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Eagle Viewing Area / Siyich'em Reserve Dike Master Plan

Draft Report
June 25, 2020
KWL Project No. 463.341-300

Prepared for:
District of Squamish and Squamish Nation

SQUAMISH

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Squamish Nation

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1. Introduction

1.1 Purpose

The Eagle Viewing Area / Siyich'em Dike Master Plan (DMP) identifies and describes the preferred upgrading concept for a 2.5 km reach of the Squamish River dike in Squamish, BC which is located in the unceded traditional territory of the Squamish Nation. The DMP also serves a resource for implementation of the preferred upgrading concept by identifying next steps and implementation phasing.

Development of a DMP for this area was identified as a high-priority action in the Squamish Integrated Flood Hazard Management Plan (IFHMP). A DMP is required for this reach of the Squamish River dike because of several factors, including long-standing land tenure issues, which make dike upgrading planning more complex than other dike reaches within Squamish. These issues are discussed further in Section 2 (Background Information and Context).

1.2 Study Area

The study area location in context to Howe Sound and the Squamish River watershed is presented on Figure 1-1. The study area features are presented in Figure 1-2.

The DMP study area focuses on the Squamish River and adjacent lands between the Squamish Nation Aikwuks and Kowtain Reserves.

The following key features are located within the study area:

- the Eagle Viewing Area (a recreational area on top of the existing dike);
- the Squamish Nation Siyich'em Reserve;
- the Eagle Run Drive/Maple Crescent residential area;
- Fisherman's Park (managed by the District);
- a large forested island is located on the water-side of the dike along the northern portion of Siyich'em Reserve dike and along the Eagle Run Drive/Maple Crescent residential area; and
- Jimmy Jimmy (Judd) Slough is a side channel of the Squamish River that runs between the large forested island and the existing dike from Fisherman's Park to where it joins the Squamish River near the south end of Siyich'em Reserve.

The legal name of the Siyich'em Reserve is "Seaichem I.R. No. 16", but the Squamish Nation approved spelling is presented to the right. This report is formatted in Arial font and uses the spelling "Siyich'em" in place of the Squamish Nation approved spelling which requires a different font.

Siy̓ích'em

Additional information on the study area is provided in Section 2.

The study area was originally defined as ending at the north end of Siyich'em Reserve (i.e. not including the Eagle Run Drive/Maple Crescent residential area and Fisherman's Park), but was expanded to Fisherman's Park due to the dike upgrading alignment concepts generated during the project. This is discussed further in Section 3 (Options Identification and Shortlisting) and Section 4 (Conceptual Design and Feasibility of Shortlisted Options).

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District of Squamish / Squamish Nation

Eagle Viewing Area / Siyich'em Reserve Dike Master Plan

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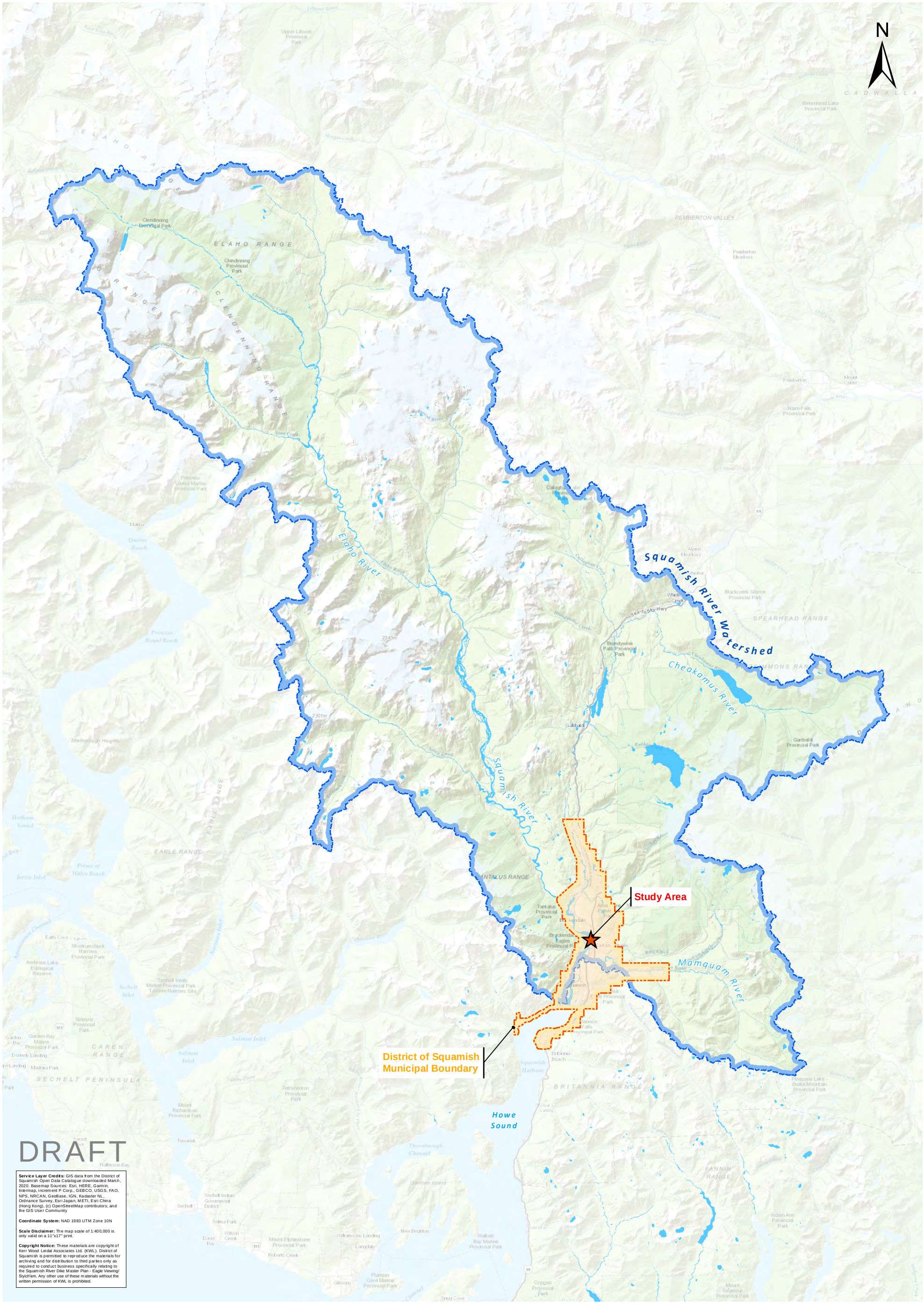

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Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:400,000 is only valid on a 11"x17" print.

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Date May 2020

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Squamish River Watershed

Figure 1-1

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District of Squamish / Squamish Nation

Squamish River Dike Master Plan - Eagle Viewing/Siyich'em

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STUDY AREA

Infrastructure: Horse Creek outlet chamber

Infrastructure: Judd Slough drainage pump station

Property and Land Ownership: Eagle Run Drive residential area

Infrastructure: Eagle Run pump station

Dike Structure: Sinkhole location from 2013 flood.

Morphology: Large forested island

Dike Structure: Gabions on dike backslope

Property and Land Ownership: Existing constrained development footprint for Siyich'em I.R. No. 16

Dike Footprint and ROW Constraint: Watershed Grill constructed agaist dike

Infrastructure: M1 Sanitary pump station

Infrastructure: Dryden Creek drainage pump station

PROJECT BOUNDARY

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Legend

- Squamish River Q500 Water Level
- Existing Sanitary Pump Station
- Existing Sanitary Main
- Existing Storm Pump Station
- Existing Storm Main
- Existing Storm Culvert
- Existing Water Main
- Existing Dike Centerline
- Eagle Viewing Area
- Park
- Squamish Nation Reserve

Parcel Ownership

- Private
- Public (Government)

Project No. 463-341

Date May 2020

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Study Area Features

Figure 1-2

1.3 Project Administration and Team

The DMP project is jointly administered by the District of Squamish (District) and the Squamish Nation (Nation). The project is funded by the National Disaster Mitigation Program (NDMP) administered by the Government of Canada and the Government of British Columbia. The project was initiated in summer 2019 and has a grant deadline in spring 2020.

The District and the Nation retained a consulting team led by Kerr Wood Leidal Associates Ltd. (KWL) to develop the DMP in collaboration with the District and Nation. KWL is providing project management, hydrotechnical and civil engineering, environmental biology, and engagement services. The consulting team also includes a geotechnical engineering subconsultant firm (Thurber Engineering Ltd., Thurber) and a landscape architecture subconsultant firm (Hapa Collaborative, Hapa).

The DMP project is managed through a Steering Committee comprising District staff, Nation members, staff and councillors. While the project and the committee are both led by the District and the Nation, the committee also includes a representative from the Government of Canada's Indigenous Services Canada department. Steering Committee members are listed in Table 1-1.

Table 1-1: Project Steering Committee Members

Name	Organization
David Roulston	District of Squamish
Chris Wyckham	District of Squamish
Gary Buxton	District of Squamish
John French	District of Squamish
Armand Hurford	District of Squamish
Paul Wick	Squamish Nation
Bob Sokol	Squamish Nation
Austin Chandler	Squamish Nation
Michelle George	Squamish Nation
Joshua Joseph	Squamish Nation
Chris Lewis	Squamish Nation
Chief Richard (Dick) Williams	Squamish Nation
Peter Baker	Squamish Nation
Monica Jacobs	Squamish Nation
Brent Baron	Indigenous Services Canada

The key consulting team members are listed in Table 1-2.

Table 1-2: Consultant Team Key Staff

Name	Organization	Role(s)
Erica Ellis	KWL	Lead Consultant Project Manager
Mike Currie	KWL	Technical Reviewer
David Roche	KWL	KWL Advisor to District
Jeff Derer	KWL	KWL Advisor to Nation
Amir Taleghani	KWL	Project Engineer
Shona Robinson	KWL	Junior Engineer
Heather Kingcott	KWL	Project Biologist
Patrick Burke	KWL	Project Biologist
Steve Coulter	Thurber	Thurber Project Manager/Geotechnical Engineer
Lukas Holy	Hapa	Hapa Project Manager/Landscape Designer
Allison Tweedie	Hapa	Landscape Designer

1.4 Dike Master Plan Development Process

The DMP has been developed through the following core phases:

- Phase A: Initiation, information gathering, and context;
- Phase B: Visioning, brainstorming, and shortlisting options;
- Phase C: Conceptual design and engagement on shortlisted options;
- Phase D: Structured options evaluation and selection;
- Phase E: Draft master plan; and
- Phase F: Final engagement and final master plan.

The project scope is structured to develop a dike upgrading concept which is preferred by both the District and the Nation, and to pursue consensus on the option across a wide range of groups including Squamish Nation members, community stakeholder groups, and regulatory stakeholders.

The option development and selection process was initiated with identifying common interests between the District and Nation for the project. These common interests were used to brainstorm several high-level concepts. The concepts were refined to enable shortlisting distinct options for conceptual design. Following engagement on the shortlisted options, additional comparison information including on cost and other feasibility factors were developed and the preferred option was identified by the Steering Committee and presented to District and Nation councils.

Each project phase involved one or more meetings with the Steering Committee to confirm direction and make decisions to allow initiation of subsequent phases. Several presentations were also made to District and Nation councils during the project to provide project information updates and to confirm key decisions.

A project charter document was developed shortly after project initiation to provide a reference for the Steering Committee, guide decision making, and outline proposed meeting dates and other key milestones. The project charter is provided in Appendix A as a general reference.

1.5 Squamish Nation and Stakeholder Engagement

Engagement with Squamish Nation members and stakeholder groups is an important component of the DMP process. Engagement activities were guided by a stakeholder engagement plan developed shortly after project initiation; this document is provided in Appendix B as a general reference.

The primary objectives of stakeholder engagement are to:

1. listen to and understand stakeholder values and desires for the study area with respect to flood protection and stakeholder-specific non-flood protection topics;
2. involve stakeholders in the review and refinement of flood protection options under consideration by the District and the Nation; and
3. foster collaboration between the District of Squamish, Squamish Nation, and stakeholders to find mutually agreeable design solutions.

In support of these objectives, the level of stakeholder engagement is generally to be at the 'involve' level as defined by the International Association for Public Participation's (IAP2) engagement spectrum, presented in figure below.

Figure 1-3: IAP2 Engagement Continuum

Groups to engage with were identified with the help of the Steering Committee and were organized in the following categories:

- Squamish Nation Siyich'em Reserve families;
- private (off Siyich'em Reserve) landowners and businesses (including restaurant on Siyich'em);
- community groups;
- regulators; and
- District and Nation internal departments.

Engagement activities were conducted as described in specific phases below:

- Phase A: Initiation, information gathering, and context:
    - launched joint District-Nation project website;
    - installed signage at Eagle Viewing Area; and
    - launched initial online survey requesting information on how people use the site and what their concerns are.

- Phase C: Conceptual design and engagement on shortlisted options:
    - targeted meetings with Squamish Nation members (Siyich'em Reserve families) and community groups;
    - correspondence with regulator authorities; and
    - public open house.
- Phase F: Final engagement and final master plan:
    - activities will be updated after final engagement is complete.

Engagement activity results and their influence on the preferred option selection project are discussed primarily in Section 5 (Preferred Option).

2. Background Information & Context

This section provides a summary of relevant background information to set the context for the dike master plan. The section begins by introducing the Squamish River watershed and then describes several factors in the master plan study area that are very influential to the process, including Siyich'em Reserve land tenure, other land uses and infrastructure, and environmental habitat.

2.1 Watershed and Flood Hazard Background Information

The Squamish River drains a watershed of over 3,800 km² that is covered by extensive glaciers and forested valleys into Howe Sound which is connected to the Strait of Georgia / Salish Sea and the Pacific Ocean.

Elevations in the watershed range mountain peaks of over 3,000 m down to tidewater at Howe Sound. The river has its source in the Pemberton Icefields, and about 20% of the watershed is glaciated (Paige and Hickin, 2000).

About 50 km upstream of Howe Sound, the Squamish River is confined within a canyon. Downstream of the canyon reach, the river assumes a steep, multi-channel braided morphology. It is likely that much of the coarse sediment delivered to the river from upstream sources is stored in this reach. As the river slope declines downstream, the river transitions from braided to wandering to meandering planform.

Major rivers flowing into the Squamish River include the Elaho River, the Cheakamus River, and the Mamquam River. BC Hydro operates a major storage-supported hydroelectric generation facility at Daisy Lake on the Cheakamus River, about 13 km upstream of the District boundary (flow is diverted from Daisy Lake through a tunnel to a powerhouse along the Squamish River). The Cheekeye River, a major tributary of the Cheakamus River, is subject to extremely large debris flow events, and has built a substantial fan located 12 km upstream of Howe Sound (the Cheekeye Fan stretches from the Cheekeye River confluence with the Cheakamus River southward to the community of Brackendale).

Downstream of the Cheekeye Fan, two major side channels (Brackendale Slough and Baynes Slough) provide flood conveyance through the right bank floodplain. Two major side channels on the left bank (Judd Slough and Harris Slough) and other smaller side channels have been cut off from the river mainstem by the Squamish River dike.

Squamish is exposed to a variety of flood hazards, including river flood hazards, debris flow hazards, and coastal flood and tsunami hazards.

As presented in Figure 1-1, the Eagle Viewing Area / Siyich'em Reserve DMP study area is located on the Squamish River, downstream of the confluence with the Cheakamus River and upstream of the confluence with the Mamquam River . The study area is primarily exposed to Squamish River flood hazards, but is also on the fringe of Cheekeye Fan and associated debris flow hazard.

The DMP project does not focus on the Cheekeye River debris flow hazard, but commentary is made in this report about how that hazard and on-going mitigation planning by others needs to be coordinated with implementing dike upgrades in the study area. There is a significant body of research into the Cheekeye River, with particular emphasis on the fan feature and the processes governing its formation. A comprehensive listing is provided by Clague et al. (2014).

The DMP study area is not affected by coastal flooding or tsunami hazards, however there is a minor tidal influence on river water levels within in the study area during periods of low flow.

Most Squamish River floods occur in the fall and early winter when large and intense multi-day storms create high flows on the local rivers, and when precipitation falling as rain throughout the watershed can bring additional runoff from alpine snowmelt. Sediment aggradation gradually or periodically increases the flood risk in some areas by filling in river channels.

In October 2003, significant flooding occurred on the Squamish River and Cheakamus River. Rainfall totalling 369 mm in 4 days caused the largest flood since continuous hydrometric records began on these rivers in the 1950s. The flood caused evacuations and damage to flood protection structures. In general, dikes considered "standard" dikes (i.e., designed for a 200-year return period or 0.5% annual exceedance probability floods) were not overtopped; however, freeboard at some locations was as little as 0.5 m, including at the Siyich'em / Eagle Viewing Area dike.

2.2 Integrated Flood Hazard Management Plan

The District adopted an Integrated Flood Hazard Management Plan (IFHMP) in 2017 following a three-year process involving significant technical work and community engagement, including engagement with the Squamish Nation.

The IFHMP provides recommendations and actions to guide a variety of policy, land use, infrastructure, and emergency preparedness/response programs for the District. In developing the IFHMP, new flood hazard and regulatory floodplain maps were established through 1-dimensional and 2-dimensional hydraulic modelling. The underlying analysis considered the anticipated climate change impacts to flood hazards, including increased precipitation and sea level rise.

Guided by the IFHMP, the District has initiated a dike design and construction program which will upgrade Squamish River dikes and construct a new sea dike to protect downtown Squamish. The District has recently upgraded the highest-priority dike reach identified in the IFHMP (Upper Judd Slough).

The IFHMP also identifies the Eagle Viewing Area / Siyich'em Reserve area as a high-priority area for dike upgrading. However, a preferred upgrading concept was not developed as part of the IFHMP because of several factors (e.g., Siyich'em Reserve land tenure issues) requiring further attention than the IFHMP could offer. Accordingly, the IFHMP recommended that a dike master plan be developed for the area to identify a preferred upgrading concept and guide implementation.

The IFHMP identified the following general design criteria for Squamish River dike upgrades:

- raising of the existing dike crest to the 500-year return period (0.2% annual exceedance probability) clear-water flood level including climate change allowances as per the IFHMP plus 0.6 m freeboard – flood level elevations without freeboard are presented on Figure 1-2;
- extension of riverside erosion protection works to the raised dike crest;
- widening the dike crest to the 6 m (20 foot) standard crest width used for mainstem river dikes in California (to support emergency response and reduce seepage);
- introduction of bioengineered erosion protection works on the dike backslope to mitigate the likelihood of failure (due to erosion) during shallow overtopping events;
- construction of a toe drain (similar to those incorporated in 2013 and 2015 upgrading projects) to intercept seepage and control hydraulic exit gradient; and

- expansion of the SROW, adopting the larger of the recommended minimum 7.5 m offset from each toe of a provincial standard dike, or a recommended minimum 3 m offset from the future toe of the super dike.

The DMP used the above criteria from the IFHMP as part of the foundation for developing upgrading concepts. The design criteria for the preferred upgrading concept is presented in Section 5 and discussion is provided on its alignment with the criteria from the IFHMP.

2.3 Siyich'em Reserve Land Tenure

Squamish lies within the unceded traditional territories of the Squamish Nation and the Tsleil-Waututh Nation. Ten Squamish Nation Reserves located throughout the Squamish River valley create an inseparable common interest in flood protection for the District and the Nation.

Many dikes in Squamish were constructed without the consent or involvement of the Squamish Nation, including the portion of the Squamish River dike which runs in trespass without land tenure through the Siyich'em Reserve. Additionally, dikes were constructed on alignments which did not protect the full extent of all Squamish Nation Reserves from flooding.

The diking-related land tenure issue is particularly significant on the Siyich'em Reserve, and has been a topic of discussion between the Squamish Nation and all levels of government for decades.

A review of historical Reserve maps provided by the Government of Canada shows that the Reserve was mapped in 1881 (NRCan 2014, BC249 CLSR BC) with a total area of 68 acres (27 hectares) comprising two land parcels:

- an island parcel (30 acres or 12 hectares) located east of the Squamish River main channel and west of a side channel adjacent to the mainland; and
- a mainland parcel (38 acres or 15 hectares) bounded by the side channel and a straight-line north-south boundary which intersects with the current Government Road (which was likely a road at the time of mapping).

A portion of the 1881 map is reproduced with spatial reference annotations in Figure 2-1.

Current Government of Canada Reserve mapping shows the Reserve has a total area of 9.8 acres (4 hectares) comprising of two land parcels:

- a narrow strip of land (3.2 acres or 1.3 hectares) located on the forested gravel bar immediately west of the Squamish River main channel; and
- a parcel of land (6.6 acres or 2.7 hectares) on the east side of the Squamish River main channel and west of the eastern edge of Government Road.

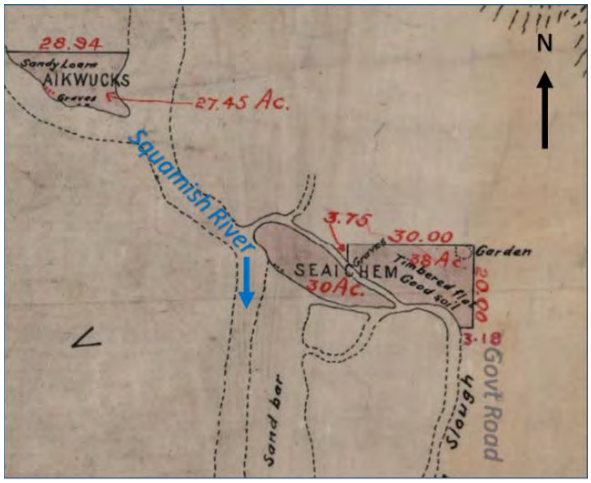

Figure 2-1: Reproduction of 1881 E. Mohun Survey Map of Reserves in the Squamish Valley

Comparing the two areas shows that the Reserve size was reduced by more than 85%. This change is the result of the Squamish River main channel alignment changing and of Government of Canada Reserve mapping practices.

Historical reports indicate that Judd Slough and Brackendale Slough (see Figure 1-2) were part of the main river channel until 1908, when a logging barge ran aground near the inlet of what is now Brackendale Slough. This disruption, combined with other factors, such as upstream diking, natural river morphology, logging practices, and watershed changes, caused debris to accumulate within Judd Slough. Subsequently, the main flow of the river was diverted into the present-day channel farther to the west. Near the south end of Judd Slough, the bouldery Stoney Creek fan redirected flow from the new main channel into Schonover Slough, which eroded to the east to become the present-day channel through Siyich'em.

Figure 2-2 presents a side-by-side comparison of the 1918 map and two historic aerial photos (1949 and 2008) which shows the transition of the Squamish River main channel from west to east. On each photo, a red arrow points to approximately the same location. From left to right, the comparison shows that the main channel has migrated from the west side of the red arrow to the east side of the red arrow, eroding much of the Siyich'em Reserve.

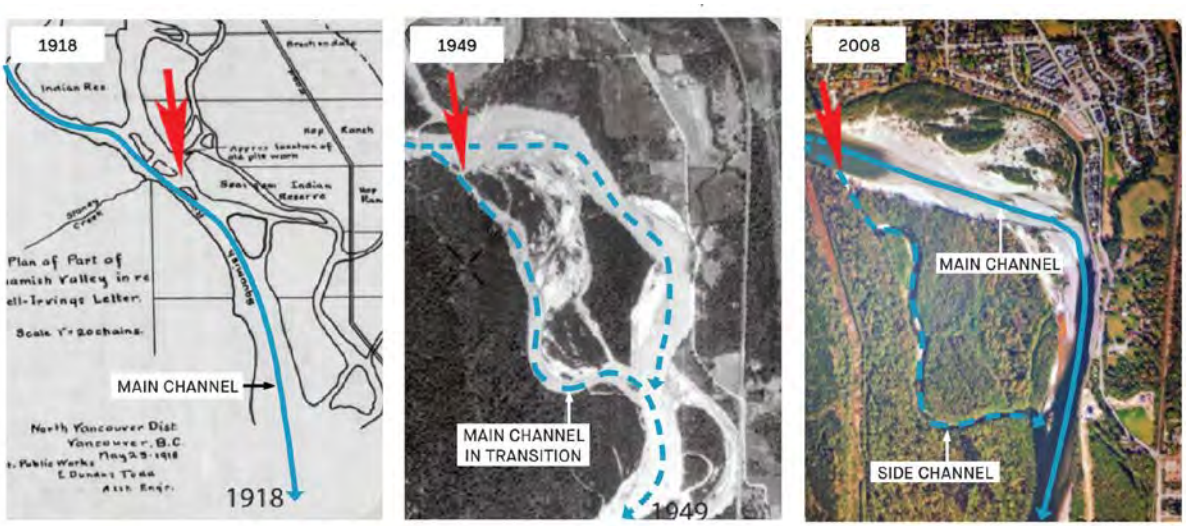

Figure 2-2: Squamish River Main Channel Alignment Change

Feeney (1950) measured land loss for five Squamish Nation Reserves (Waiwakum I.R. No. 14 Aikwucks I.R. No. 15, Seaichem I.R. No. 16, Kowtain I.R. No. 17, and Yekwaupsum I.R. No. 18) and found a total loss of over 90 acres (37 hectares) to river erosion prior to 1950. The most extreme loss occurred at Siyich'em, where Feeney (1950) calculated a loss of 39 acres (16 hectares) at that time.

Subsequent construction of the flood protection dikes followed the river channel, which had remained relatively stable since the mid-1900s (e.g., Feeney, 1950). By isolating Judd Slough and Harris Slough, the dike created hydraulic conditions that continue to favour the current river alignment, making it unlikely that the river will naturally return to its pre-1908 course. The Squamish Nation has expressed concerns about the dike alignment and its impacts for Reserve lands, particularly because it "locks in" past losses while leaving unprotected parts of the riverbank vulnerable to continued flooding and further erosion.

Figure 2-3 presents an overlay comparison of the current Reserve mapping (solid red line) and historic mapping (dashed orange line - possibly the 1881 survey) accessed through the Government of Canada Reserve mapping database.

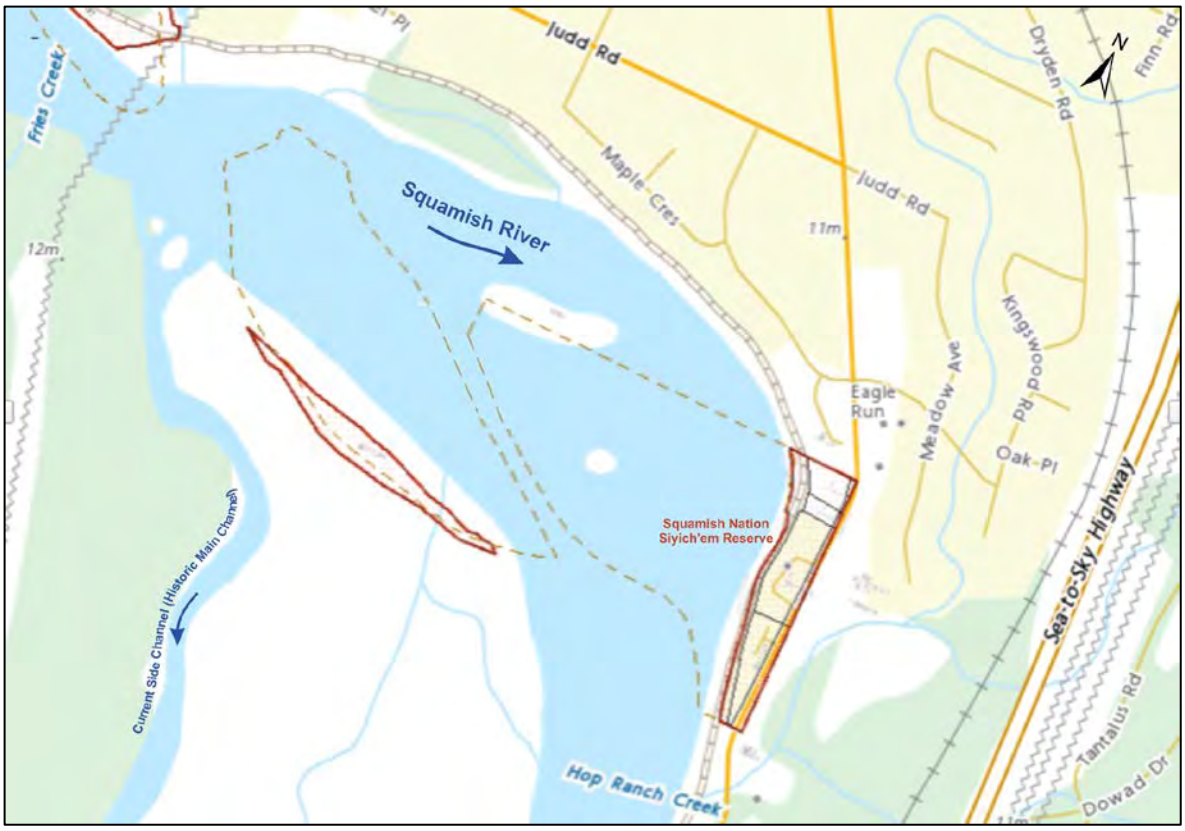

Figure 2-3: Comparison of Current (solid red line) and Historic (orange dashed line) Siyich'em Reserve Boundaries

This comparison shows that the Squamish River shifted east and eroded the majority of the Reserve land such that only a narrow strip of the original island parcel remains and less than half of the original mainland parcel remains.

It is understood that under Government of Canada Reserve mapping practices, a Reserve boundary may be defined as the ordinary high-water mark of a watercourse and erosion of the land overtime would lead to Reserve size reduction as the ordinary high-water mark moves into remaining land. Appendix C provides the Government of Canada Surveyor General's legal description report for the Siyich'em Reserve which provides additional information on the historical surveys and changes in mapped reserve boundaries.

In addition to the significant loss of land through erosion, the existing dike further limits the available land on Siyich'em Reserve. The existing dike runs through the Reserve without land tenure. The dike is maintained by the District with permission from the Nation.

In addition to the dike, a portion of Government Road also runs through Siyich'em Reserve without land tenure. The portion of Government Road in trespass through the Reserve is highlighted on Figure 2-4.

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Squamish River Dike Master Plan - Eagle Viewing/Siyich'em

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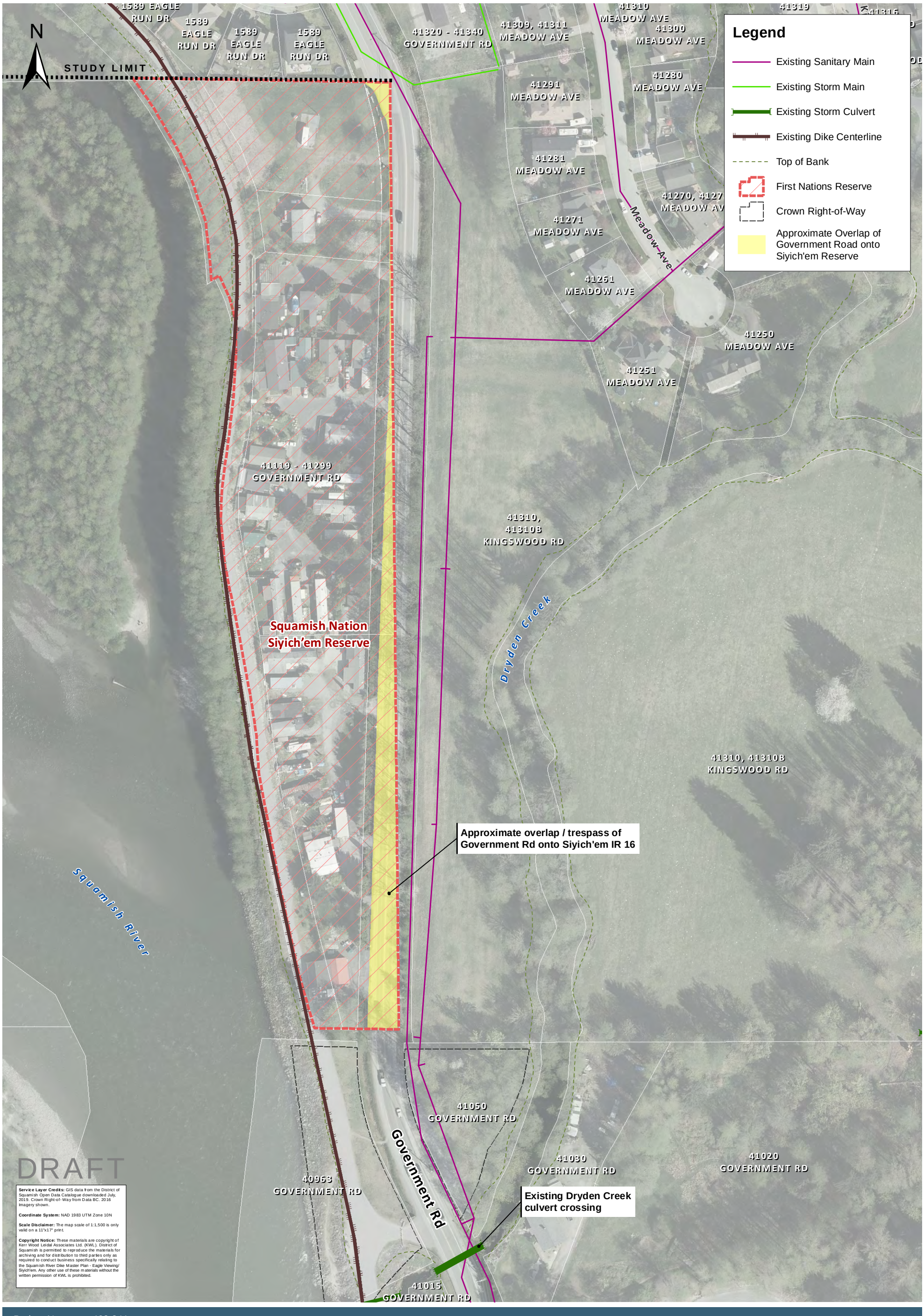

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Government Road Alignment

Figure 2-4

2.4 Existing Flood Protection and Drainage Infrastructure

The existing dike alignment, drainage infrastructure, and adjacent features are presented on Figure 1-2.

Many deficiencies have been noted with the existing dike as part of previous projects and this project. These deficiencies include:

- insufficient crest elevation based on IFHMP dike upgrading criteria (500-year return period flood level (including climate change considerations) plus 0.6 m freeboard);
- a history of seepage, particularly on the Siyich'em Reserve, which is understood to cause seasonal, nuisance flooding for residents;
- internal instability (piping) issues as noted during the 2003 flood;
- non-standard dike geometry (including gabion basket retaining walls as part of the land-side slope), as compared to provincial guidelines listed in Section 2.7;
- structures attached to and/or on the dike crest which impede access for regular or emergency activities (including a restaurant building on Siyich'em Reserve which is attached to the dike crest, and the Eagle Viewing Area picnic shelter and related structures);
- lack of land tenure and/or standard setback distance between dike toe and structures, particularly on the Siyich'em Reserve, in the Eagle Run Drive residential area, and at a private residence south of the Eagle Viewing Area;
- seismic performance which does not meet the provincial seismic guidelines listed in Section 2.7 (this is discussed further later in the report); and
- deep river scour holes adjacent to the dike toe, particularly near the Dryden Creek pump station.

The existing dike through the study area also includes several drainage structures which convey creek flow and urban runoff into the Squamish River. These include:

- flood box and pump station at Jimmy Jimmy (Judd) Slough;
- flood box at Horse Creek, connected to Jimmy Jimmy (Judd) Slough behind the dike by a culvert;
- Eagle Run Drive urban stormwater pump station; and
- flood box and pump station at Dryden Creek.

The most recent comprehensive master drainage plan for the study area (KWL, 1992) is considered out of date. An updated master drainage plan is required to provide commentary on the condition of the existing drainage infrastructure. However, in general and based on KWL's familiarity with several of the drainage structures, it is assumed that all of the drainage structures would require replacement in the future for the purposes of the dike master plan.

2.5 Land Use, Ownership, and Other Infrastructure

Figure 2-5 presents land ownership and District of Squamish land use zoning for the study area.

Land use along study area includes:

- residential (Siyich'em Reserve, Eagle Run Drive residential area);
- agricultural (a ranch/farm stand property located east of Government Road near the Eagle Viewing Area);
- commercial (a restaurant located on the Siyich'em Reserve);
- recreational (the Eagle Viewing Area);
- institutional (Easter Seals camp located east of Government Road near the Eagle Viewing Area); and
- provincial park (Brackendale Eagles Provincial Park is located on the west side of the Squamish River main channel).

Other, non-flood/drainage-related infrastructure along the study area are presented on Figure 1-2 and include:

- Government Road;
- watermain within Government Road;
- Easter Seals (M1) sanitary lift station, near Dryden Creek; and
- sanitary main which is partially located parallel and east of Government Road through a right-of-way along private properties.

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District of Squamish / Squamish Nation

Squamish River Dike Master Plan - Eagle Viewing/Siyich'em

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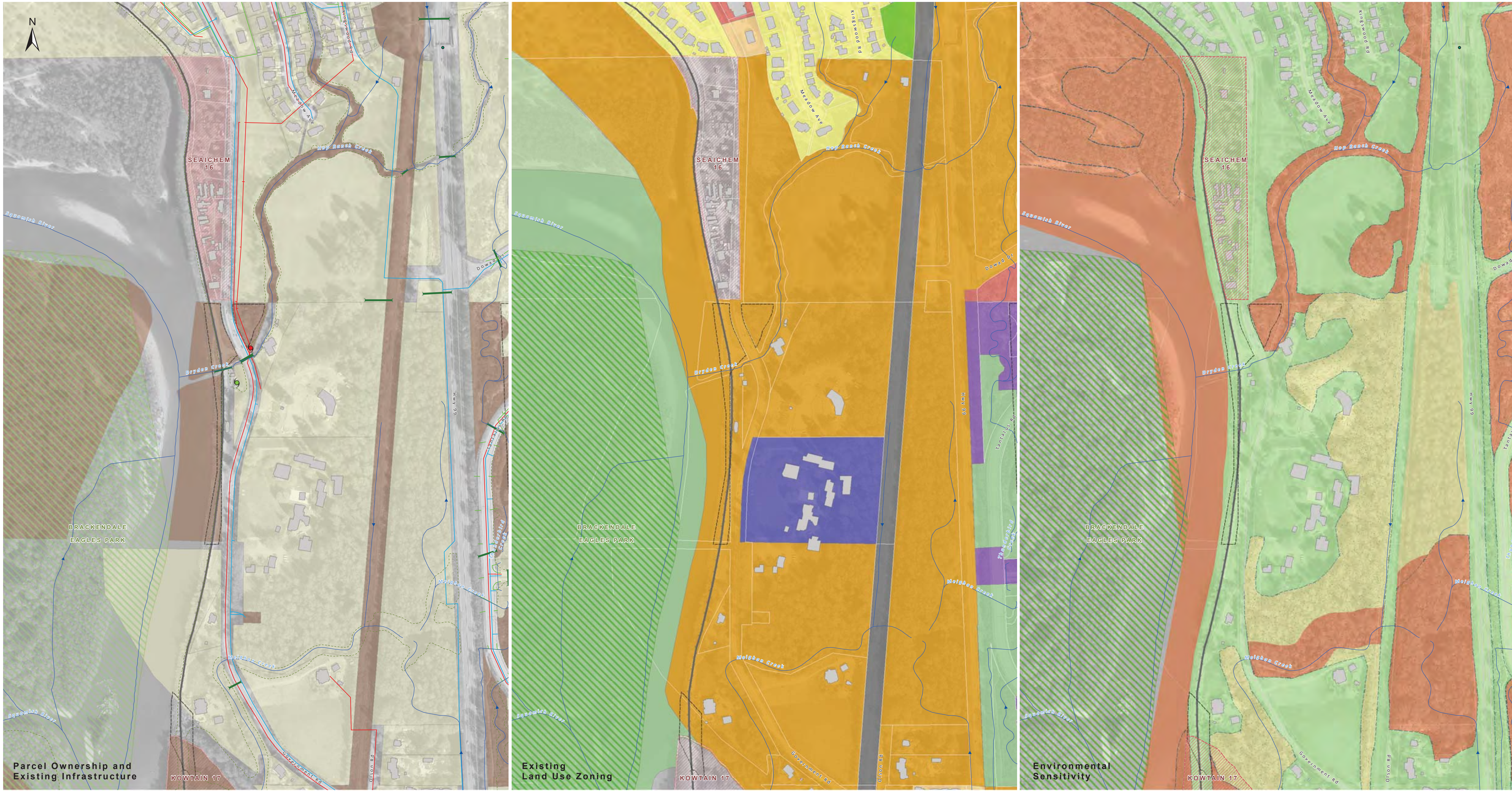

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Scale Disclaimer: The map scale of 1:3,000 is only valid on a 22"x34" print.

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Legend (Parcel Ownership and Existing Infrastructure):
- First Nations Reserve
- Provincial Park
- Crown Right-of-Way
- Building Footprint
- Dike Centerline
- Existing Storm Pump Station
- Existing Sanitary Lift Station
- Existing Storm Main
- Stm_Culvert
- Existing Watermain
- Existing Sanitary Main
- Top of Bank
- Watercourse

Parcel Ownership
- Government (Federal, Provincial, Municipal)
- Private
- Reserve

Legend (Existing Land Use Zoning):
- First Nations Reserve
- Provincial Park
- Building Footprint
- Crown Right-of-Way
- Dike Centerline
- Watercourse

Zoning
- Comprehensive Development
- District Assembly
- Ecological Reserve
- Local Commercial
- Park and Public Use
- Rail Transportation
- Resource
- Residential
- Multiple Family Residential
- Rural Residential

Legend (Environmental Sensitivity):
- First Nations Reserve
- Provincial Park
- Crown Right-of-Way
- Building Footprint
- Dike Centerline
- Watercourse
- Wetland

Environmental Sensitivity (ESA Level)
- Low
- Medium
- High

Project No. 463.341
Date May 2020
Scale 0 15 30 60 (m) 1:3,000

Land Use and Ownership

Figure 2-5

2.6 Environmental Considerations

This sub-section provides an introduction to habitat values within the Squamish River watershed as a whole and a summary of the baseline habitat review conducted for a portion of the study area.

Squamish River Watershed

The Squamish River watershed area falls within the Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra biogeoclimatic zones.

The watershed offers feeding, spawning, and rearing habitat for four listed aquatic species, including Green sturgeon (*Acipenser medirostris*), Cutthroat trout (*Oncorhynchus clarkii*), coho salmon (*Oncorhynchus kisutch*), and bull trout (*Salvelinus confluentus*). The Squamish River and its tributaries also support regionally-important anadromous runs of Chinook (*Oncorhynchus tshawytscha*), pink (*Oncorhynchus gorbuscha*), and chum salmon (*Oncorhynchus keta*), and steelhead (*Oncorhynchus mykiss*).

Eight mammals, three amphibians, and two reptiles of conservation concern occur within the watershed, including the federally endangered Pacific water shrew (*Sorex bendirii*) and two federal species of special concern, the grizzly bear (*Ursus arctos*) and the coastal tailed frog (*Ascaphus truei*). The watershed provides important wintering, migration, feeding and/or breeding habitats for a variety of migratory and resident waterfowl, shore birds, raptors, and song birds, including the federally endangered northern spotted owl (*Strix occidentalis caurina*), the great blue heron (*Ardea herodias fannini*), a federal species of special concern, and fourteen other listed bird species.

Low elevation habitat within the watershed has been significantly altered by past and present human use. Anthropogenic pressures include residential and industrial developments, hydroelectric power projects, railway corridors, mercury contamination, former garbage dumps, invasive species, and development of the local dike system. Historic construction of flood protection dikes isolated former side channels like Judd Slough, Harris Slough, Whittaker Slough, and Crescent Slough.

Study Area Habitat Review

Baseline habitat conditions were reviewed during both a desktop study and a brief, one-day site visit. The habitat review was limited in overall spatial scope and did not cover the entire study area, including the north/west of Siyich'em Reserve, as those areas were added to the DMP study area after the baseline habitat review was completed. The habitat review identifies and describes aquatic habitats (including a list of probable fish species), vegetation and terrestrial habitats, and birds and terrestrial wildlife. The assessment also identified several species of conservation concern which may be present within the study area, including fish species (bull trout, cutthroat trout, and green sturgeon), vegetation (15 plant species), birds (15 species), mammals (8 species including the Pacific water shrew), and amphibians/reptiles.

Appendix D provides a report describing the habitat review and results in additional detail.

Figure 2-5 also provides sensitive habitat mapping for the study area.

2.7 Relevant Guidelines

The provincial and local guidelines that have been considered in developing the DMP are listed below.

- Dike Design and Construction Guide, Best Management Practices for British Columba – Ministry of Water, Land, and Air Protection, July 2003.
- Riprap Design and Construction Guide – Ministry of Environment, Lands, and Parks, March 2000.
- Environmental Guidelines for Vegetation Management on Flood Protection Works to Protect Public Safety and the Environment – Ministry of Environment, Lands, and Parks, and Department of Fisheries and Oceans Canada, March 1999.
- Seismic Design Guidelines for Dikes 2nd Edition – Ministry of Forests, Lands, and Natural Resource Operations, 2014.

3. Options Identification and Shortlisting

This section describes the approach taken by the project team and the Steering Committee to identify and shortlist dike upgrading options in the study area.

3.1 District and Nation Common Interests

Several complex and potentially conflicting factors influencing the project arise out of the context discussed in Section 2. These factors include Squamish Nation loss of land and land tenure issues relating to historic diking decisions, the District's lack of a right-of-way or sole authority to upgrade the dike through Siyich'em Reserve, and transportation and parking pressures in the study area related to the Eagle Viewing Area and commercial businesses.

While the DMP is focused on upgrading flood protection, it acknowledges that planning for future flood protection in the study area needs to be done within the context of other issues and ideally with a view to start to address other issues where reasonable to do so.

To guide the process, the project team worked with the Steering Committee to develop a list of common interests as a lens through-which to weigh and consider options.

(1) Address Public Safety

- Provide flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan.
- Avoid transfer of flood risk.
- Incorporate pedestrian and traffic safety.

(2) Recapture Squamish Nation Land and Enable Beneficial Use

- Facilitate historical Reserve land restoration.
- Enable Nation use and enjoyment of land.

(3) Optimize Project Costs

- Funding to work within the context of the District's diking capital plan.
- Consider sustainable life-cycle funding for all project components.

(4) Minimize Impacts to Environmental Habitat

- Minimize impacts to habitat.
- Incorporate habitat enhancement and historical restoration where possible.

(5) Address Immediate Flood Risk while Enabling Long-term Approaches

- Address immediate flood risk with an option that is feasible for early implementation.
- Enable long-term (generational) approaches, including potential river channel migration and land recapture. This reflects a concept put forward by the Squamish Nation to relocate the Squamish River main channel into its historic channel to the west. While not directly a dike upgrading concept, the ability to accommodate a future change is considered in developing diking options.

(6) Acknowledge Site History and Culture

- Reflect Siyich'em Reserve land history in plan and in option development.

(7) Enable Future Collaboration on Access Issues

- Enable future collaboration on District access for dike maintenance.
- Enable future collaboration on issues related to public access.

3.2 High-Level Concepts (Original Study Area)

As previously stated, the original study area for the project was limited to the area between the north boundary of the Kowtain Reserve and the north boundary of the Siyich'em Reserve.

KWL and Hapa developed several high-level dike upgrading concepts for the original study area focusing at first on dike alignment and footprint. The concepts were reviewed with the Steering Committee and refined into the following list of concepts (visualizations used to discuss the majority of these high-level concepts are provided in Appendix E). It is important to note that these high-level concepts are not all distinct or complete dike upgrading options. This list of concepts was used to advance discussion with the Steering Committee as an intermediate step towards shortlisting distinct options, which is discussed in the following sub-section.

1. **Minimize Dike Fill** – The dike would be raised on its existing footprint using land-side retaining walls to avoid further impacting Siyich'em Reserve and other development.
2. **Raise Siyich'em Reserve** – The land encompassing Siyich'em Reserve would be raised to dike height at the river side of the Reserve, sloping down towards Government Road. This concept would apply only to Reserve and could be paired with the above concept south of Siyich'em Reserve.
3. **Straighten Government Road** – Government Road would be straightened so it is off the Siyich'em Reserve, and Dryden Pump Station would be replaced at a new location during works. This concept is not a standalone dike alignment and could be paired with other approaches.
4. **Relocate Government Road** – Government Road would be dramatically realigned, along the railway corridor several hundred meters east of its current location. The existing road area would form part of the new dike and could be paired with the concept to raise Siyich'em Reserve.
5. **Raise Government Road** – Government Road would be raised along the reach to function as the dike. This could be paired with the concept to raise Siyich'em Reserve.
6. **Reclaim the Slough** – For the reach along Siyich'em Reserve, the dike would be raised by expanding the footprint to the water-side (west), into Jimmy Jimmy (Judd) Slough, minimizing impacts on the Siyich'em Reserve.
7. **New Dike Alignment to Restore Reserve Land** – In the reach along Siyich'em Reserve, the dike would be realigned to the west, joining the existing dike at Fisherman's Park. This would create dike protection for the large forested island next to Siyich'em Reserve, with potential to address historic loss of land and land tenure issues through restoring Reserve land.

8. **Realign Squamish River** – While not directly a diking option, it was requested that the concept to realign the Squamish River main channel to its historic alignment to the west be noted as a concept. As discussed as part of the common interests, this is not a dike upgrading option that would directly satisfy the primary purpose of the DMP. However, the concept of long-term river alignment change is acknowledged in the DMP and compatibility discussed for advanced options.

3.3 Shortlisting of Options (Original Study Area)

Two Steering Committee meetings were used to advance from the list of high-level concepts presented in the Section 3.1 to a shortlist of distinct options for conceptual design and engagement. The options refinement and shortlisting process was conducted through facilitated discussions with reference to the common interests presented earlier.

The original study area was divided into 2 reaches (Siyich'em and the Eagle Viewing Area) and the following options were shortlisted by the Steering Committee. Conceptual design and feasibility information for the shortlisted options is provided in Section 4.

Siyich'em Reach

Three (3) options were shortlisted in the Siyich'em reach which covers the Reserve area. Figure 3-1 summarizes the conceptual alignment of the shortlisted options in the Siyich'em reach.

The options are briefly described below. Additional information is provided in Section 4.

Option A – Retaining Wall

Option A was developed based on high-level concept #1 (minimize dike fill). This option would involve raising the existing dike and minimizing the footprint to the existing dike footprint on the Reserve by retaining the dike fill on the land-side with a vertical wall.

Option B – Land Raising

Option B was developed based on high-level concept #2 (raise Siyich'em Reserve). This option would involve removing existing structures on the Reserve, filling the land to the dike crest elevation and regrading the land the to accommodate replacement structures, infrastructure, and utilities. It may not be possible to raise the entire footprint of the Reserve to the dike crest elevation. Detailed grading would depend on future redevelopment form and could be optimized through detailed design.

Option C – New Dike Alignment to Recapture Land

Option C was developed based on high-level concept #7 and would involve constructing a new dike which would diverge from the existing dike near the southern portion of the Siyich'em Reserve, cross Jimmy Jimmy (Judd) Slough and be routed on the large forested island along an alignment setback from the Squamish River. Unlike Option A and Option B, this option would not tie into the existing dike on the northern boundary of the Siyich'em Reserve. Option C would tie into the existing dike at Fisherman's Park and would act as a replacement for the existing dike along the Eagle Run Drive residential area between Fisherman's Park and the north boundary of Siyich'em. As discussed in Section 4, the original study area was expanded to Fisherman's Park accommodate contemplation of Option C and comparison against Option A and Option B. The new dike alignment would partially disconnect a large, forested island from the Squamish River and the option is shortlisted with the concept that partial connection could be maintained via a new fish-friendly pump station at the outlet of Jimmy Jimmy (Judd) Slough.

Figure 3-1: Conceptual Alignments of Shortlisted Options in the Siyich'em Reach

Eagle Viewing Area Reach

Only one option was shortlisted for the Eagle Viewing Area which covers the area between the southern boundary of Siyich'em Reserve and the northern boundary of the Kowtain Reserve.

The shortlisted option is **Land-side Raise** which refers to raising the dike crest and expanding the footprint towards the land-side (east) wherever there is space. This essentially involves a conventional dike raising approach with the footprint expanding towards Government Road. Where Government Road or other structures obstruct the expansion, the work could include retaining walls or a partial raising of Government Road. These sub-options are discussed further in Section 4 and Section 5.

The rationale for shortlisting only one option for the Eagle Viewing Area is that it became apparent through the options development and shortlisting process that the Siyich'em reach is more complex and is likely to be a relatively higher cost component of the overall dike upgrading project. Based on this and the common interest to manage costs, the project scope was more focused on the Siyich'em reach options. The land-side raise approach is believed to be the simplest and lowest cost concept for the Eagle Viewing Area, and was deemed to be appropriate through the options development and shortlisting process.

4. Conceptual Design & Feasibility of Shortlisted Options

This section describes the conceptual design and feasibility considerations developed for the shortlisted options. Section 4.1 describes how and why the original study area was expanded to Fisherman's Park after the shortlisting of options for conceptual design. The remainder of the sub-sections describe the conceptual design criteria and the conceptual design options reach-by-reach. Class-D construction cost estimates developed for all options are compared at end of this section.

4.1 Study Area Expansion and Inclusion of Eagle Run Drive Dike

As described in Section 3, the development and shortlisting of Option C (New Dike Alignment to Recapture Land) in the Siyich'em reach necessitated an expansion of the study area because Option C extends beyond the Siyich'em Reserve and ties into the existing dike at Fisherman's Park.

To provide a defensible comparison of Options A, B, and C, the limits need to be the same. Accordingly, the study area was expanded to Fisherman's Park to consider the Eagle Run Drive dike reach.

Based on discussions with the District, it was assumed that if Option A or Option B is selected as the preferred option in the Siyich'em reach, the logical future upgrading north of the Siyich'em Reserve would involve raising the existing dike along Eagle Run Drive. This is presented as a new option, named ERD for convenience.

Figure 4-1 presents the high-level conceptual alignments for all of the shortlisted options.

The figure shows how Option A and Option B would be linked with ERD, while Option C is a standalone option. Option C would negate the need for future upgrading of the existing dike along Eagle Run Drive. This has potential infrastructure and community advantages which are discussed in this section.

The only shortlisted option in the Eagle Viewing Area (Land-Side Raise) is named EVA for convenience in links with any of Option A + ERD, Option B + ERD, or Option C to complete the study area.

The conceptual design options are described by reach in the following sub-sections.

Figure 4-1: Conceptual Alignments of Shortlisted Options

4.2 Conceptual Design Criteria and Geotechnical Analysis

The relevant guidelines referenced in Section 2.7 were considering in identifying the following design criteria which were used to develop conceptual designs for the shortlisted options:

- Crest elevation based on the 500-year return period (0.2% annual exceedance probability) Squamish River flood level including climate change allowances plus 0.6 m freeboard. The flood level was extracted from the Squamish River hydraulic modelling results from the IFHMP and are presented on Figure 1-2.
- Minimum 6 m width for dike crest as referenced in the IFHMP.
- Maximum 3H:1V slope for dike fill land-side slopes (except where retaining walls are used).
- Maximum 2H:1V slope for bank protection dike water-side slopes.

- Adequate factors of safety for geotechnical stability (discussed further below) considering:
    - Static (flood condition) stability
    - Seepage and internal erosion (piping)
    - Seismic (non-flood condition) stability
- Bank protection up to the dike crest as referenced in the IFHMP.
- Dike toe scour protection (e.g. self-launching riprap toe).
- Dike access criteria including:
    - Access ramps spaced at a maximum of 2 km
    - Turnouts provided every 300 m to 500 m (unless an access ramp is provided in between)
- Preferred land tenure in favour local diking authority (as discussed in the following sections, this may not be achievable for Option A and Option B which maintain the existing alignment through Siyich'em Reserve).

Geotechnical Analysis and Design Input

Thurber conducted geotechnical analysis focusing on static stability, seepage, and seismic performance to support input into the conceptual design of the shortlisted options. The DMP focuses on conceptual design and generally does not involve analysis to support detailed design. However, a geotechnical field investigation and high-level numerical analysis calculations were included in the scope of the project to indicate whether and to what extent seepage control and ground improvement measures for seismic performance would need to be incorporated into the conceptual design. These components can have a significant impact on the overall cost of flood protection upgrading and were assumed to be required based on previous experience on Squamish River dikes.

The geotechnical field investigation, which involved drilling on the dike, was conducted before the original study area was expanded and no geotechnical information was collected upstream of Siyich'em Reserve. Thurber was able to expand their numerical analysis to provide some commentary for the expanded area, as presented in their report, but the uncertainty of results is higher due to a lack of site-specific data. Thurber assumed that the ground conditions on the new alignment could be represented by the ground conditions along the drilled locations. This is an untested assumption that adds uncertainty.

The geotechnical analysis and design input are documented in a Thurber report provided in Appendix F. The design input was incorporated into the conceptual design of the shortlisted options and is discussed reach-by-reach in the following sub-sections.

4.3 Conceptual Design and Feasibility Considerations by Reach

In this section, the conceptual design of shortlisted options and related feasibility considerations are described by reach.

For each shortlisted option, the following items are provided:

- general description of option and design components;
- conceptual alignment (previously provided in Figure 4-1);
- typical cross-section;

- discussion of compatibility of option with respect to the District and Nation common interests presented in Section 3.1; and
- discussion of technical and administrative feasibility considerations.

Class-D cost estimates are provided in the following section.

Discussion of community engagement activities is provided in Section 5.

Eagle Run Drive Reach

As described in Figure 4-1, the Eagle Run Drive reach extends from Fisherman's Park to the northern boundary of the Siyich'em Reserve.

There are two shortlisted options in this reach:

- ERD – Raising the existing Eagle Run Drive dike on its existing alignment; and
- Option C – Constructing a new dike from the southern portion of the Siyich'em Reserve to Fisherman's Park.

ERD Option

As previously discussed, the ERD option was added to the project when the original study area was expanded to Fisherman's Park triggered by the identification and shortlisting of Option C. Accordingly, the ERD option would be likely implemented in this reach if Option A or Option B is selected in the Siyich'em reach. The ERD option would involve raising the existing dike along Eagle Run Drive by 1 m to 1.5 m and using a retaining wall on the land-side edge of the 6 m wide dike crest to minimize the dike footprint to minimize encroachment onto private properties located along Eagle Run Drive.

Refer to Figure 4-1 for the conceptual alignment and to Figure 4-2 for a typical cross-section.

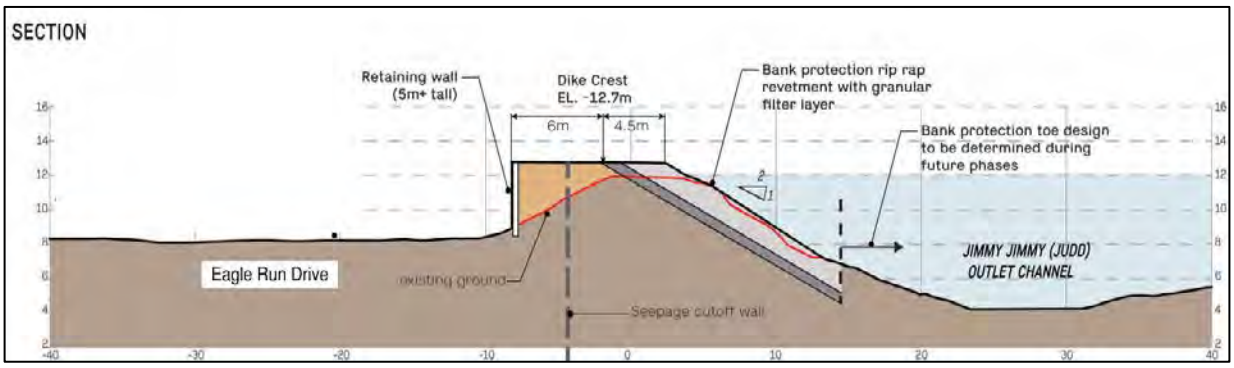

Figure 4-2: Eagle Run Drive Existing Dike Upgrade (ERD) Typical Cross-section

The water-side slope of the dike would be surfaced with a 2H:1V slope riprap revetment with toe landing near or into Jimmy Jimmy (Judd) Slough. Accordingly, the construction may involve instream works in Jimmy Jimmy (Judd) Slough to enable dike construction and to restore the channel following dike construction. As described in the geotechnical report provided in Appendix F, a 16 m tall seepage cutoff wall would be incorporated into the dike. For efficiency, this could likely be combined with the land-side edge retaining wall as a single steel sheetpile wall. Additionally, ground improvement works involving a

7 m wide and 4.5 m deep zone of ground improvements (soil mixing panels) would be required along the water-side edge of the dike to achieve provincial seismic performance criteria.

Three existing drainage structures (Judd Slough pump station, Horse Creek floodbox, and Eagle Run Drive pump station) are located along the ERD option and would need to be upgraded in the future, either directly as part of the dike upgrading project or in a phased approach.

The ERD option was assessed with respect to the common interests described in Section 3.1. Findings are summarized in Table 4-1.

Table 4-1: ERD Option Compatibility with District and Nation Common Interests

Common Interest	ERD
Address Public Safety	• Provides flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan. • Avoids transfer of flood risk. • No change to internal floodway capacity behind the dike.
Recapture Squamish Nation Land and Enable Beneficial Use	• No land recapture is achieved.
Optimize Project Costs	• Refer to Class D construction cost estimates for capital cost (Section 4.4). • Operation and maintenance includes two pump stations and 3 flood boxes along Eagle Run Drive.
Minimize Impacts to Environmental Habitat	• Jimmy Jimmy (Judd) Slough habitat will be disturbed during rip rap construction and ground improvements. • Some tree removal during dike raising and rip rap refurbishment. • Pump stations & flood boxes can be re-built to be "fish-friendly". • Public access will be low, similar to existing.
Address Immediate Flood Risk while Enabling Long-term Approaches	• Compatible with potential future approaches to realign Squamish River main channel to historic alignment.
Acknowledge Site History and Culture	• No major change – landscaping would provide potential to reflect site history and culture.
Enable Future Collaboration on Access Issues	• District already has a right-of-way over the ERD dike which may need to be expanded. • Public trail connectivity is broken through Siyích'em Reserve.

ERD was also assessed with respect to technical and administrative feasibility considerations. Findings are summarized in Table 4-2.

Table 4-2: Technical and administrative feasibility summary for ERD

Feasibility Topic	ERD Impact
Construction Impacts to Residents/Stakeholders	• Disturbance to Eagle Run Drive residents includes backyard / landscaping impacts and potential for vibration near structures.
Constructability & Phasing	• ERD involves challenging construction conditions along existing dike due to existing structures and Jimmy Jimmy (Judd) Slough. • Complex ground improvement works near Jimmy Jimmy (Judd) Slough. • Better suited to phasing of upgrades, as this involves improvement of an existing dike.
Environmental Permitting	• Water Sustainability Act – routine, moderately complex. • Fisheries Act – routine, moderately complex; will require habitat compensation. • Species at Risk Act – potentially complex permit for Pacific water shrew and Roell's brothella. However, this option does not directly intersect with critical habitat.
Dike Maintenance Act Permitting	• Some challenges expected on right-of-way and seismic performance issues.
Hydraulics & geomorphology	• No significant impact on Squamish River hydraulics and geomorphology.
Geotechnical	• Ground improvements conceptual design was developed without site-specific drilling information which adds high uncertainty.
Operations & Maintenance	• Operation and maintenance includes two pump stations and 3 flood boxes along Eagle Run Drive. • Bank protection is setback from the Squamish River requiring less maintenance.

Option C

This option involves constructing a dike on a new alignment heading north-west from Siyich'em Reserve along and setback from the active Squamish River bank and connecting to the existing dike at Fisherman's Park. This approach would enable the Squamish Nation to recapture historic reserve land and unceded land which was eroded and then rebuilt through deposition over several decades.

The Option C alignment features are presented in Figure 4-3.

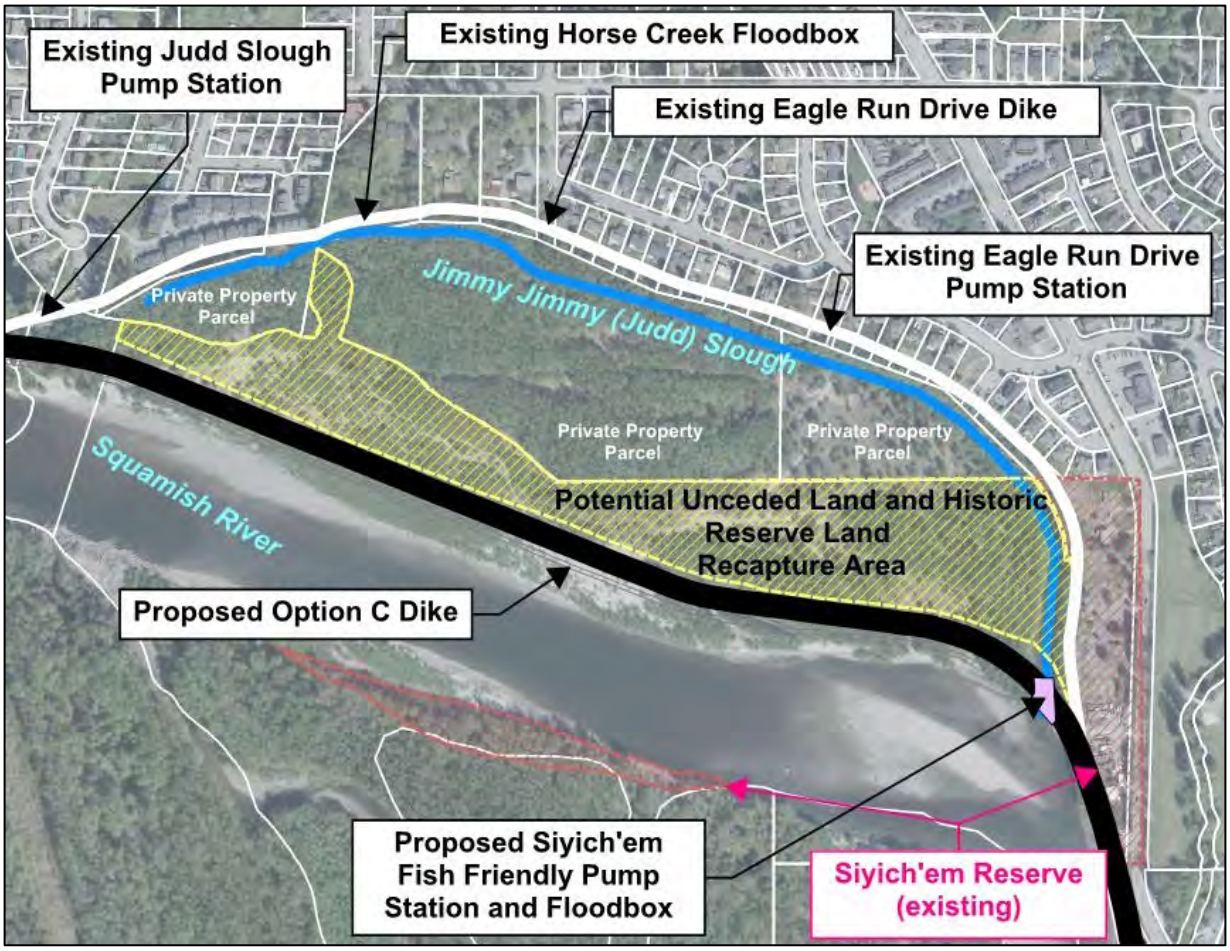

Figure 4-3: Option C Alignment and Features

The Option C dike would newly protect all of the land between the Option C dike and the existing Eagle Run Drive dike. These lands are a mixture of private land parcels based on historic land surveys and Crown land. At the same time, these lands are also part of the unceded traditional territory of the Squamish Nation.

It is understood that there are legal and administrative tools for the Squamish Nation to recapture land to add to the Siyich'em Reserve. These legal and administrative processes are outside the scope of this project. Figure 4-3 shows a polygon of land labelled as "Potential Unceded Land and Historic Reserve Land Recapture Area"; however, this presented polygon is for discussion purposes only. The polygon includes all land between the existing dike and the proposed Option C alignment, with the exception of private property parcels.

The area of the potential land recapture polygon is approximately 9.8 hectares which represents approximately 36% of the historic Reserve size and more than 245% of the current Reserve size. The DMP does not contemplate or prescribe any future land uses for the potential recaptured land which would be under the Nation's discretion for the beneficial use of the Squamish Nation.

Option C also provides significant opportunity for the resolution of dike land tenure and access issues. This approach minimizes dike footprint within the existing Siyich'em Reserve boundary; however, the existing restaurant building structure on Reserve which is attached to the dike would need to be removed. The new alignment provides the opportunity for the District and Nation to start discussions on whether the new dike would be located on Reserve land with an agreement to allow for District maintenance, or for the dike to be located on Crown land with a right-of-way for District maintenance, or other potential approaches.

Figure 4-4 provides a typical cross-section for Option C.

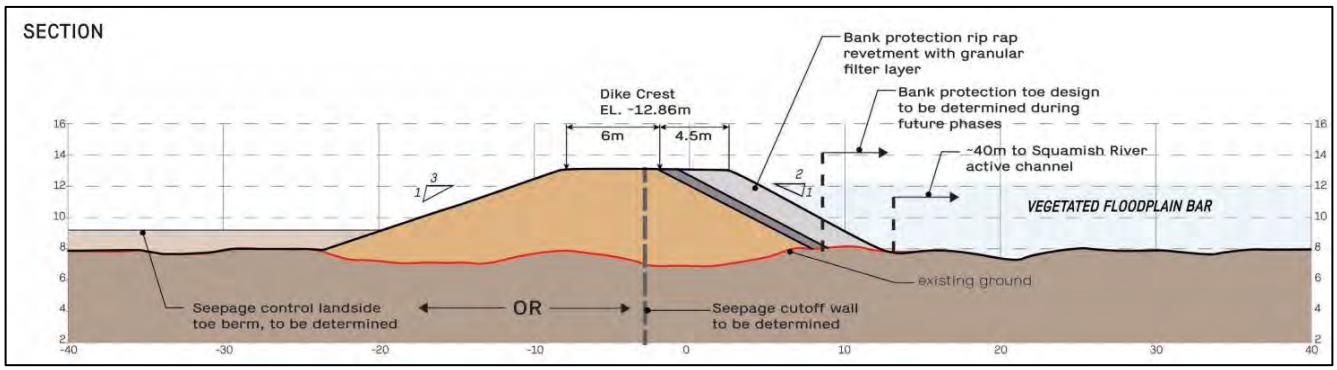

Figure 4-4: Option C Typical Cross-section

The conceptual design involves a 3H:1V land-side slope, a 6 m wide dike crest, and a riprap revetment for bank protection sloped at 2H:1V. For Option C, there are two alternatives to provide seepage control for dike stability. The first is a 16 m deep steel sheetpile seepage cutoff wall that could be embedded into the dike core; the second would involve a land-side toe berm which would extend 15 m from the land-side slope toe. The height of the land-side toe berm would be approximately 1.5 m. The latter approach is much more cost-effective. However, it would need to be coordinated with the Squamish Nation as it would extend into the potential Reserve recapture land. This is not expected to a major obstacle as a variety of land uses could be accommodated on top of the land-side toe berm.

Option C also requires ground improvement works to achieve provincial seismic performance criteria. Within the Eagle Run Drive reach, the requirement is estimated to be the same as the ERD option, involving a 7 m wide and 4.5 m deep zone of ground improvements (soil mixing panels) would be required along the water-side edge of the dike. Along the portion of Option C in the Siyich'em reach (i.e. downstream end of Option C), the requirement is higher, involving two zones of ground improvement on either side of the dike. On the water-side, the zone of ground improvement is estimated to be 24 m wide and 16 m deep. On the land-side, the zone is estimated to be 10 m wide and 6.5 m deep. Additional information is provided in the geotechnical report by Thurber in Appendix F.

As the Option C alignment encroaches into the Squamish River primary floodway, high-level hydraulic modelling was conducted using the existing Squamish River 1-dimensional hydraulic model to investigate the potential for Option C to transfer flood risk. The analysis focused on the design flood event (500-year return period / 0.2% annual exceedance probability Squamish River flood with climate change allowances as per the IFHMP).

The investigation revealed that the Option C alignment could result in:

- a maximum 0.3 m water level rise along the Option C dike alignment;
- a maximum 0.3 m water level rise extending to 500 m upstream of Fisherman's Park; and
- a maximum 0.1 m water level extending further upstream and gradually reducing to zero approximately 2 km upstream of Fisherman's Park.

The hydraulic modelling analysis results are uncertain due to the complexity of the river channel and side channels. The uncertainty can be reduced through a 2-dimensional hydraulic modelling analysis.

These impacts are considered manageable as part of the District's ongoing dike upgrading program and do not represent an insurmountable feasibility issue.

In addition to upstream dike upgrading, it would be important to review the impact of the new alignment on dike breach and internal floodway hydraulics which influence flood construction levels as guided by the IFHMP.

The new dike alignment would partially disconnect a large, forested island from the Squamish River. Partial connection could be maintained via a fish-friendly pump station at the outlet of Jimmy Jimmy (Judd) Slough. The dike alignment would be set back from the active river channel by 30 m or more, except for the connection points at Fisherman's Park and at the existing dike near the south edge of Siyich'em Reserve.

Additional future work is required to better understand the impact of the partial disconnection on environmental habitat. Specifically, 2-dimensional hydraulic modelling and/or potentially physical modelling would help quantify the frequency that the forested island is inundated under current conditions. The frequency of inundation that would be disrupted by Option C can be used to quantify the aquatic habitat value of the island.

As part of engagement on the shortlisted options (refer to Section 5), Fisheries and Oceans Canada (DFO) provided written feedback (refer to letter in Appendix H) highlighting concerns around habitat impacts related to the partial disconnection and the need for additional work to quantify the impact.

Future work can also provide additional commentary on the potential for Option C to impact Squamish River fluvial geomorphology. Option C appears to be highly compatible with the Squamish Nation supported concept to realign the Squamish River to its historic channel alignment. Additional hydraulic and fluvial geomorphology studies could improve the understanding of how the Squamish River would respond to Option C, including potential erosion and deposition transfer of risk and how Option C could be linked with a potential future river realignment concept.

As Option C would replace the existing dike along Eagle Run Drive, the option provides the opportunity to replace the existing 3 drainage structures along Eagle Run Drive with one new fish-friendly pump station and floodbox at the outlet of Jimmy Jimmy (Judd) Slough.

Option C was assessed with respect to the District and Nation common interests presented in Section 3.1. Findings are summarized in Table 4-3.

Table 4-3: Option C Compatibility with District and Nation Common Interests

Common Interest	Option C
Address Public Safety	• Provides flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan. • Minor flood risk transfer upstream can be managed through on-going dike upgrading program and future upgrades to flood construction level policies. Additional 2-dimensional hydraulic modelling analysis can reduce uncertainty.
Recapture Squamish Nation Land and Enable Beneficial Use	• Significant opportunity to address Siyich'em Reserve loss of land. • Compatible with potential Government Road realignment.
Optimize Project Costs	• Refer to Class D construction cost estimates for capital cost (Section 4.4). • O&M includes 1 new fish-friendly pump station flood box at the outlet of Jimmy Jimmy (Judd) Slough. • Bank protection maintenance would be higher than ERD option due to higher exposure to Squamish River.
Minimize Impacts to Environmental Habitat	• Lower Jimmy Jimmy (Judd) Slough habitat will be disturbed considerably at south end for dike crossing & pump station. Ecological conditions in Jimmy Jimmy (Judd) Slough and on the large, forested island will be altered by construction of a new dike. Additional work is required to better understand the habitat impacts. • Considerable tree removal on the large, forested island, but most existing trees along dike would not be impacted. • New pump station & flood box will be "fish-friendly".
Address Immediate Flood Risk while Enabling Long-term Approaches	• Highly compatible with potential future approaches to realign Squamish River main channel to historic alignment.
Acknowledge Site History and Culture	• Land recapture provides more significant opportunities to reflect site history and culture.
Enable Future Collaboration on Access Issues	• Opportunity for District of Squamish to establish a formal right-of-way for dike maintenance. • Significant opportunity for District and Nation to discuss potential for trail connectivity from Eagle Viewing Area to Fisherman's Park on new dike crest.

Option C was also assessed with respect to technical and administrative feasibility considerations. Findings are summarized in Table 4-4.

Table 4-4: Technical Feasibility Summary for Option C

Feasibility Topic	Option C
Construction Impacts to Residents/Stakeholders	• Less disturbance to Siyich'em Reserve during construction than Option A and Option B, though existing restaurant would be impacted. • No disturbance to Eagle Run Drive residents due to nearby works.
Constructability & Phasing	• Challenging construction where footprint is near active river channel. • Ground improvement implementation is routine (more space than ERD). • Bank protection works are routine. • Least suited to phasing, as this is a new dike.
Environmental Permitting	• Water Sustainability Act – complex; substantial change from existing conditions. During a WSA Change Approval, changes to water use, impacts to habitat, and impacts to provincially listed species at risk may be considered. • Fisheries Act – complex; will require considerable habitat compensation. Subject to uncertainty related to habitat value of vegetated island in the Squamish River that would be partially disconnected from the river. Refer to engagement response letter provided by DFO in Appendix H. • Species at Risk Act – potentially complex permit for Pacific water shrew. However, this option does not directly intersect with critical habitat.
Dike Maintenance Act Permitting	• Major challenges expected on justifying potential floodplain impacts, potential flood risk transfer and seismic performance issues.
Hydraulics & geomorphology	• Results in an increase in water levels which can be managed through dike upgrading program. Additional work required to better understand impacts to dike breach and internal floodway hydraulics which influence flood construction levels. • May result in scour and other morphologic changes. • Potential increase in risk of river blockage, debris jam, and ice jam concerns due to less space. Potential debris issue downstream if side channel widens. High uncertainty – requires future analysis to assess feasibility issues (2-D modelling, etc.) • Encroaching on the Squamish River primary floodway is not in line with global river engineering and floodplain management best practices of providing more room for river floods and geomorphic processes.
Geotechnical	• Ground improvements conceptual design was developed without site-specific drilling information which adds high uncertainty.
Operations & Maintenance	• Fewer pump stations and floodboxes to maintain than ERD. • More significant bank protection close to Squamish River active channel to maintain. Higher inspection effort required (visual, bathymetric, etc.) • River changes may require additional bank protection along the Squamish River if the setback between the Option C dike and the Squamish River natural bank is reduced over time in the future.

Siyich'em Reach

As described in Figure 4-1, the Siyich'em reach is located between the Eagle Run Drive reach and the Eagle Viewing Area reach.

There are three shortlisted options in this reach:

1. Option A (dike raise with retaining wall on Siyich'em);
2. Option B (raising the land on Siyich'em Reserve); and
3. Option C (a new dike alignment from the southern portion of Siyich'em Reserve to Fisherman's Park).

Option C was previously described as part of the Eagle Run Drive reach and the following focuses only on Option A and Option B.

Option A

This combination involves raising the existing dike through Siyich'em Reserve by approximately 1.5 m while limiting the dike footprint to the existing footprint by using retaining walls to contain the raised dike.

Option A would result in a total retaining wall height will be 5 m or more and the wall would disrupt views for existing structures on the Reserve. This approach aims to prevent any further dike encroachment onto Siyich'em land; however, the existing restaurant building structure on Reserve which is attached to the dike would need to be removed.

Provincial dike design guidelines discourage structures within 7.5 m of the dike toe and therefore following the guidelines would suggest not reconstructing the structure as-is. However, it is important to note that the existing dike and the upgrade under Option A would still be on the Reserve and outside of provincial Dike Maintenance Act jurisdiction.

A typical cross-section is provided in Figure 4-5.

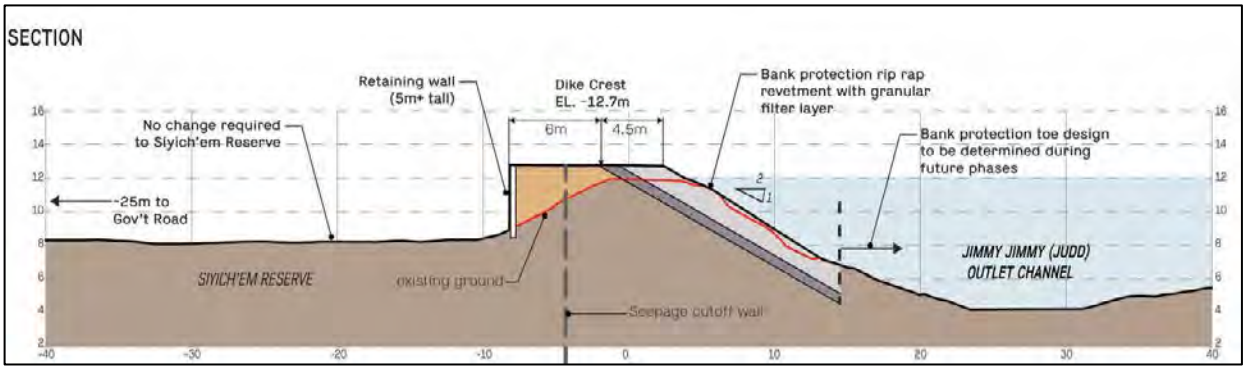

Figure 4-5: Option A Typical Cross-section

In the Siyich'em Reserve area, a 16 m deep steel sheetpile cutoff wall would be incorporated into the dike for seepage control, with the exposed portion acting as a retaining wall. The seepage cutoff wall can be combined with the land-side retaining wall.

Ground improvement works are also required for Option A to achieve provincial seismic performance criteria. As per the geotechnical report by Thurber (Appendix F), a zone of ground improvement approximately 24 m wide and 18 m deep would be required along the water-side edge of the alignment.

Existing riprap bank protection may require upgrades, which would involve limited work in Jimmy Jimmy (Judd) Slough, and the Squamish River, to provide adequate protection against river scour. Based on Thurber's analysis, ground improvement measures would likely be required to improve seismic performance of the proposed dike upgrade.

Land tenure for dike maintenance (e.g. a right-of-way) does not currently exist along the Siyich'em Reserve and the preferred right-of-way width, including extending 7.5 m from the dike toe, would not be possible given the location of existing structures on Siyich'em.

Option A was assessed with respect to the District and Nation common interests presented in Section 3.1. Findings are summarized in Table 4-5.

Table 4-5: Option A Compatibility with District and Nation Common Interests

Common Interest	Option A
Address Public Safety	• Provides flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan. • Avoids transfer of flood risk.
Recapture Squamish Nation Land and Enable Beneficial Use	• No land recapture is achieved. • No further encroachment onto Siyich'em, but the proposed retaining wall will be an imposing dike structure which will further disrupt views and space around structures. • Compatible with potential Government Road realignment.
Optimize Project Costs	• Refer to Class D construction cost estimates for capital cost (Section 4.4). • Bank protection is sheltered through lower Jimmy Jimmy (Judd) Slough, so maintenance should be lower than for Option C.
Minimize Impacts to Environmental Habitat	• Full reach of lower Jimmy Jimmy (Judd) Slough habitat will be disturbed during rip rap construction and ground improvements. • Some tree removal during dike raising and rip rap refurbishment.
Address Immediate Flood Risk while Enabling Long-term Approaches	• Compatible with potential future approaches to realign Squamish River main channel to historic alignment.
Acknowledge Site History and Culture	• No major change.
Enable Future Collaboration on Access Issues	• No improvement to existing access issues, due to dike trespassing through Siyich'em Reserve. • Public trail connectivity is broken through Siyích'em Reserve.

Option A was also assessed with respect to technical and administrative feasibility. Findings are summarized in Table 4-6.

Table 4-6: Technical Feasibility Summary for Option A

Feasibility Topic	Option A
Construction Impacts to Residents/Stakeholders	• Some disturbance to Siyich'em Reserve during construction including impacts to the existing restaurant.
Constructability & Phasing	• Option A involves challenging construction conditions along Siyich'em due to existing structures • Challenging ground improvement and bank protection works construction. • Better suited to phasing of upgrades, as this involves improvement of an existing dike.
Environmental Permitting	• Water Sustainability Act – routine, moderately complex. • Fisheries Act – routine, moderately complex; will require habitat compensation. • Species at Risk Act – potentially complex permit for Pacific water shrew. However, this option does not directly intersect with critical habitat.
Dike Maintenance Act Permitting	• Some challenges expected on right-of-way and seismic performance issues.
Hydraulics & geomorphology	• No significant impact on river hydraulics and geomorphology.
Geotechnical	• No major issues.
Operations & Maintenance	• Lack of land tenure for dike maintenance. • ERD extension has more pump stations and floodboxes to maintain than Option C • Less bank protection close to Squamish River active channel to maintain than Option C

Option B

This option involves raising as much of the Siyich'em Reserve as is practical to the design dike crest elevation. The raised land would slope down gradually, or through the use of retaining walls, to meet Government Road. This approach would require removal and replacement of all existing structures and services on the Reserve, resulting in short-term disruption; however, this may benefit the Reserve in the long-term as the replacement structures (and future development) would be significantly more protected from seasonal seepage issues and afforded a better vantage over the river.

A typical cross-section is provided in Figure 4-6.

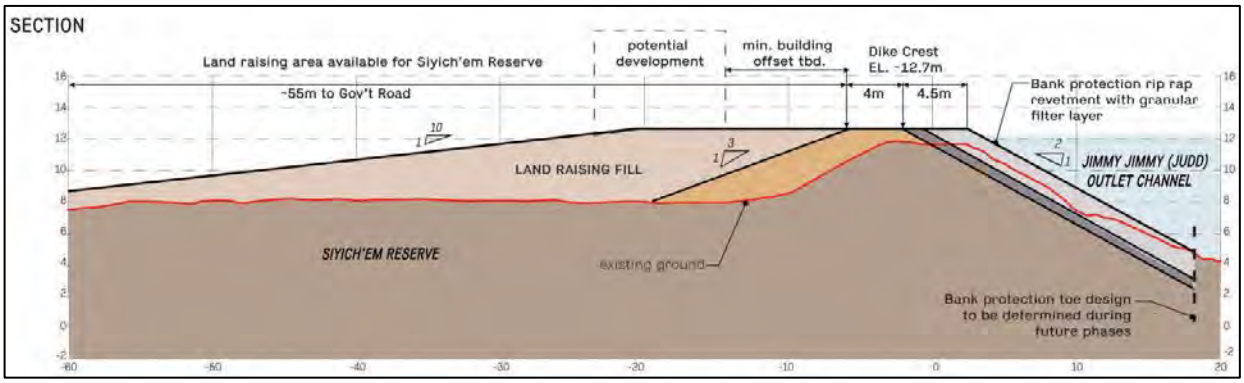

Figure 4-6: Option B Typical Cross-section

The land raising would negate the need for a deep cutoff wall within the dike for seepage control, as structures would be raised to high enough elevations to avoid seepage.

Under this approach, the entire raised land area would serve as flood protection. However, for regulatory purposes, the dike could be defined as only the portion of land raising above the existing dike. The conventional setback requirement, extending 7.5m from the dike toe, could be considered for relaxation given the area of raised land acting as part of the dike. However, it's important to note that existing dike maintenance land tenure issues would not be resolved under this option.

Existing riprap bank protection may require upgrades, which would involve limited work in Jimmy Jimmy (Judd) Slough, and the Squamish River, to provide adequate protection against river scour. Based on Thurber's analysis, ground improvement measures would likely be required to improve seismic performance of the proposed dike upgrade. It is estimated that the ground improvements would be implemented on a 24 m wide and 18 m zone along the water-side edge of the dike.

Option B was assessed with respect to the District and Nation common interests presented in Section 3.1. Findings are summarized in Table 4-7.

Table 4-7: Option B Compatibility with District and Nation Common Interests

Common Interest	Option B
Address Public Safety	• Provides flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan. • Avoids transfer of flood risk.
Recapture Squamish Nation Land and Enable Beneficial Use	• No land recapture is achieved. • Temporary but significant disruption of beneficial use during construction, over a longer window than for Option A. • Dike remains on Siyich'em Reserve, but is at grade, improving long-term beneficial use of dike. • Compatible with potential Government Road realignment.
Optimize Project Costs	• Refer to Class D construction cost estimates for capital cost (Section 4.4).
Minimize Impacts to Environmental Habitat	• Full reach of lower Jimmy Jimmy (Judd) Slough habitat will be disturbed during rip rap construction and ground improvements. • Same tree removal as A, plus removal of all trees on Siyich'em Reserve.
Address Immediate Flood Risk while Enabling Long-term Approaches	• Compatible with potential future approaches to realign Squamish River main channel to historic alignment.
Acknowledge Site History and Culture	• No major change.
Enable Future Collaboration on Access Issues	• No improvement to existing access issues, due to dike trespassing through Siyich'em Reserve. • Public trail connectivity is broken through Siyích'em Reserve.

Option B was also assessed with respect to the technical and administrative feasibility. Findings are summarized in Table 4-8.

Table 4-8: Technical Feasibility Summary for Option B

Feasibility Topic	Option B
Construction Impacts to Residents/Stakeholders	• All Siyich'em Reserve occupants are displaced during construction & homes/structures are re-built. • Disturbance to Eagle Run Drive residents includes garden impacts, vibration near structures. • Requires more fill placement than Option A, so higher traffic volumes.
Constructability & Phasing	• Option B is less challenging than Option A due to removal of structures for land raising. • Ground improvements and bank protection works will be challenging. • Potentially suited to phasing with development of Siyich'em Reserve.
Seepage Control	• Provides minimal seepage control during flooding events, compared with status quo; however, structures are raised so would not be impacted.
Environmental Permitting	• Water Sustainability Act – routine, moderately complex. • Fisheries Act – routine, moderately complex; will require habitat compensation. • Species at Risk Act – potentially complex permit for Pacific water shrew. However, this option does not directly intersect with critical habitat.
Dike Maintenance Act Permitting	• Some challenges expected on right-of-way and seismic performance issues.
Hydraulics & geomorphology	• No significant impact on river hydraulics and geomorphology.
Operations & Maintenance	• Lack of land tenure for dike maintenance. • ERD extension has more pump stations and floodboxes to maintain than Option C • Less bank protection close to Squamish River active channel to maintain than Option C

Eagle Viewing Area Reach

The Eagle Viewing Area reach is located south of the Siyich'em Reserve as shown on Figure 4-1.

Eagle Viewing Area (EVA) Land-side Raise

The only shortlisted option in this reach involves raising the existing dike crest by approximately 1.5 m between Siyich'em Reserve and the north boundary of Kowtain I.R. No. 17.

A typical cross-section is provided in Figure 4-7.

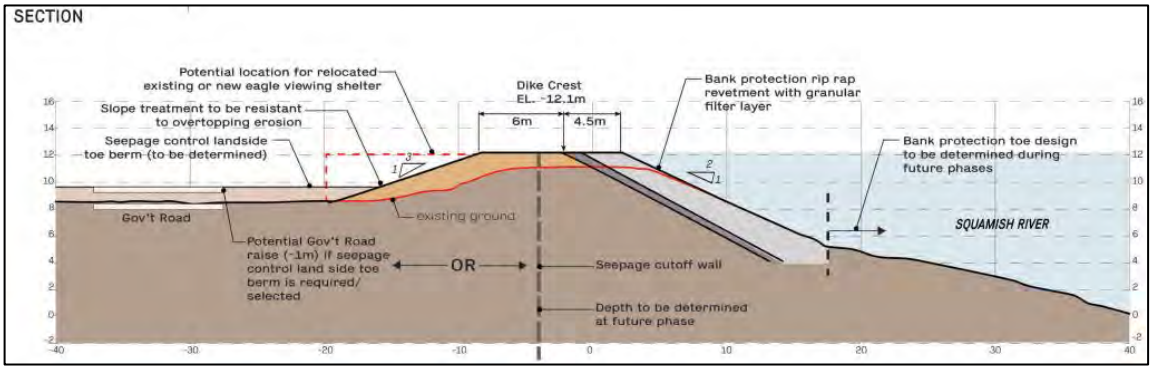

Figure 4-7: Eagle Viewing Area Land-side Dike Raise Typical Cross-section

In general, the dike footprint would be expanded towards the land (east) with a vegetated slope at a gradient of 3 horizontal to 1 vertical. Retaining walls would be used to limit the footprint in areas with limited space due to existing infrastructure and/or structures. Existing riprap bank protection may need to be upgraded which would involve work in the Squamish River to provide adequate protection against river scour.

Seepage control would be provided using either an internal, deep seepage cut-off wall or a land-side toe berm (approximately 15 m wide, 1.5 m thick), depending on whether space is available in given sections of the reach. Government Road could also be partially raised to accommodate the land-side toe berm, if cost effective.

Based on analysis by Thurber (Appendix F), ground improvement measures may be required to improve seismic performance of the proposed dike upgrade. It is estimated that one zone of ground improvement (14 m wide and 9 m deep) along the water-side edge of the dike would be required.

Existing eagle viewing facilities (shelter, interpretative signage, etc.) and benches would be removed and replaced/upgraded.

Dryden Creek pump station would likely need to be replaced at time of dike upgrading.

The Eagle Viewing Area land-side dike raise was assessed with respect to the District and Nation common interests presented in Section 3.1. Findings are summarized in Table 4-9.

Table 4-9: Eagle Viewing Area Land-side Raise Compatibility with District and Nation Common Interests

Project Value	Eagle Viewing Area Reach Impact
Address Public Safety	• Provides flood protection that meets the intent of the Squamish Integrated Flood Hazard Management Plan. • Avoids transfer of flood risk.
Recapture Squamish Nation Land and Enable Beneficial Use	• This reach does not impact Squamish Nation Land, as it is south of Siyich'em Reserve.
Optimize Project Costs	• Refer to Class D construction cost estimates for capital cost (Section 4.4). • O&M includes 1 pump station and 1 flood box at Dryden Creek. • Rip rap maintenance would be higher than Siyich'em Reach due to direct river exposure.
Minimize Impacts to Environmental Habitat	• Some tree removal during dike raising and rip rap refurbishment. • Pump station & flood box will be re-built "fish-friendly". • Improved access will increase human presence in the area.
Address Immediate Flood Risk while Enabling Long-term Approaches	• Compatible with long-term river realignment concept.
Acknowledge Site History and Culture	• Potential for educational signage describing site history.
Enable Future Collaboration on Access Issues	• Opportunity for District of Squamish to establish a formal right-of-way for dike maintenance across existing private property.

The Eagle Viewing Area land-side dike raise option was also assessed with respect to technical and administrative feasibility. Findings are summarized in Table 4-10.

Table 4-10: Technical Feasibility Summary for Eagle Viewing Area Reach

Technical Feasibility Topic	Eagle Viewing Area Reach Commentary
Construction Impacts to Residents/Stakeholders	• Impacts private property at 40813 Government Road during construction.
Constructability & Phasing	• Ground improvements in vicinity of existing development are relatively challenging. • Bank protection works are more challenging given direct exposure to the Squamish River. • Possible to upgrade dike incrementally, for example, immediate dike raising followed by future rip rap upgrades.
Environmental Permitting	• Water Sustainability Act – routine, moderately complex. • Fisheries Act – routine, moderately complex; will require habitat compensation. • Species at Risk Act – potentially complex permit for Pacific water shrew. Proposed alignment overlaps with shrew critical habitat.
Dike Maintenance Act Permitting	• Some challenges expected on right-of-way and seismic performance issues.
Hydraulics & geomorphology	• Limited impact on river hydraulics and geomorphology.
Geotechnical	• Dike reach has limited drilling data; local heterogeneity may impact ground improvement requirements.
Operations & Maintenance	• One pump station and floodbox to maintain at Dryden Creek. • Significant bank protection close to Squamish River active channel to maintain. Higher inspection effort required (visual, bathymetric, etc.).

4.4 Construction Cost Estimates

Class-D cost estimates have been prepared for each option. The complete cost estimates are presented in Appendix G. This sub-section describes the cost estimating approach and limitations, and presents a comparison of the cost estimates to support option evaluation.

Approach and Limitations

Class-D construction cost estimates have been prepared with limited site information, such as geotechnical investigations and area drainage plans, and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.

The cost estimates include the following components:

- general items (mobilization, demobilization, bonding, etc.);
- site preparation;
- ground improvement for seismic performance;
- dike construction;
- utilities (including drainage structure upgrades);
- restoration, finishes, and amenities; and
- allowances and contingences (including professional services, habitat impact compensation, and construction risk contingencies).

Approach and limitations for major items are discussed below.

Ground Improvement for Seismic Performance

Based on the geotechnical report (Appendix F) reflecting Thurber's analysis, the following levels of ground improvement were applied in the cost estimate.

- Option A – 430 m^3/m
- Option B – 430 m^3/m
- Option C – 113 m^3/m
- Eagle Run Drive – 30 m^3/m
- Eagle Viewing Area – 130 m^3/m

Based on input from Thurber, ground improvement was estimated at a unit rate of \$50/m^3.

Dike Construction

Dike fill for the conceptual design and cost estimate was assessed based on adding dike fill to the existing ground profile based on the typical cross-sections presented in this section. Fill was also allotted for access ramps and turnarounds along the dike, as per the BC Dike Design & Construction Guidelines (refer to Section 2.7).

Rip rap upgrades to a 2 m thick layer were assumed along the water-side of the dike. Additional riprap installation volumes were allotted to provide a self-launching toe, which would provide erosion protection in the case of river deepening. Land-side dike finishing included an allowance for

hydroseeding, where applicable. The granular crest surface pathway includes railings in areas where retaining walls are present.

Utilities

Option C and Eagle Run Drive both impact flood infrastructure related to Jimmy Jimmy (Judd) Slough. For Option C, a fish-friendly pump station and flood box is proposed at the south end of the reach, to replace all existing flood boxes/pump stations between Siyich'em Reserve and Fisherman's Park. For Eagle Run Drive, existing flood infrastructure in the dike includes: Horse Creek flood box, Eagle Run pump station and flood box, and Judd Slough pump station and floodbox. Replacement of these structures was costed assuming that Judd Slough and Horse Creek infrastructure would be fish-friendly. Required flow rates for the pump stations were assumed based on an assumed 0.018 $m^3/s/Ha$ design flow, including a climate change allowance. The assumed design flow input was based on previous KWL experience with Squamish pump stations.

Dryden Creek pump station and flood box replacement would be required for compatibility with the proposed dike design in the Eagle Viewing Area reach. This cost was based on a 2012 cost estimate by KWL, adjusted for inflation and with a 30% premium for fish-friendly design.

All of the above flood infrastructure upgrades are considered at a conceptual level; drainage studies are necessary for more accurate assessment of projected upgrade costs.

In addition to drainage infrastructure, an allowance was included for new utility servicing to Siyich'em Reserve for Option B.

Restoration, Finishes & Amenities

For all options along Siyich'em Reserve, an allowance was included for removal and replacement of the existing restaurant on the Siyich'em Reserve as this structure is built directly on the existing dike and must be removed for any of the proposed options.

For Option A, a small allowance was included for landscaping restoration next to the new retaining wall.

For Option B, replacement of the single-family homes and mobile homes on Siyich'em Reserve was considered, including an 8-month residential displacement compensation for households.

For Option C, water access ramps were included for Squamish Nation beneficial use.

The Eagle Run Drive ERD option includes an allowance for restoration, landscaping, and trail furniture, while the Eagle Viewing Area includes a bare-minimum landscaping allowance and EagleWatch program shelter re-installation allowance.

Allowances and Contingencies

A 30% contingency was applied to cost estimates for Option A, Option B, and the Eagle Viewing Area cost estimates, as these are relatively conventional approaches & involve minimal access challenges. However, a 40% was applied for Option C, due to challenging work near active Squamish river channel, and Eagle Run Drive, which are more challenging than A & B due to space limitations & more interface with private properties.

A 5% allowance for habitat enhancement as compensation for habitat impacts was incorporated into each option, with the exception of Option C which is expected to have a higher level of impacts and was accordingly assigned a 10% allowance.

Construction Cost Comparison of Shortlisted Options

Table 4-11 provides a comparison of the construction cost estimates. Full cost estimates for each option are provided in Appendix G.

The table is organized to provide a direct comparison of the distinct options for the full study area:

- Option A + ERD + EVA;
- Option B + ERD + EVA; and
- Option C + EVA.

Table 4-11: Summary of Class D Cost Estimate Findings for Entire Study Area

Components	Option A + ERD + EVA	Option B + ERD + EVA	Option C + EVA
Length	**2.5 km**		**2.2 km**
Siyich'em Reach Option A, B, or C cost	$ 28 M	$ 34 M	$ 74 M
ADD Eagle Run Drive Existing Alignment to Options A and B	$ 38 M		-
ADD Eagle Viewing Area Land-side Expansion Option all options	$ 40 M		
Total for Comparison ($ million)	$ 106 M	$ 113 M	$ 114 M

The comparison shows that dike upgrading construction cost is expected to be on the order of approximately $100 million within the study area, regardless of which distinct option is selected.

As revealed in detail in Appendix G, the key items contributing to magnitude of the cost estimates are ground improvements for seismic performance, bank protection, seepage control, and drainage structure upgrades.

There may be potential approaches to phase works to manage costs but it is not expected to change the cost comparison in support of option selection. Phasing concepts are discussed in Section 6 for the implementation of the preferred option.

While the difference between the lowest cost option (Option A + ERD + EVA) and the highest cost option (Option C + EVA) is $8 million, the general finding of the comparison is that cost is not a significant distinguishing factor for the option selection given the high amount of uncertainty involved the conceptual design and cost estimates. Interpreted another way, the comparison suggests that the preferred option selection should focus on other factors. This is discussed further in Section 5.

5. Engagement and Preferred Option Selection

This section provides a summary of the community engagement activities conducted on the conceptual design of the shortlisted options and documents the preferred option selection.

5.1 Engagement on Shortlisted Options

Section 1.5 provides an overview of the Squamish Nation and stakeholder engagement activities conducted in support of the DMP.

In addition to the project website launch and initial online survey on values and concerns for the study area, several engagement activities were conducted to get feedback on the shortlisted options.

These activities include:

- a meeting with Squamish Nation Siyich'em residents/families;
- a meeting with community and environmental groups;
- a meeting with private land-owners in the study area (outside of Siyich'em);
- correspondence with key regulatory stakeholders including Fisheries and Oceans Canada, BC Inspector of Dikes Office, and BC Parks; and
- a public open house hosted on December 5, 2019 at the Squamish Adventure Centre.

The public was also invited to respond to a second online survey requesting input on the shortlisted options.

Appendix H provides the key engagement materials and a summary of feedback from the targeted meetings, correspondence from regulators, and a summary of online survey results. The feedback from regulators (DFO, BC Inspector of Dikes Office, and BC Parks) includes questions and areas of uncertainty that need further clarification for the regulators to provide additional input. The project risk associated with the uncertainty was considered in the selection of the preferred option and the implementation plan (Section 6) includes next steps to address these items.

5.2 Preferred Option Selection

The preferred option for DMP is **Option C + EVA**, as depicted in Figure 4-1, reproduced (with emphasis) to the right. The preferred option was identified through discussion between the Steering Committee members. The primary factor in selecting this option was the potential for Option C to address historic wrongs related to land tenure, loss of land via erosion, and dike trespass issues on Siyich'em Reserve, while still having a similar construction cost to the other options.

The preferred option was unanimously endorsed as the preferred option with next steps identified for advancing the option by both the District council and Nation council in February 2020. A copy of the District report to council is provided in Appendix I.

5.3 Refined Conceptual Design and Other Features

The conceptual design involved in the development and evaluation of shortlisted options was limited to high-level alignment and general form. Following options evaluation, the conceptual design for the preferred dike option was refined and is presented on a series of plan figures presented in Appendix J.

The plan figures show the approximate footprint of the preferred option and indicate approximately where retaining walls, internal seepage cut-off walls, and seepage control land-side toe berms would be used. The refined conceptual design is the starting point for advancing towards preliminary and detailed design of the preferred option. Implementation actions and sequencing are discussed in Section 6.

Preliminary and detailed design stages may result in changes to the preferred option design footprint as additional information, analysis, and engagement influences the project. In particular, additional design work aided by topographic survey is required to better understand and explore the detailed design of the dike within the southern portion of Siyich'em Reserve as the new dike alignment turns to the north-west (southern end of Option C in the shortlisted designs). The dike alignment presented in Appendix J attempts to limit encroachment of the dike into the Squamish River and uses a retaining wall to limit the footprint to not further encroach onto Siyich'em Reserve and the existing restaurant building.

It may be possible to shift the alignment to the west to reduce the dike trespass on Siyich'em Reserve at this location, but it would increase the potential habitat impacts of the project and add further complexity to the environmental permitting and compensation requirements. The interaction between the dike and the existing restaurant building will also require additional investigation to be led by the Squamish Nation. While it is generally not preferred to have structures attached to dikes, it may be possible to develop a special design to modify the dike and the existing restaurant building to accommodate each other. Next steps related to this are also discussed further in Section 6.

Additionally, a preliminary public amenity concept plan has been prepared for the Eagle Viewing Area showing how eagle viewing infrastructure, parking, washrooms, and other features discussed through the design and engagement phases can be incorporated into the preferred dike option. The preliminary public amenity concept plan is presented in Appendix K.

Finally, a conceptual design to relocate Government Road to resolve the historic trespass of the road on Siyich'em Reserve has been prepared and is presented in Appendix L. To resolve the trespass through the Reserve, the road corridor would be shifted to the east which encroach onto private property located on the east side of the road. The District would require land tenure on the edge of the private property to implement the realignment. This has not been explored as part of this project, but is listed as a next step for implementation in Section 6.

5.4 Final Round of Engagement

A final round of engagement will be conducted in Spring / Summer 2020 to report back to the community and stakeholders on the preferred option selection.

6. Implementation

This section identifies next steps to advance the preferred option towards implementation, and discusses potential funding and phasing considerations.

6.1 Next Steps

A series of next steps is required to advance the master plan towards implementation (construction).

The next steps have been organized into the following categories listed below and are discussed in more detail in the following sections:

- Land tenure administrative processes;
- Additional analysis and feasibility assessments;
- Preliminary design and engagement;
- Regulatory engagement;
- Detailed design, engagement, and permitting; and
- Construction, operation, and maintenance.

Land Tenure Administrative Processes

- Initiate legal administrative process for Siyich'em Reserve land recapture. This next step would be led by the Squamish Nation.
- Explore land tenure required to realign Government Road off Siyich'em Reserve. This next step would be led by the District of Squamish.
- Initiate additional discussions on land tenure and maintenance authority for new dike alignment.
- Initiate engagement relating to two private land parcels located between ERD dike and Option C. This next step would be led by the District of Squamish.
- Address land tenure issues related to dike upgrading through the private property located near the south end of the Eagle Viewing Area (40813 Government Road). This next step would be led by the District of Squamish.

Additional Analysis and Feasibility Assessments

- Conduct additional geotechnical investigation and seismic performance analysis for the new dike alignment. Refine conceptual design for ground improvement and associated cost estimates.
- Conduct a comprehensive bathymetric survey of the Squamish River and side channels within the study area to support a hydrotechnical and geomorphic assessment (see below).
    - This could also contribute to a larger survey program that would support sediment assessment and modelling for future updating of the IFHMP.

- Conduct a hydrotechnical and geomorphic assessment involving 2-dimensional hydraulic / morphodynamic modelling to address the following questions:
    - What is the current frequency of inundation for the forested island that would be partially disconnected from the Squamish River by the preferred option?
    - What are the potential impacts of the preferred option on flow velocities and erosion/deposition, in particular for the current side channel (with and without an associated log jam removal at the side channel entrance)?
    - What are the potential impacts of the preferred option on dike breach and internal floodway hydraulic patterns, and is there a need to update flood construction levels outside of future IFHMP updating cycle?
- Related to the hydrotechnical assessment, conduct a review of options for the fate of the existing Eagle Run Drive dike and the advantages and disadvantages of maintaining it, removing it, and other options.
- Assess area-specific feasibility of dike riprap upgrades, particularly the self-launching toe.
- Conduct an environmental habitat impact assessment with input from the hydrotechnical and geomorphic assessment to better understand the potential habitat impact associated with changes to ecological condition and function within Jimmy Jimmy (Judd) Slough and the forested island. The assessment should also include:
    - Development of habitat impact compensation concepts; and
    - Identification of potential measures and associated cost to reduce the frequency/impact of disconnection of the forested island from the Squamish River (i.e. through features at the pump station and/or additional flow exchange culverts, etc.).
- Update the Brackendale Master Drainage Plan and define the design criteria for replacement of Dryden Creek pump station and the proposed Jimmy Jimmy (Judd) Slough pump station. Update cost estimates for drainage works to Class C level (including decommissioning of the existing Jimmy Jimmy (Judd) Slough pump station, the Horse Creek floodbox, and the Eagle Run Drive pump station as part of this next step). This assessment may also involve structural, geotechnical, and electrical assessments of the existing Dryden Creek pump station facility to confirm whether or not a full replacement is required.
- Consider the potential debris flow hazard posed by the Cheekeye Fan, which will likely factor into pump station design criteria, as well as the fate of the existing ERD dike.
- Consider the need for an archaeological assessment, particularly along the new dike alignment (necessity to be confirmed w Squamish Nation).

Preliminary Design and Engagement

- Review design options as the south end of the Siyich'em Reserve and in particular at the interaction of the dike and the existing restaurant building. Ideally, a long term vision for the area and specifically for the restaurant building would be provided by the Squamish Nation based on engagement to allow the development of dike design details to incorporate the vision.
- Conduct additional design and engagement on public amenity improvements for the Eagle Viewing Area.

- Initiate scoping of material sources for dike fill and riprap, including potential reopening of Squamish Nation quarry (i.e. Cheekye Quarry on Squamish Valley Road).
- Prepare preliminary design drawings and specifications based on the additional analysis and feasibility assessments. The preliminary design should be developed based on a complete ground-based topographic and bathymetric survey of the site. Update cost estimates to Class-C or Class-B level.
- Prepare preliminary design drawings and specifications for the drainage station upgrades, based on the outcome of the updated Brackendale Master Drainage Plan.
- Conduct additional engagement with Squamish Nation, community stakeholders, and the public to consult and gather feedback on the preliminary design.
- Conduct a constructability review to determine construction constraints including construction access issues, environmental construction windows (bird and aquatic), and water level related construction windows.

Regulatory Engagement

- Meet with environmental regulatory agencies to provide an update on the project and seek feedback and level of support prior to initiating the permitting process. Discuss habitat impact compensation needs and potential approaches, including both on-site, off-site, and previously conducted enhancement projects.
- Meet with the BC Inspector of Dikes Office to provide an update on the project and seek feedback and level of support prior to initiating the permitting process. Discuss land tenure issues, including lack of right-of-way for maintenance through Squamish Nation Reserve lands. Ideally, the District and the Nation have identified a generally preferred approach for land tenure and maintenance authority for the new dike alignment ahead of this engagement.

Detailed Design, Permitting, and Engagement

- Prepare detailed design drawings and specifications for dike works as well as related civil works (e.g., drainage stations).
- Initiate environmental and administrative permitting processes.
- Conduct a final round of engagement with Squamish Nation members and the public to provide information on the detailed design and final opportunities for input.

Construction, Operation, and Maintenance

- Construct the works, required environmental compensation works, and drainage stations – funding and phasing considerations are discussed in the following sub-section.
- Develop operation and maintenance (O&M) procedures, agreements, and manuals for the dike works and replacement drainage pump stations.

6.2 Funding and Phasing Considerations

Cost sharing opportunities with other levels of government will define the phasing considerations for the master plan.

In general, two high-level approaches are possible based on what funding opportunities are available:

1. A full program funded approach; and
2. A phased funding approach.

Under a full program funded approach, a large funding grant would be sought to fund the entire master plan implementation, which would occur over a few to several year period. The prime example of a funding opportunity for this approach is the Disaster Mitigation and Adaptation Fund (DMAF) administered by the Government of Canada through Infrastructure Canada. DMAF provides up to 75% cost sharing for indigenous recipients and the Squamish Nation would be able to apply for other federal funding programs for a total federal contribution of up to 100%. Municipal governments are eligible for up to 40% cost sharing by the federal government. DMAF targets large projects and has a minimum required cost threshold of $20 million. Additionally, DMAF allows for bundling of project components that work in a complementary manner to reduce risk. DMAF-funded projects need to be implemented by 2028 under the current program.

Under a phased funding approach, the master plan would be implemented through individual funding applications. The number of phases would depend on the funding sources available. Smaller funding programs would require several successful applications to implement portions of the master plan. For example, the provincial Community Emergency Preparedness Fund (CEPF) administered by the Union of British Columbia Municipalities (UBCM) provides funding for structural flood protection with a current maximum contribution of $750,000 per application. Under this approach, full implementation would likely take longer than a decade. Phasing is best suited for the Eagle Viewing Area reach of the master plan and is not well suited for the proposed new dike alignment between Fisherman's Park and Siyich'em Reserve.

A hybrid approach involving both of the above approaches may be possible as well. For example, a phased approach could be initiated immediately for the Eagle Viewing Area while additional analysis and feasibility assessments which mostly focus on the Siyich'em reach are conducted.

Direct engagement with funding agencies and Indigenous Services Canada can help the Nation and the District determine the best approaches to undertake in pursuing support and funding for implementation of the master plan. This engagement should also include the coordination of drainage station replacement into the proposed dike upgrades, which may be funded separately from the proposed works.

Report Submission

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Statement of Limitations

Revision History

Revision #	Date	Status	Revision	Author
C	June 25, 2020	DRAFT FINAL	Draft final report (DoS comments addressed)	ATAL/SJR
B	May 29, 2020	DRAFT FINAL	Draft final report (section 6 added)	ATAL/SJR
A	March 31, 2020	DRAFT	Partial draft report (sections 1 to 5)	ATAL/SJR

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