conservation strategy for coho salmon (Oncorhynchus kisutch), Interior Fraser River populations. Fisheries and Oceans Canada, Vancouver, BC. Available from https://go.exlibris.link/1pT8qbNc.

Irvine, J.R., and Bradford, M. 2000. Declines in the Abundance of Thompson River Coho Salmon in the Interior of Southern British Columbia, and Canada's Coho Recovery Plan. *In* Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk. *Edited by* L.M. Darling. B.C. Ministry of Environment, Lands and Parks, Kamloops, B.C. pp. 595–598.

Karakatsoulis, J., Paul, S., Osborne, R., Ortner, C., and Anderson, M. 2005. Skeetchestn Indian

Band: Research and Development in Riparian Zone Management. University College of the Cariboo and Thompson Rivers University. Available from https://skeetchestnnr.ca/wp-content/uploads/2022/09/SIBRDRZM.pdf.

Kemp, P.S., and O'Hanley, J.R. 2010. Procedures for evaluating and prioritising the removal of fish passage barriers: a synthesis. Fish. Manag. Ecol. **17**(4): 297–322. doi:10.1111/j.1365-2400.2010.00751.x.

Langill, D.A., and Zamora, P.J. 2002. An audit of small culvert installations in Nova Scotia: habitat loss and habitat fragmentation. Can. Tech. Rep. Fish. Aquat. Sci. **2422**: 1–35.

Mahlum, S., Cote, D., Wiersma, Y.F., Pennell, C., and Adams, B. 2018. Does restoration work? It depends on how we measure success. Restor. Ecol. **26**(5): 952–963. doi:10.1111/rec.12649.

Mazany-Wright, N.J., Noseworthy, S., Sra, S., Norris, S.M., and Lapointe, N.W.R. 2021. Breaking down barriers: a practitioners' guide to watershed connectivity remediation planning. Ottawa, Ontario. Available from https://cwf-fcf.org/en/resources/research-papers/CWF-WCRP-Guide.pdf.

Miller, I. 2012. Fish Passage in BC – Status, Issues and Solutions.Fish Passage Technical Working Group, Victoria, BC. Available from https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fish-passage/fish_passage_in_bc.pdf

Moore, J.W., and Schindler, D.E. 2022. Getting ahead of climate change for ecological adaptation and resilience. Sci. (American Assoc. Adv. Sci. **376**(6600): 1421–1426. doi:10.1126/science.abo3608.

Moore, R.D., Fleming, S.W., Menounos, B., Wheate, R., Fountain, A., Stahl, K., Holm, K., and Jakob, M. 2009. Glacier change in western North America: influences on hydrology, geomorphic hazards and water quality. Hydrol. Process. 23: 42-61. doi:10.1002/hyp.7162.

Mount, C., Norris, S., Thompson, R., and Tesch, D. 2011. GIS Modelling of Fish Habitat and Road Crossings for the Prioritization of Culvert Assessment and Remediation. Watershed Manag. Bull. **14**(2): 7–13.

O'Hanley, J.R., and Tomberlin, D. 2005. Optimizing the removal of small fish passage barriers. Environ. Model. Assess. **10**(2): 85–98. doi:10.1007/s10666-004-4268-y.

Ogren, S.A., and Huckins, C.J. 2015. Culvert replacements: improvement of stream biotic integrity?: Culvert replacements. Restor. Ecol. **23**: 821–828. doi:10.1111/rec.12250.

Park, D., Sullivan, M., Bayne, E., and Scrimgeour, G. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. Can. J. For. Res. **38**(3): 566–575. doi:10.1139/X07-179.

Pépino, M., Rodríguez, M.A., and Magnan, P. 2012. Impacts of highway crossings on density of brook charr in streams: Highway impacts on stream fish populations. J. Appl. Ecol. **49**(2): 395–403. doi:10.1111/j.1365-2664.2012.02108.x.

Poff, N.L., Brinson, M.M., and Day, J.W. 2002. Aquatic ecosystems & global climate change: potential impacts on inland freshwater and coastal wetland ecosystesm in the United States. Pew Center on Global Climate Change, Arlington, Va. Available from https://go.exlibris.link/1p1K2QZy.

Polfus, J.L., Manseau, M., Simmons, D., Neyelle, M., Bayha, W., Andrew, F., Andrew, L., Klütsch, C.F.C., Rice, K., and Wilson, P. 2016. Łeghágots'enetę (learning together): the importance of indigenous perspectives in the identification of biological variation. Ecol. Soc. **21**(2): 18. doi:10.5751/ES-08284-210218.

Quinn, T.P. 2018. The behavior and ecology of Pacific salmon and trout. *In* Second. University of Washington Press, Seattle; Bethesda, Maryland;

Reiser, D.W., and Bjornn, T.C. 1979. Habitat requirements of anadromous salmonids. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Or. Available from https://go.exlibris.link/tcT96KqN.

Roni, P., Beechie, T.J., Bilby, R.E., Leonetti, F.E., Pollock, M.M., and Pess, G.R. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North Am. J. Fish. Manag. **22**(1): 1–20. doi:10.1577/1548-8675(2002)022<0001:AROSRT>2.0.CO;2.

Roni, P., Hanson, K., and Beechie, T. 2008. Global Review of the Physical and Biological Effectiveness of Stream Habitat Rehabilitation Techniques. North Am. J. Fish. Manag. **28**(3): 856–890. doi:10.1577/M06-169.1.

Salmond, A., Brierley, G., Hikuroa, D., and Lythberg, B. 2022. Tai Timu, Tai Pari, the ebb and flow of the tides: working with the Waimatā from the Mountains to the Sea. New Zeal. J. Mar. Freshw. Res. **56**(3): 430–446. doi:10.1080/00288330.2022.2096084.

SFC. 2021. Secwepemc leading salmon conservation and recovery in the Thompson – Shuswap. Briefing Note to the SFC Steering Committee.

Thompson, R. 2013. Assessing Fish Passage at Culverts – the method, its metrics and preliminary findings from over 4,000 assessments.B.C. Ministry of Environment. Available from https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/fish-passage/assessing_fish_passage.pdf.

Torterotot, J.-B., Perrier, C., Bergeron, N.E., and Bernatchez, L. 2014. Influence of Forest Road Culverts and Waterfalls on the Fine-Scale Distribution of Brook Trout Genetic Diversity in a Boreal Watershed. Trans. Am. Fish. Soc. **143**(6): 1577–1591. doi:10.1080/00028487.2014.952449.

Turner, N.J., and Berkes, F. 2006. Coming to Understanding: Developing Conservation through Incremental Learning in the Pacific Northwest. Hum. Ecol. an Interdiscip. J. **34**(4): 495–513. doi:10.1007/s10745-006-9042-0.

Walters, A.W., Bartz, K.K., and McClure, M.M. 2013. Interactive Effects of Water Diversion and Climate Change for Juvenile Chinook Salmon in the Lemhi River Basin (U.S.A.). Conserv. Biol. **27**(6): 1179–1189. doi:10.1111/cobi.12170.

Warren, M.L., and Pardew, M.G. 1998. Road Crossings as Barriers to Small-Stream Fish Movement. Trans. Am. Fish. Soc. **127**(4): 637–644. doi:10.1577/1548-8659(1998)127<0637:RCABTS>2.0.CO;2.

Weir, L., Doutaz, D., Arbeider, M., Holt, K.R., Davis, B., Wor, C., Jenewein, B., Dionne, K., Labelle, M., Parken, C.K., Bailey, R.E., Vélez-Espino, L.A., Holt, C.A., Region, C.D. of F. and O.P., and Secretariat, C.S.A. 2022. Recovery Potential Assessment for 11 Designatable Units of Chinook Salmon, Oncorhynchus tshawytscha, Part 2: Elements 12 to 22. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Ottawa ON.

Available from https://dfo-mpo.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMwfV1NS8NAEB2sRRQ8KCpaPxjvTczHJqbH0th6kRYVPJZtmjRgTUqzrebfO7NuexD0uASWTXbYvDe89xbA92zH-nUmsKPznpA1lXMWcqo5wdwkDBjsEmRI2JwcD6LnOIgH_pPpZFQ6PHqdVtZazuiMtKdZaX0sSnumDXdG138niNT4nvNlL6ZZAxqiQxSs2R.

Weller, J.D., Moore, R.D. (Dan), and Iacarella, J.C. 2023. Stream thermalscape scenarios for British Columbia, Canada. Can. Water Resour. J. doi:10.1080/07011784.2023.2267028.

Wickham, S.B., Augustine, S., Forney, A., Mathews, D.L., Shackelford, N., Walkus, J., and Trant, A.J. 2022. Incorporating place-based values into ecological restoration. Ecol. Soc. **27**(3): 32. doi:10.5751/ES-13370-270332.

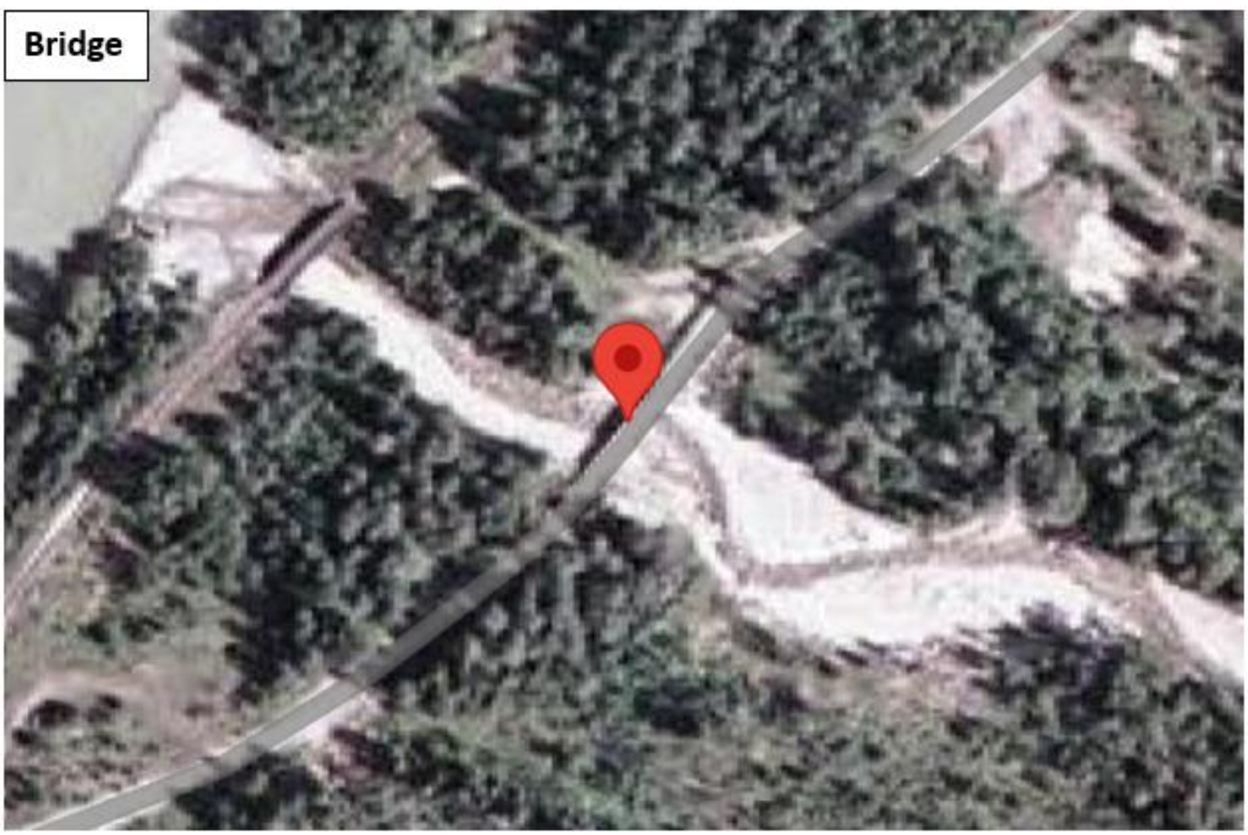
Wong, C., Ballegooyen, K., Ignace, L., (Gudia) Johnson, M.J., and Swanson, H. 2020. Towards reconciliation: 10 Calls to Action to natural scientists working in Canada. Facets **5**(1): 769–783. doi:10.1139/facets-2020-0005.

Wood, D.M., Welsh, A.B., and Todd Petty, J. 2018. Genetic Assignment of Brook Trout Reveals Rapid Success of Culvert Restoration in Headwater Streams. North Am. J. Fish. Manag. **38**(5): 991–1003. doi:10.1002/nafm.10185.

Appendix A: Collaborative Team Members

Name	Affiliation
Tina Donald	Fisheries and Wildlife Manager / Tk'wenem7i'ple7 (Councillor) Natural Resources Department Simpcw
Aaron Gillespie	Program Manager Secwepemc Fisheries Commission
Jeremy Sterling	Fisheries Biologist Secwepemc Fisheries Commission
Caroline Feischl	Ecology Department Lead Simpcw Resources Group
Ceryne Staples	Ecosystems Biologist Simpcw Resources Group
Emma Hodgson	Research Scientist North Thompson Salmon Ecosystems Research Program Fisheries and Oceans Canada
Violaine Pemberton-Renaud	Biologist North Thompson Salmon Ecosystems Research Program Fisheries and Oceans Canada
Sean Naman	Research Scientist North Thompson Salmon Ecosystems Research Program Fisheries and Oceans Canada

Appendix B: Examples of Google Maps Eliminated Crossings




No Road

Appendix C: Culvert Assessment Datasheet

Closed Bottom Structure (CBS) Field Measurement Form

Location and Overview Data			
Date of Assessment			
PSCIS Crossing ID *(only needed if this is a re-assessment)*			
My Crossing Reference			
Crew Members			
UTM/GPS (NAD 83)	*Zone*	*Easting*	*Northing*
Decimal degrees	*Latitude*	*Longitude*	
Stream Name			
Road Name			
Road Km Mark			
Road Tenure (for FSR)			
Stream Information			
Channel Width *Stream Width Ratio*	*Avg. Channel Width (m)*	*Culvert Dia.(m)*	*SWR*
1st (m): 2nd (m): 3rd (m):			
Stream Slope (%)			
Beaver Activity	*Yes*	*No*	
Fish Sighted?	*Yes*	*No*	
Valley Fill	*DF*	*SF*	*BR*
Habitat Value below	*Low*	*Medium*	*High*
Habitat Value above	*Low*	*Medium*	*High*

Field Observations and Assessment Measurements			
Crossing Type	*OBS CBS Other*		
Crossing Subtype	*Bridge, Pipe Arch, Wood Box Culvert, Round Culvert, Oval Culvert, Concrete Box, Ford*		
Culvert Diameter or Span for OBS (m)	1st pipe	2nd pipe	3rd pipe
Culvert Length or Width for OBS (m)			
Continuous Embeddedment?	*Yes No*		
If Embedded, Average Depth of Embeddedment	*Inlet* ____*m*	*Outlet* ____*m*	*Average* ____*m*
Resemble Channel?	*Yes No*		
Backwatered?	*Yes No*		
If Backwatered, to what Percentage			
Fill Depth (m)			
Outlet Drop (m) (A+B)	*Invert-ToP(A)*	*ToP – BoC(B)*	*OD*
Outlet Pool Depth (m) (C-B)	*ToP – BoP(C)*	*ToP – BoC(B)*	*OPD*
Inlet drop (m)	*Yes No*		
Culvert Slope (%)			
Recommendations (leave blank)			
Culvert Fix	*RM OBS SS ASM BW*		
Recommended Diameter or Span (m)			

Photo checklist	**Comments**
☐ This datasheet ☐ Culvert inlet ☐ Culvert outlet ☐ Culvert barrel ☐ Downstream habitat ☐ Upstream habitat	

Appendix D: Details of Barrier Pipe Arches

Pipe Arch Image Number	Barrier Status	Notes on Barrier Status
1	Barrier	Barrier due to outlet drop, higher culvert slope, lack of embedment, relatively high stream width ratio, and long culvert length
2	Barrier	Barrier due to outlet drop, higher culvert slope, lack of embedment, and long culvert length
3	Barrier	Barrier due to higher culvert slope, lack of embedment, and long culvert length
4	Barrier	Barrier due to outlet drop, higher culvert slope, lack of embedment, and relatively high stream width ratio
5	Potential Barrier	Potential barrier due to higher culvert slope and minimal embedment
6	Potential Barrier	Potential barrier due to lack of embedment and long culvert length

Pipe Arch 2


Pipe Arch 3

Pipe Arch 4


Pipe Arch 5


Pipe Arch 6
Aug 23, 2021 at 9:42:58 AM
11U 357323 5826002

Appendix E: Initial Brainstormed Culvert Prioritization Metrics

Proposed Database Columns	Comments
Crossing ID	Included in final database
Longitude	Included in final database
Latitude	Included in final database
Crossing Type	Included in final database
Crossing Subtype	Included in final database
Barrier Status	Included in final database
Watershed	Included in final database
Distance from culvert to watershed outflow	Eliminated as this metric was time intensive to derive and number of downstream culverts determined to more relevant and sufficient
Known spawning population	Included in final database
Distance from culvert to known spawning location	Eliminated as location / area of spawning population is estimated and presence of known spawning population in watershed determined to be more relevant and sufficient
Number of blocked culverts downstream	Included in final database
Number of culverts blocked upstream	Included in final database
Distance to closest blocked culvert upstream	Included in final database
Number of species at risk in watershed	Shifted to number of at-risk conservation units following further discussion with the Secwepemc Fisheries Commission
Stream length upstream with 0-5% gradient (km)	Shifted to 0-3% gradient to correspond to gradient range used in provincial stream crossings model
Stream length upstream with 6-10% gradient (km)	Shifted to 3-5% gradient to correspond to gradient range used in provincial stream crossings model
Stream length upstream with 11-15% gradient (km)	Shifted to 5-8% gradient to correspond to gradient range used in provincial stream crossings model
Stream length upstream with 16-25% gradient (km)	Shifted to 8-15% gradient to correspond to gradient range used in provincial stream crossings model. Ranges >15% determined to be unnecessary as 15% gradient is considered barrier to Pacific salmon.
Upstream habitat quality (Low, Med, High)	Included in final database
Fish Present	Determined to be unnecessary as does not distinguish between salmon and other species and only determined immediately above and below culvert – would be assessed during habitat confirmations
Land Owner (general)	Included in final database
Total area burned upstream	Determined to be unnecessary
Flow placeholder (TBD later)	Determined to be beyond the scope of this process as a whole
Local knowledge + notes	Determined to be beyond the scope of this step in the process
Priority Level	Determined to be beyond the scope of this step in the process
Cost of Remediation	Determined to be beyond the scope of this step in the process
Group to take on push for remediation	Determined to be beyond the scope of this step in the process

Appendix F: Simpcw Natural Resources Department Six Directives

Simpcw

People of the Rivers

Natural Resource Department – Directives

DIRECTIVES	AREAS/ISSUES	CONCERNS
Séwllkwe (water)	▪ Barriere River ▪ Louis Creek ▪ Dunn Creek/Lake ▪ Finn Creek ▪ Lemieux Creek ▪ Raft River ▪ Mad River	▪ Simpcw aims to protect traditional fishing spots and enhance fish habitat. ▪ Slope stability and riparian areas will be priority as well as an overall aquatic ecosystem protection practice. ▪ Community watersheds and downstream affects will be in careful consideration.
Melámen (medicine) Plants and Fauna	▪ Western Yew ▪ Labrador Tea ▪ Balsam Root ▪ Wild Potato (Spring Beauty) ▪ Indian Hellebore	▪ Careful consideration given to plants and medicines of interests, where buffers, avoidance or other adequate retentions will be recommended and/or required.
Ckwnémten (Cultural Uses)	▪ Expressions of culture, places of cultural practice, locales of spiritual and ceremonial significance and places on the landscape where our people lived and were buried, and includes objects, sites and knowledge.	▪ Certain areas designated will be automatic assessment for CHR &/or PFR. ▪ Concentrated areas of cultural importance will be chosen by Simpcw prior to field seasons. ▪ Historical and present-day cultural use areas/resources are of equal value to Simpcw.
Wildlife: - **Tmesmescéń** - **Spyu7**	▪ Mountain Caribou-preservation of specific habitats, with minimal or total avoidance. ▪ Ungulates-Moose habitat and deer winter range (priority due to forest fires).	▪ Careful consideration and attention will be paid towards preserving specific habitat towards prevention of predation and allow species more natural security. ▪ Road deactivation and full rehabilitation will be required one harvesting activities have finished within Simpcwúlecw.
Archaeological Sites	▪ The physical artifacts that remain at traditional sites of our ancestors.	▪ Simpcw adheres to the *Heritage Conservation Act* (HCA) in recognizing sites that are protected if they pre-date 1846. ▪ Archaeological site protection is *not limited to pre-1846* for Simpcw. ▪ Post 1846 sites are equally significant to Simpcw, where Simpcw aims to work with proponents to create appropriate protection and mitigation plans.
Símpcwemc (People of Simpcw)	▪ Simpcwúlecw (Territory of Simpcw)	▪ The tmicw, melámen, animals, seasons, cycles of nature – interconnectedness.