Central Squamish Estuary Restoration Project

C1-PAC-02 / 17-HPAC-01341-A4 YEAR 4

2020 – 2021

FINAL REPORT

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Executive Summary

The work completed this year (2020/2021) on the Central Squamish Estuary Restoration Project (CERP) focused on the area referred to Culvert #4, with the replacement of the former undersized culvert with a fish friendly 3m x 3m concrete box culvert. The construction of Culvert #4 was similar to that undertaken in the 2019 season with the replacement of Culvert #3. However, due to the direct proximity of the Squamish River adjacent to the work site, the upgrade and replacement were technically more complex and required more detailed engineering design, including river and estuary coffer dam construction. These dams were required in order to keep the site dry enough to allow the work to be undertaken safely.

Modelling was undertaken in 2020 to study the effects of the removal of the lower Spit and how sediment and flood levels would be affected with the removal of the lower 1 km of the structure. As well, for the third year, the fisheries and biophysical monitoring programs that commenced in 2018 were continued. The findings of the full four years of the monitoring programs will be summarized in 2022 at the completion of the CERP; this will enable determination of the overall effectiveness of the restoration efforts of the culvert upgrades and the Spit removal.

In early January 2021 the project team of the SRWS, Fisheries and Oceans Canada (DFO), and Squamish Nation discussed the results of the 2020 Culvert #4 installation as part of Phase 1 and what the next steps of the project should be and how to advance Phase 2 – Spit Removal. The results of the “Squamish Training Berm Removal – Phase 2” model by SNC Lavalin were delivered in February 2021. Meetings were planned for March 2021 with the District of Squamish, Squamish Terminals, and Ministry of Forests, Lands, and Natural Resource Operations and Development (MFLNROD) to discuss the next steps to move forward with Phase 2 and the other phases of the CERP project.

Due to COVID-19 restrictions no in-person community meetings were held during the 2020 / 2021 season but various video conference calls and site meetings were held throughout the year.

Table of Contents

Table of Figures:

Abbreviations:

CERP – Central Estuary Restoration Project
CSEB – Canadian Society for Environmental Biologists
DFO – Fisheries and Oceans Canada
DOS – District of Squamish
FWCP – Fish and Wildlife Compensation Program
IFR – InStream Fisheries Research
MFLRNOD – Ministry of Forests, Lands, and Natural Resources, Development and Operations
PIT – Passive Integrated Transponder
SNC-L – SNC Lavalin
SRWS – Squamish River Watershed Society
SWS – Squamish Windsports Society
WMA – Wildlife Management Area

1.0 Introduction and Project Description

The Central Estuary Restoration Project (CERP) is a multi-year project focused on improving fish access for salmonids between the Squamish River and the central estuary. The focus is to restore declining Chinook salmon populations by improving rearing habitat within the estuary. To achieve this objective, the scope of the project includes three phases (Figure 1):

- Phase 1 – Culvert Upgrades: replace culverts at key locations along Training Berm with fish passage friendly culverts.
- Phase 2 – Spit Realignment/Removal: realign or modify the southern 1,100m end of the Training Berm, also referred to as the Spit, to restore access to over 300 hectares of salmon rearing habitat.
- Phase 3 – Bridge Pond Rewatering: install flow control structures across CN Spur Line to improve water quality between the Bridge Pond/Cattermole Slough and Pretty Slough in the central estuary (in the area managed by Squamish Nation referred to as Site "A").

Project Site Location:

The Squamish Estuary, located approximately 52 km north of Vancouver, is situated at the head of Howe Sound where the Squamish River discharges a drainage area of over 3,650 km2. The Squamish estuary encompasses the tidal waters of upper Howe Sound, from the confluence of the Squamish River upstream to the Mamquam River, the Mamquam Blind Channel, and Stawamus River. The project site is located within the Skwelwil'em Squamish Estuary Wildlife Management Area (WMA) which is Crown land managed by the provincial government (MOE 2007). Access along the Training Berm Road is maintained by the District of Squamish (DOS) through a lease agreement with the provincial government in order to provide access at the south end for wind sports activities between May and September annually. The entire CERP project site is within the territorial lands of Squamish Nation.

History of the Training Berm:

The Training Berm, an antiquated structure which was constructed in the early 1970s by BC Rail, was originally intended to "train" the Squamish River along the western edge to facilitate the construction of a coal port in the estuary. The federal government of the day shut the port development down, but the 5 km road remained in place limiting fish access and river flow from the Squamish River to the central estuary. In 1994, twin corrugated steel pipe (CSP) culverts were installed by Fisheries and Oceans Canada (DFO) at the site referred to as Location #3 (Figure 2). From 2001 until 2013 the SRWS, in partnership with DFO, installed an additional eight more culvert crossings to improve tidal exchange between the river and estuary. From 2013 until 2017 the SRWS commissioned a study to determine how the juvenile salmonids were utilizing the culverts. The result of the study determined that salmonids were not able to access the culverts, which were all sized 1.2 m in diameter or

smaller and were poorly positioned to be effective at allowing fish passage as they were either submerged or elevated above the river depending upon the tidal cycle. The lack of access to the estuary for the juvenile salmonids may have resulted in the loss of a certain percentage of the juvenile chinook population as they were forced directly into Howe Sound (Lingard et al., 2018a).

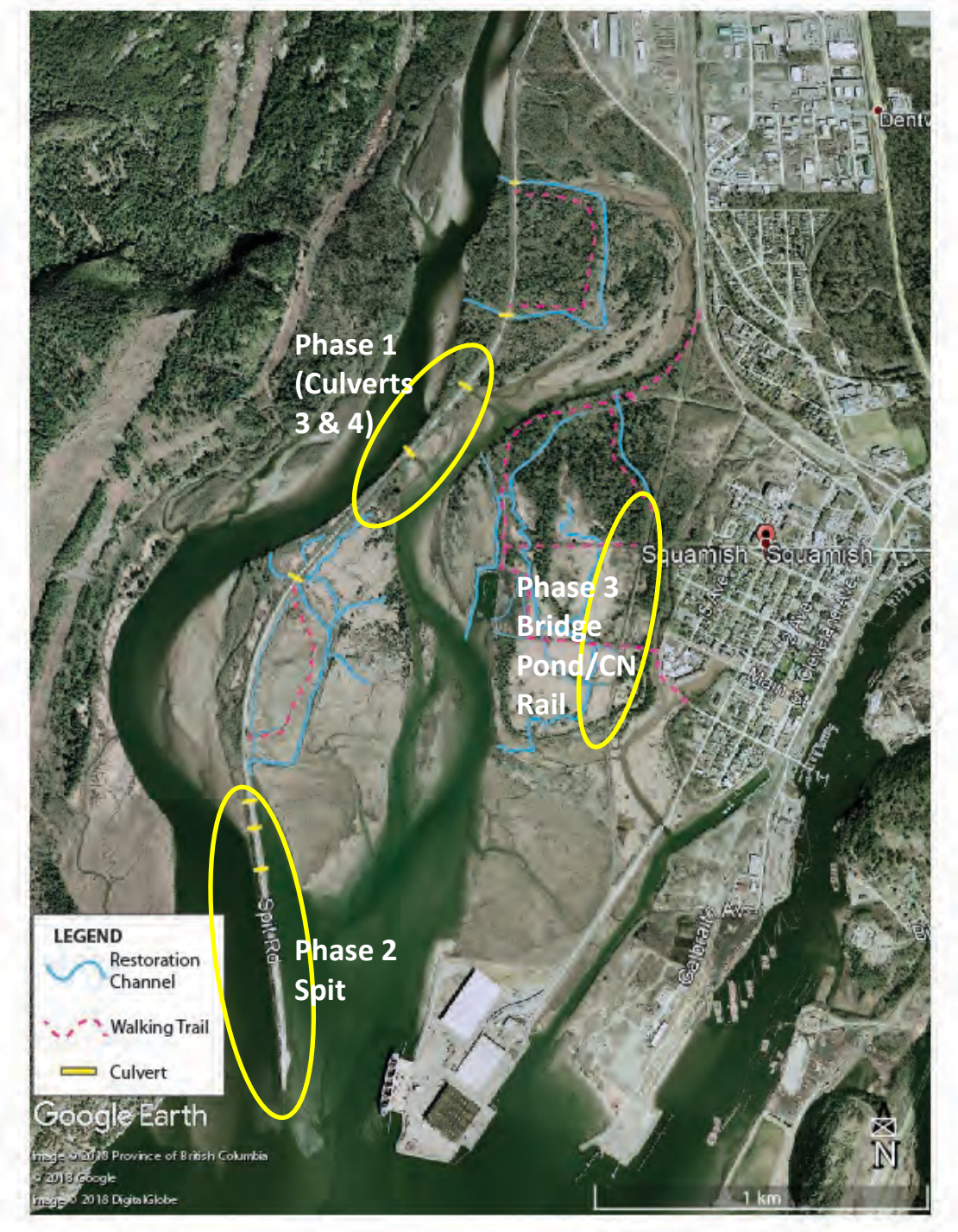

Figure 1: Central Estuary Restoration Project Phases

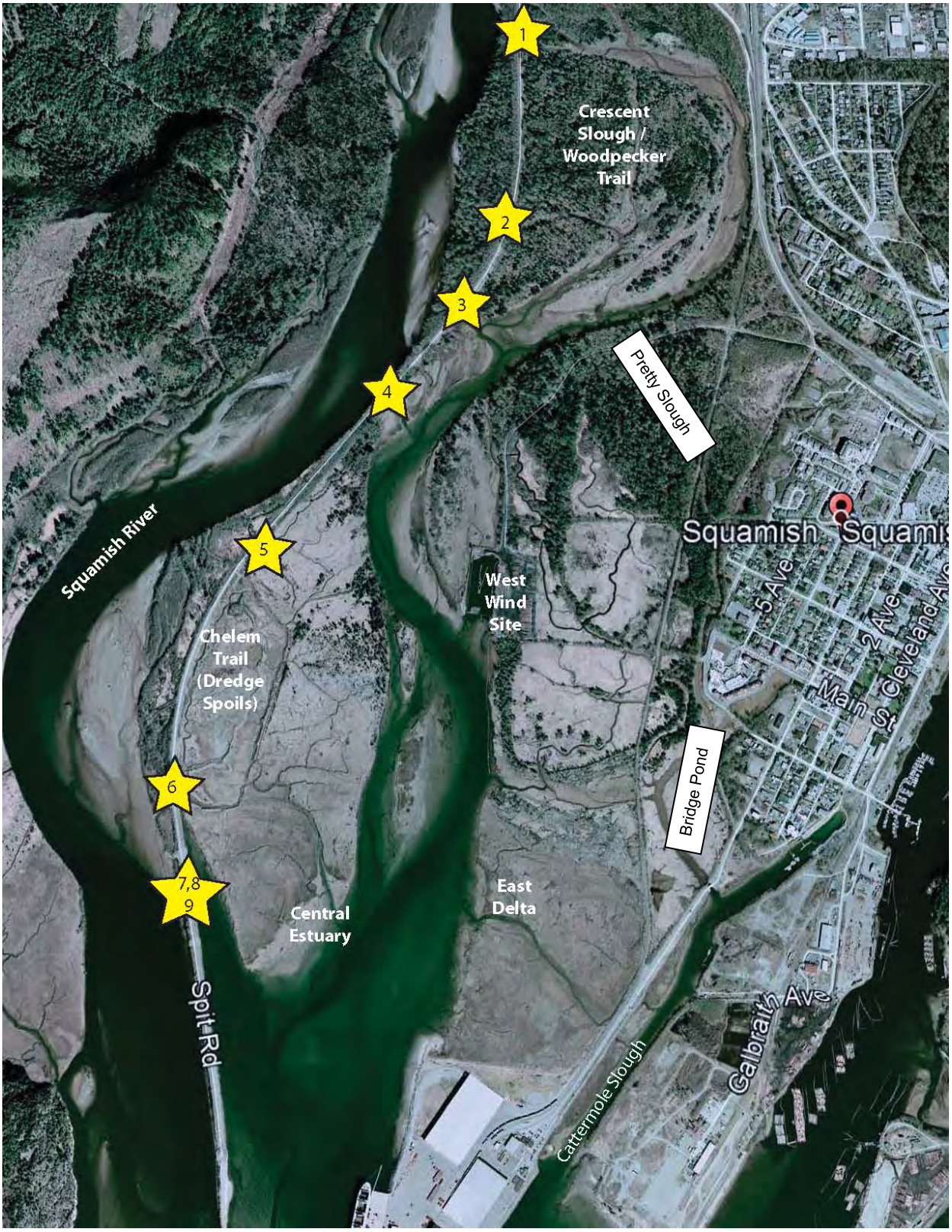

Figure 2: Location map of culvert crossings (1 to 9 in yellow stars) Squamish estuary

Alignment with Priority Issues (as outlined in recovery plans)

The CERP project is consistent with the main priority areas identified in the Cheakamus River Watershed Action Plan (FWCP 2017) and the Squamish Salmon Recovery Plan (2005) including:

I. Restore access to estuary for juvenile salmonids, focus on providing rearing habitat for Chinook salmon. Estuary channels provide excellent rearing habitat for Chinook fry. Over 95% of the juvenile Chinook salmon captured migrating out of the Cheakamus River between 2001 and 2020 were first year fry (Lingard et al., 2018b). These Chinook fry require a period of residency in estuarine waters during their first spring prior to entry into saltwater. The Squamish River estuary and its tidal channels provide this critical Chinook salmon rearing habitat for the Cheakamus River Chinook salmon populations. Without adequate connections between the Squamish River and the estuary delta, fish passage is severely limited, and studies have indicated the habitat is underutilized (Lingard 2018).

II. The loss of fundamental estuarine flow processes where fresh water moves in diverse patterns and mixes with marine waters is another factor that is addressed in all three phases of the project.

III. Another limiting factor addressed is the potential to improve the growth and survival of Chinook salmon fry growth. A large component of the Chinook salmon fry produced from spawning grounds on the Cheakamus River leave the river soon after emergence and rear and feed in the mainstem Squamish River and the estuary channels for some months prior to their migration into Howe Sound. By improving Cheakamus River Chinook fry and smolt access to and use of the warm, nutrient rich waters of the Squamish River estuary their overall productivity and survival would be expected to increase (Mangusson and Hillborn 2003).

IV. Incidental benefits are also expected for other species of interest including steelhead and cutthroat trout, and pink, coho and chum salmon. As well, bull trout and coho salmon from the Cheakamus River watershed may spend varying periods of time in the Squamish River estuary during their life cycle. Herring and other marine species will also benefit from this project.

Project Urgency

The importance to restore fish passage across the Training Berm between the Squamish River and the central estuary cannot be overstated. This project is recognized as being of high importance to Squamish Nation, the Provincial government, and Federal Fisheries who all recognize that coastal Chinook salmon populations are in decline and that access to the

estuary is critical for their survival. Chinook salmon are recognized for their importance as a source of food and cultural significance to Squamish Nation, a source of revenue for sports and recreation fishing enthusiasts, and as a vital link to the health of the south coast resident Killer Whale (SRKW) populations. In addition, Chinook salmon are considered to be of cultural and ecological importance in British Columbia and of federal conservation concern (COSEWIC 2019). There is also a need to restore access between the Squamish River and the central estuary to all life stages of salmonids as it is not fully understood how the Training Berm has impacted the overall ecosystem of the watershed and health of the salmon populations. What is known is that following the construction of the Training Berm in the early 1970s many stocks, including pink salmon and Chinook salmon runs all but plummeted.

Benefit to Salmon

The focus of the CERP multi-year project is to improve Chinook salmon (*Oncorhynchus tshawytscha*) populations and overall health. However, the project will also benefit coho salmon (*O. kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), steelhead (*O. mykiss*), as well as other salmonids, char, herring, and marine habitat in general.

2.0 Goals and Objectives

The intended focus of this year was to move the project onto Phase 2 of the Central Estuary Restoration Project – Spit Removal. However, these plans changed over several meetings and discussions in early 2020.The project was refocused, instead, on the installation of a second fish friendly culvert as a continuation of Phase 1 – Fish Passage Improvements across the Training Berm. The decision to hold off plans on the Spit removal allowed for the completion of the Spit Removal Analysis modelling to be completed by SNC-L in February 2021.

The shifting of the project focus onto a second culvert upgrade was still within the original project scope, which identified opening the Training Berm at several key locations to improve passage of outmigrating juvenile Chinook salmon between the Squamish River and the central estuary. The location for the second culvert upgrade was approximately 250 m south of the Culvert #3 upgrade completed in 2019 and is referenced as Culvert #4. Historically, the Squamish River flowed directly through this location prior the construction of the Training Berm in 1970. The upgrade of the culvert at this location was extremely important for the improvement of accessibility between the river and the estuary for outmigrating juvenile Chinook salmon. The two culvert upgrades, combined with the plans for the Spit removal in 2021, are all intended to work towards restoring Chinook salmon populations in the region.

In order to assess the success of the culvert upgrades for both the 2019 Culvert #3 upgrade and the 2020 Culvert #4 replacement, ongoing biophysical and fisheries monitoring commenced in early March 2020 and ran until November 2020. The fisheries monitoring program made use of acoustic tags to track the movement of wild sub-yearling and yearling Chinook salmon as they emigrated from the Squamish River. Fisheries monitoring also included a robust bi-weekly fishing program throughout the estuary to evaluate habitat usage and distribution of all salmonids. The biophysical monitoring included water quality sampling, studying sediment transport, and observing changes in vegetation and seral communities in the intertidal and uplands adjacent to the culverts.

Table 1. Summary of Project Phases & Monitoring Programs

Goal	Objective	Details	Date Achieved
Fisheries & Biophysical Monitoring	Establish baseline data followed by consistent monitoring design following physical works associated with Phases 1, 2, and 3	Fisheries monitoring using various techniques including PIT tags, acoustic tags, Gee trapping & seine netting at various locations in the Squamish River and Estuary. Biophysical monitoring for water quality, sediment transport, vegetation colonization and invertebrate populations at various locations in the Squamish River and estuary	2018 2019 2020 2021 (update provided in this reporting year) 2022 (wrap up and summary of overall effectiveness of restoration activities)
Phase 1: improve fish accessibility across Training Berm	Replace fish passage obstructing culverts across Squamish Training Berm	Culvert replacement at Location #3	May 2019
		Culvert replacement at Location #4	September 2020
		Additional culvert replacements (Locations #1 & #2)	For the future once the DOS installs the downtown flood control diking
Phase 2: remove or realign Spit to provide direct access to lower 77 hectares of habitat	Modification of Spit	Wave modelling Spit Modification modelling	June 2020 March 2021
		Meetings & consultation	2018 - present
		Construction	Planned for September 2021
Phase 3: Bridge Pond re-watering	Install a flow control structure across the CN Spur line to provide controlled flows into the Bridge Pond	Fisheries monitoring & Biophysical monitoring	Summer 2018, 2019, 2020, 2021
		Design & Approval	On hold until the DOS upgrades the Third Avenue flood dike

3.0 Study Area

The Squamish Training Dike is a 5 km structure that extends from the confluence of the Mamquam River downstream to Howe Sound and confines the Squamish River to its western bank. The focus of this phase of the project was to improve fish passage across Culvert #4 located at latitude 49.704932 longitude -123.173303 (Figure 1).

4.0 Methods

A summary of the project is appended to the end of this report in a compilation of the daily reports detailing the construction of the Culvert #4 installation from the preliminary clearing of the site from August 11, 2020 to the completion of the installation on October 1st , 2020.

Decision Making on Construction for 2020:

The development of the project began in early March following discussions with the project partners: Fisheries and Oceans Canada and Squamish Nation. The decision to focus the works in 2020 around the replacement of Culvert #4 was based on the observations of fish passage obstructions between the river and estuary over the past 5 years at this location. The culvert was either submerged or elevated, which did not allow access to outmigrating juvenile salmonids, or, when the culvert was flush with the river during the diurnal tidal cycles, it created a velocity barrier, channeling river flows through the 1.2 m diameter steel pipe at a speed that was prohibitive to juvenile salmonid passage. Once the decision to move forward with the Culvert #4 upgrade was agreed upon by the project partners, the SRWS contacted the stakeholders, including the District of Squamish, the Provincial government, and Squamish Terminals, to obtain their support in principle of the project. There was no objection to moving forward with the culvert upgrade pending approval of the design and securing all the necessary permits. The main concerns about an increased opening at this location were mostly around the potential increase in sediment transport and the possibility of impacting the operations of the Squamish Terminals' west berth. However, the sediment transport study that had been completed in 2019 by Kerr Wood Leidal provided a model that identified the increase in sediment transport downstream to the Squamish Terminals to be negligible (KWL 2018). The DOS was mainly concerned around potential changes that could impact flood risk to the municipality, but this section of the Training Berm did not function in any flood control manner as was clearly shown in the 2019 Kerr Wood Leidal flood modelling that had been completed on behalf of the SRWS (KWL 2019).

Construction Scheduling:

WSP was hired to assist with developing the construction schedule and the culvert design. WSP developed the culvert design, the Hydrotechnical Memo (WSP 2020), and assisted with all construction, layout of equipment, including a 300-tonne crane, and the final armouring and river / estuary embankment protection. In early May the culvert order was placed with Langley Concrete to start manufacturing the 3m x 3m concrete box culvert. The final length of the culvert was approximated but it was not until the final culvert design was completed in June 2020 that the actual length of 35 m was confirmed. A total of 13 segments were ordered. Due to the proximity to the river the engineering design team deemed headwalls would not be necessary at this location. In July 2020 the SRWS signed a Memorandum of Understanding with the District of Squamish to coordinate the construction of the box culvert and follow DOS standards and guidelines (DOS MOU 2020).

In early August, the SRWS was granted a tree removal permit to remove the trees around the work site. A tree nesting survey was completed as is summarized in a report by Lake Trail Environmental “Tree Removal for the Culvert #4 Fish Passage Improvements for Chinook and Other Salmonids in the Squamish Estuary” (Tryon 2020). Prior to any trees being removed the site was monitored for several weeks. While one nest had initially been observed at the start of the survey period, strong winds had shaken the nest apart well before the actual tree removal commenced.

All permits were obtained prior to any work commencing and included approvals pursuant to the Provincial government Wildlife Act, Water Sustainability Act, and Lands Management Act.

Physical work on the culvert upgrade commenced August 11, 2020. The site was completely secured with fencing and signage to keep the public from trespassing while construction was underway. Whistler Excavating was hired as heavy equipment / operator contractor. The site was contained with the construction of coffer dams on both the river side and the estuary side of the berm. A security guard remained on site during the nights to ensure the area was not vandalized.

As with any project of this magnitude, unexpected issues arise and the construction of Culvert #4 was no different. The original construction of the coffer dams had been designed to a height based on summer freshet flows. However, following a significant storm event in mid-August, the height of the coffer dams was increased by 1 m to prevent overtopping by the river. This proved to be very timely as two more significant and out-of-season storm events occurred during the construction period in September.

August 21, 2020 high-water event overtopping first coffer dam as it was constructed

September 23, 2020 reconstructed river coffer dam during large high-water event able to keep out floodwaters

With the coffer dams in place, the existing culvert was removed, and the excavated material was stockpiled along the berm road. Any excavated material that contained organics was

separated out and was later set aside to end haul to a suitable location off-site. Otherwise, the rest of the excavated material was used as backfill overtop of the new box culvert.

Photo taken September 1 showing the exposed former 1.2 m steel pipe culvert

Once the site was isolated and the steel pipe culvert removed along with the excess fill material, the site was graded as per the Hydrotechnical Memo and drainage rock and base rock were layered and compacted. The use of a high-power pump that ran 24/7 for the entire duration of the project allowed the site to remain “in the dry”. A drainage channel was constructed along the southern edge to allow water to flow from the river to the estuary side (where the pump was set up) to remove seepage through the river side coffer dam.

Photo taken September 9, 2020 showing pump in action and drainage channel on left side

From September 10 to 11 all the culvert pieces were trucked up from Langley Concrete and, with the use of 300 tonne crane, were individually placed from the river side moving east to the estuary side of the site. Each piece was secured in place with the small excavator that would gently “nudge” the culvert segments together until the gaskets were secured into position. Once the culverts segments were positioned over the graded pad work then commenced to back-fill the excavation. As the material was backfilled it was compacted to specifications outlined in the DOS MOU.

September 10, 2020 culvert segment placement with Gwil 300-t crane

Geotextile fabric was installed below the amouring material in order to add an extra layer of friction to prevent future slippage of the backfill along the road, slopes, and armouring. The final stages of the project included heavy armouring on the estuary side to prevent scour. As well, the river entranceway was heavily armoured to protect against erosion from large woody debris and large flows.

September 22, 2020 backfilling; note geotextile layer below armouring

September 24, 2020 placement of geogrid to prevent road slippage

September 29, 2020 geofabric placement on estuary side (above photo) and river side (photo below)

Once the berm road was restored to its original grade, no-post barriers were installed on either side to prevent traffic from driving down either side. As well, railings and danger signage were installed on both sides of the culvert to prevent people from falling over the edge of the culverts.

Safety railing and *Signage warning of dangerous currents*

The final component of the construction was the placement of just under 1,800 native riparian trees and shrubs along the disturbed areas. Volunteer support included BCIT students and students from the local schools. Strict COVID-19 safety protocols were followed This

volunteer support provided an invaluable assistance to the placement of the riparian vegetation.

October 5, 2020 BCIT students help with riparian planting

October 15, 2020 school-led program of restoration activities. Note placement of no-post barriers

Wave Modelling and Spit Removal Modelling:

In continuation of the plans initiated in the previous year around Phase 2 Spit Removal, SNC Lavalin was hired to undertake a wave modelling study to identify how the existing Spit functions and what role, if any, it performs to deflect wave action that could result in flood risk to the downtown. To this end, two models were completed between 2020 and 2021 by SNC-L including the “Squamish Training Berm Realignment – Wave Impact Assessment” modelling (SNC-L 2020) and the “Squamish Training Berm Removal – Phase 2” modelling of the spit removal (SNC-L 2021). These models were intended to study the effects of sediment and flood changes with the removal of the lower 1 km of the Spit Berm. SNC-L developed a hydrodynamic and sediment transport model coupled with wave modelling using the Delft3D Suite for the existing and future scenario of the removal of the lower 1 km of the Spit. The model was run for both scenarios for a period of 14 days that included one typical storm event and an average winter river discharge. An updated bathymetry survey was also conducted in advance of the modelling to provide current physical characteristics.

The results of these models showed that the berm removal could result in larger currents and slightly larger waves in the upper central channel and in the vicinity of the west berth of the Squamish Terminals (which could allow for an increase in river scour and the movement of sediment that has built up in the Terminals’ navigation channel in recent years).

Fisheries Monitoring:

As part of the fisheries monitoring program several approaches were undertaken to study the movement of juvenile Chinook salmon between the river and the estuary during their outmigration phase in the spring. The program that was developed in 2019 was expanded and improved upon in 2020. In 2019, the initial program involved the release of 100 juvenile Chinook salmon from Tenderfoot Hatchery that were implanted with acoustic telemetry tags between the Squamish River and the estuary (Jimmy Jimmy beach) (Figure 3).

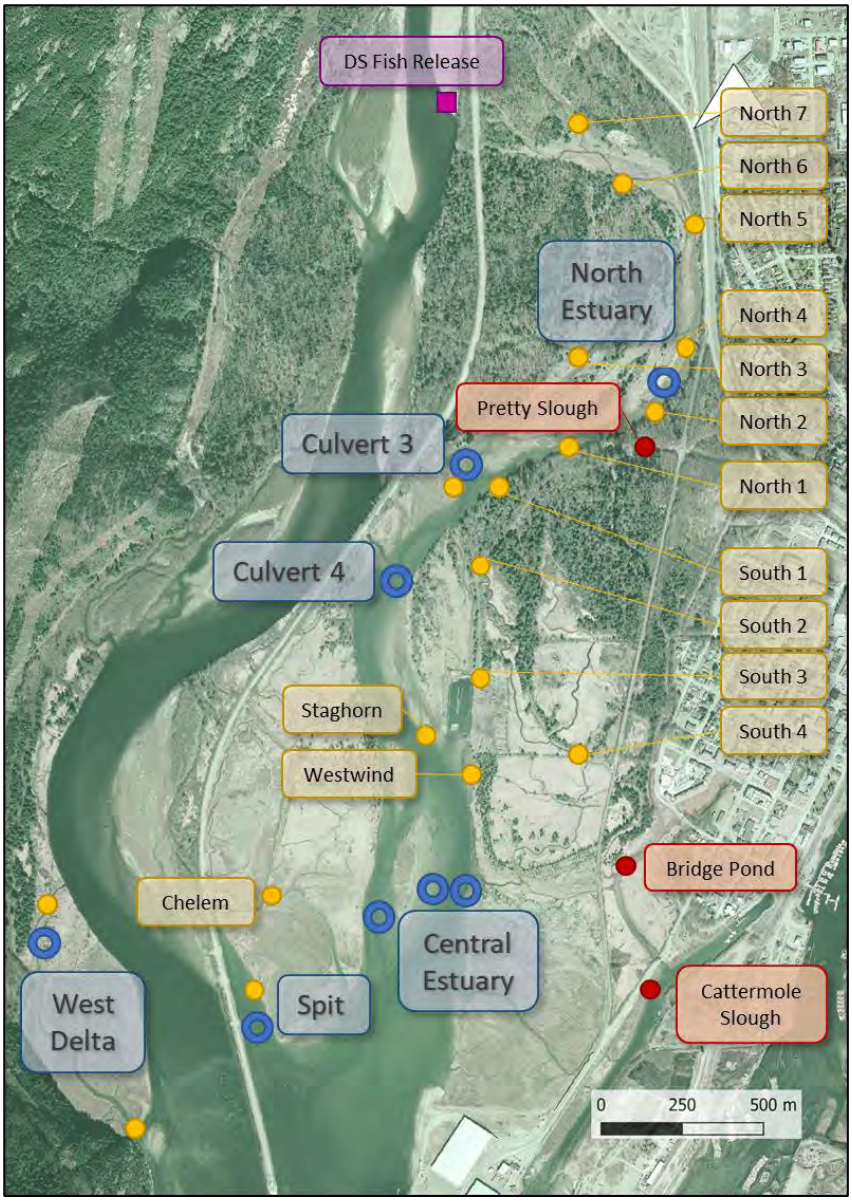

Figure 3. Map of study site including acoustic receiver locations (blue) and fishing locations for both occupancy modeling (yellow) and assessments of presence or absence in Site A (red). The downstream (DS) release site is shown.

In 2020, with the innovation of smaller tags, juvenile wild salmon could be tagged. Acoustic receivers placed at strategic locations in the river and estuary were able to detect the movement of these fish.

A standardized capture protocol in the estuary was also followed every two weeks to monitor changes in species assemblages spatially and temporally. The data collected as part of this study will be analyzed as part of an occupancy model by Master's graduate student Stephanie Lingard who is working with the SRWS in 2021 on a MITACS grant. Included in this study area were the Cattermole Slough as part of future Phase 3 (Installation of Flow Control Structures across the CN Spur Line). The water quality in the upper Cattermole

Slough in the area referred to as the Bridge Pond has been quite poor for many years and establishing baseline data on species assemblages will be useful for comparison purposes and to establish the effectiveness of future restoration activities.

Of the tagged fish released into the Squamish River only a small proportion were observed to enter via Culvert #3, while most migrated around the Spit and accessed the estuary from Howe Sound. It is expected that with the additional Culvert #4 in place that in 2021 more juvenile Chinook salmon will be able to access the estuary (IFR 2020).

Biophysical Monitoring:

In order to evaluate the success of the restoration activities, the biophysical monitoring program was again undertaken in 2020. The program developed by Lake Trail Environmental Consulting was undertaken (Tryon 2021), with several monitoring stations established throughout the site (Figure 4).

The monitoring program was carried out to collect data on water quality (dissolved oxygen, pH, salinity / conductivity, and temperature), sediment transport, invertebrate assemblages, and changes in vegetation associated with the restoration activities around the upgrades of Phase 1 – Culverts #3 and #4, the proposed Phase 2 – Spit Removal, and Phase 3 – Bridge Pond rewatering. Details of the program include:

1. Conductivity
    - Type: automatic using a conductivity logger
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.
    - Rationale: Conductivity can be used to evaluate the degree of mixing of freshwater and salt water that is expected to increase as a result of restoration.

2. Dissolved Oxygen
    - Type: Instantaneous measures taken manually with a YSI meter
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.
    - Rationale: This will evaluate if restoration activities prolong the duration of acceptable DO levels for Chinook rearing during the summer period.

3. Temperature
    - Type: automatic with Tidbit loggers and water level loggers
    - Type: Instantaneous when D.O. measures collected
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.

- Rationale: This will evaluate if improved mixing from restoration will prolong the duration of acceptable temperatures for Chinook rearing during the summer period.

4. Nutrients
    - Type: Water sample sent in for laboratory analysis (Phosphorus and Nitrogen)
    - Objective: To detect changes in the physio-chemical environment as a result of restoration activities.
    - Rationale: Nutrients in estuaries are important for production and are often cited as a key factor in supporting critical life stages for salmon. However, previous studies indicated the Squamish estuary is nutrient-poor. Monitoring dissolved phosphorus, nitrogen and will evaluate if improved mixing from restoration actions will result in increased nutrient concentrations that would be beneficial for salmon productivity.

<u>Physical Habitat (flows, channel dimensions):</u>

Monitoring of physical habitat for critical estuarine life stages of Chinook salmon (smolting and migration) to include:

1. Tidal channel dimensions
    - Type: Rod and level survey of channel dimensions prior to and following restoration activities.
    - Objective: To detect changes in the physical environment as a result of restoration activities.
    - Rationale: This will evaluate if restoration activities result in improvements (e.g. increased pools) or degradations (increased widening, decreased pools) in tidal channel morphology as it relates to chinook salmon habitat.

2. Flows through channels and culverts
    - Type: Direct measurements of water flow velocities through culverts and tidal channels using a flow meter.
    - Type: Indirect measurements of flow velocities through culverts by measuring water depth and relating to culvert dimensions and slope.
    - Objective: To assess range in flow velocities against known flow thresholds for critical life stages of Chinook:
        i. smolting - for culverts and tidal channels
        ii. adult migration - for culverts only

Table 2: Monitoring Station Site Locations

Site	Site Name	Location Description	UTM[1]	Water Level	Conductivity	Temperature	Sediment	Channel	Soils	Vegetation
A	River Station	Logger station installed along left bank of Squamish River 600m upstream of Culvert 1	10U 487884 E 5507607 N	X		X				
B	Culvert 1	Monitoring site is ~300m downstream (east side) of culvert 1. Includes logger station in tidal channel, 2 sediment stations in marsh, 2 channel cross sections, and 4 soil/veg transects adjacent to tidal channel	10U 488177 E 5506994 N	X		X	X	X	X	X
C	Bailey Street	Area adjacent to Wilson Slough Intake. Logger Station in Crescent Slough adjacent to Bailey Street and 330m downstream (south) of intake. Two sediment stations and one channel cross section station across main channel.	10U 488530 E 5506410 N		X	X	X	X		
D	Culvert 2	No longer a monitoring station - loss of staff gauge. Possible future monitoring.	10U 487895 E 5506375 N							
E	Culvert 3	Area east of Culvert 3. Includes logger station 70m upstream main tidal channel from where culvert 3 tidal channel enters. Logger station removed for winter season and re-set in spring. Also includes 4 sediment stations-2 in marsh (2018 install), 2 in mudflat (2019 install), and one cross section across culvert 3 tidal channel. 4 veg/soil transects perpendicular to and east of Spit road.	10U 487901 E 5505991 N	X	X	X	X	X	X	X
F	Culvert 4	Area east of Culvert 4. Logger station in Culvert 4 pool. Culvert 4 tidal channel has 2 cross-sections and main channel has 1 cross section 70m downstream (south) of culvert 4 tidal channel confluence. Also includes 4 sediment stations-2 in marsh (2018 install), 2 in mudflat (2019 install). One vegetation transect north and perpendicular to C4 tidal channel.	10U 487530 E 5505810 N	X		X	X	X	X	X
	Culvert 7	Hobo tidbit loggers installed on either side of culvert	10U 486995 E 5504561 N			X				
	Culvert 9	Hobo tidbit loggers installed on either side of culvert	10U 487038 E 5504352 N			X				
G	Lower Estuary	Logger station installed on a piling complex (dolphin) in lower estuary approximately 500m east of Culvert 8. 4 sediment stations: 2 in marsh (2018 install) and 2 in mudflats (2019 install), all on northeast side of main tidal channel in vicinity of logger station.	10U 487516 E 5504466 N	X	X	X	X		X	
H	Cattermole Slough	Logger station installed June 2019 in Cattermole Slough below stinky pond.	10U 488382 E 5504457 N	X	X	X				

1 UTM location is central to all stations at monitoring site.

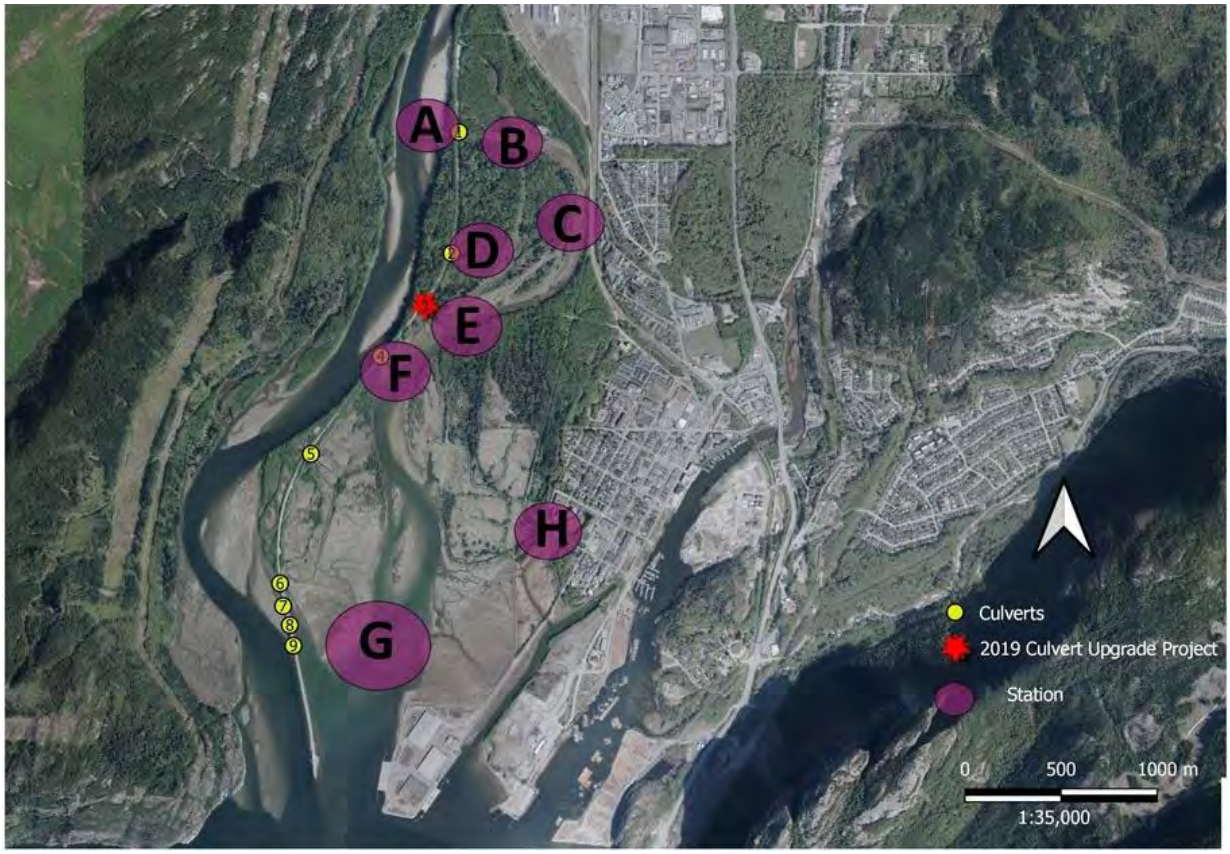

Figure 4 Monitoring stations site locations

The expectation of the restoration activities with the culvert upgrades and then with Phase 2 Spit removal is that by increasing connectivity between the river and the estuary there will be greater flushing of estuarine habitats and improved water quality within preferred ranges for smolting Chinook salmon. Seven stations, including one in the river and six in the central estuary, were established to monitor temperature with automatic data loggers (Figure 4). Of those stations, six also collect water level data and five collected conductivity data (for calculation of salinity).

Greater periods of marsh inundation and increased area of marsh coverage are also expected to be improved in association with the culvert upgrades as the pathways for sediment to enter the estuary from the river are opened. Sediment, vegetation, and soil surveys will provide a measure by which to monitor changes in marsh communities and coverage, as well as changes in soil carbon and sediment accretion rates. In 2018 and 2019, metrics were collected at 17 sediment stations, 10 vegetation transects, 39 vegetation plots, and 20 soil plots (Figure 4).

A summary of the biophysical monitoring program for the past three years will be submitted in 2022 following the completion of Central Estuary Restoration Project in order to assess the

effectiveness of the culvert upgrades at Culvert #3 and #4 as well as the removal of the lower portion of the Spit. The data collected with the biophysical monitoring program will be combined with the results of the fisheries monitoring program.

Engagement with the Public, Stakeholders, and Community:

Due to COVID-19 restrictions and safety protocols no indoor in-person meetings were held from April 2020 to March 2021. However, there were numerous Zoom meetings and on-site field meetings held with Fisheries and Oceans Canada and Squamish Nation, staff from the DOS and Province, and with WSP.

Riparian Planting:

Just under 1,800 native riparian trees and shrubs were planted around Culvert #4. Much of the planting took place in October with the help of volunteer support from BCIT, the local schools, and other volunteers. COVID-19 safety protocols were followed.

Table 3: Riparian Species Planted at Culverts #4

Plant Description for	**Culverts #4**		
Plant Name	Common Name	# plants	size
Cornus sericea	Red osier dogwood	35	1 gal pots
Mahonia nervosa	Dull Oregon grape	100	1 gal pots
Myrica gale	Sweet gale	25	1 gal pots
Polystichum munitum	Sword ferns	400	1 gal pots
Ribes sanguineum	Red-flowering currant	25	1 gal pots
Rosa nutkana	Nootka rose	25	1 gal pots
Rubus parviflorum	Thimbleberry	200	1 gal pots
Rubus spectabilis	Salmonberry	100	1 gal pots
Salix sitchensis	Sitka willow	75	1 gal pots
Spirea douglasii	Purple spirea/hardhack	250	1 gal pots
Spirea douglasii	Purple spirea/hardhack	504	plugs
Thuja plicata	Western red cedar	50	1 gal pots
Total		1,789	

November 2, 2020 Don Ross Secondary School students help with riparian planting as part of educational outreach program (lead by Rhonda O'Grady on the right explaining about the plants to the class)

5.0 Results and Outcomes

The results from the 2020 / 2021 year included the upgrade to a fish-friendly culvert at Location #4, ongoing monitoring and studies of salmon outmigration and usage of the estuary and biophysical monitoring, as well as the completion of the Wave Modelling and Squamish Training Berm Removal modelling, both completed by SNC-L. Educational programming and volunteer support resulted in the planting of just under 1,800 native riparian trees and shrubs along the disturbed areas around Culvert #4. The challenges faced with COVID-19 protocols and safety restrictions affected the way in which the community and volunteers were able to provide support, but accommodations were made to ensure safety at all times. The final culvert installation included the installation of safety rails and signage warning of potentially dangerous flows through the new culvert.

Planning and studies for the Phase 3 construction of flow control structures across the CN Spur Line are ongoing. The outcomes from the year included meetings, reports, engineering and hydraulic modelling, riparian planting, educational programming, and ongoing networking and outreach.

6.0 Discussion

This project has been developed in partnership with Fisheries and Oceans Canada and Squamish Nation and is of importance to improve the overall health of Chinook salmon stocks and restore the estuary to previous pre-development conditions. Support has also been recognized from the local sports fish advisory board, recreational fishing groups, Ministry of Forests, Lands, and Natural Resource Operations, and other community stewards.

The results of the restoration efforts to restore Chinook salmon access to the estuary is an important program for the Salish Sea. Closer to home it allows Squamish Nation's ability to harvest local salmonids, as well as provide educational programming. The project allows for engagement with local universities, technical institutes, and local schools in hands-on experiential learning opportunities including tree planting, mapping, monitoring, and the development of long-term post-graduate research studies. In addition to allowing community and student engagement, the SRWS has been able to sponsor a University of British Columbia Master's student to study Chinook salmon behaviour associated with the restoration efforts. Students from School District #48 regularly participate in special events, programs, and activities directly associated to this project including studying wildlife and fish movement, planting native riparian vegetation, undertaking tree and bird surveys, and learning about the natural habitat and environment (for more on these programs check our website: https://www.squamishwatershed.com/outreach-program.html).

7.0 Recommendations

The main recommendation moving forward is to continue to monitor the effectiveness of Culverts #3 and #4 for the next few years to collect data on salmon movement and biophysical changes. At this time, no further culvert replacements or upgrades are proposed but at such time in the future that the DOS embarks on the downtown flood dike upgrades, the replacement of either or both Culverts #1 and #2 should be examined. Likewise, at such time as either the Squamish Terminals, CN Rail, or the District of Squamish decide to modify the CN Spur Line to accommodate sea level rise increased flood levels then Phase 3 of the project, to install flow control structures across the CN Spur Line, should be explored.

The plan for 2021 / 2022 fiscal is to move forward with the Phase 2 – Spit Removal phase of the project. The current plan, based on the modelling completed by SNC-L, is to remove the 1.1 km portion of the lower Spit between the yellow gate and the turn-around at the south end of the Spit. The plans are to leave the windsports launch site intact.

8.0 Acknowledgement

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- Katrina Cook, Stephanie Lingard, and Cole Martin, InStream Fisheries Research Inc
- Lora Tryon, Lake Trail Environmental Consulting

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- DOS engineering department
- Judith Cullington, JCA and Associates
- Squamish Windsports Society
- Squamish Environment Society, and
- Squamish Streamkeepers

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