# Place Glacier Hazard Report

Conceptual Design Options Summary

Date:
January 16, 2026

Prepared for:
Squamish-Lillooet Regional District

Prepared by:
Stantec Consulting Ltd.

Project/File:
111700836

# Revision Record

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| A3 | Final | ML | 01/15/2026 | GV | 01/16/2026 | BH | 01/16/2026 |

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Prepared by: Digitally signed by Lee, Michelle
Date: 2026.01.16 13:33:03-08'00'

Signature

Michelle Lee, EIT

Printed Name

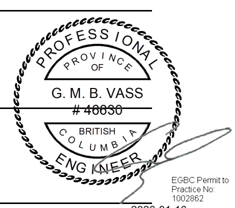
Reviewed by: Digitally signed by Heppner, Bethany
Date: 2026.01.16 15:55:25-06'00'

Signature

Bethany Heppner, P.Eng.

Printed Name

Approved by:




Signature

Graeme Vass, P.Eng.

Printed Name

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# Executive Summary

Stantec Consulting Ltd. (Stantec) prepared the *Place Glacier Hazard Report – Conceptual Design Options Summary* for the Squamish-Lillooet Regional District (SLRD) to provide mitigation options for the ongoing flood hazards associated with glacial lake outburst floods from the ice-marginal lake on Place Glacier. Two significant outburst events have occurred recently in July 2024 (2024 Outburst Event) and June 2025 (2025 Outburst Event). The 2024 Outburst Event triggered a debris flood within Place Creek, avulsion, and realignment of the channel towards Gates Lake from the historical alignment towards Poole Creek which caused structure damage and resulted in emergency response works to re-establish the pre-event Place Creek alignment. The 2025 Outburst Event triggered a smaller debris flood in comparison and caused damage to the 2024 emergency response works.

Assumptions for the ice-marginal lake are that future outburst events of similar magnitude to those experienced in 2025 and 2024 are likely to occur annually until the glacier recedes sufficiently to eliminate the lake, posing persistent hazards to the communities along Place Creek and Poole Creek. Stantec previously (2025b) completed hydraulic modeling and hazard assessment for the 2025 Outburst Event, and 1 in 200-year fall clearwater and debris flood flows to characterize the hazard level and identify the properties at risk. Based on the modelled results, the outburst events may pose high hazards levels (H3–H5) to the communities upstream of the Poole Creek Road culvert crossing. This project refined the hydraulic model developed as part of the previous work and assessed hazard extents associated with the 2024 Outburst Event. The overall hazard extents are similar between both scenarios; however, within the area immediately upstream of the Poole Creek Road culvert crossing the extents of the higher hazard ratings were larger and flows were projected to overtop the Poole Creek Road culvert crossings for a prolonged period of time (~12 hours). Upgrade and replacement of the Poole Creek Road culvert crossing could reduce flood hazards to upstream properties; however, there is potential for a transfer of risk to downstream infrastructure. Further downstream, flow was contained within the banks through both the Pemberton Portage Road and the railway bridge; however, bridge superstructure information (i.e. low chord, high chord elevation) was not available. Resilience of these structures from repeated exposure to outburst events is currently unknown.

Five conceptual design options were evaluated to mitigate outburst events with all options requiring repair of the 2024 emergency response works:

1. Install siphon in ice-marginal lake.
2. Install pumps in ice-marginal lake.
3. Drill conduit through bedrock adjacent to ice-marginal lake.
4. Construct dam at outlet of the cirque lake.
5. Use explosives to fracture open conduit through glacier.

The options were evaluated for their feasibility, cost, construction consideration, operation and maintenance, and environmental impact. Based on the options evaluations, Stantec recommends that Option 5 be progressed and implemented prior to the anticipated 2026 Outburst Event, along with emergency preparedness procedures.

# 1 Introduction

In the summer of 2024, Stantec Consulting Ltd. (Stantec) provided engineering and geohazard services to the Squamish-Lillooet Regional District (SLRD) associated with re-establishing the Place Creek alignment following a debris flood that was initiated by a glacial lake outburst flood (GLOF) from the Place Glacier (2024 Outburst Event). From June 18 to 20, 2025, the same lake situated on Place Glacier experienced a rapid emptying that caused another debris flood event within Place Creek (2025 Outburst Event). Photos provided by the Pemberton Valley Dyking District (PVDD) indicated that portions of the re-established channel banks were damaged, and sediment deposition within the lower reaches of the channel reduced freeboard and increased the potential for an avulsion and flow diversion away from the Poole Creek catchment to the Gates Lake catchment, as occurred in 2024.

Stantec was retained by the SLRD, immediately following the 2025 Outburst Event, to complete an assessment of debris flood and debris flow hazards that could impact the community of Birken; homes along Place Creek and Poole Creek; and Ministry of Transport and Transit (MOTT) culvert crossing of Poole Creek, based on the current condition of Place Creek and response to extreme rainfall events in the fall and winter. This work included: i) developing a two-dimensional hydraulic model of Place Creek and Poole Creek extending from the Place Glacier down to the confluence of Poole Creek with the Birkenhead River; ii) developing a debris flow hazard model using Stantec's proprietary software (DebrisFlow Predictor); iii) conducting hazard assessments based on model results; iv) developing a conceptual design to mitigate potential debris flood risks posed in the immediate future by extreme rainfall events—referred to as Phase 1 (Stantec 2025a). This assessment was completed in October 2025 and indicated that the 2025 Outburst Event had an equivalent magnitude to the 1 in 200-year return period flow, meaning that the communities may be subject to flood hazards associated with a 1 in 200-year return period flow magnitude (or greater) on a yearly basis. The emergency works constructed in response to the 2024 Outburst Event sustained damage as a result of the 2025 Outburst Event—it is unknown to what degree of damage the 2024 emergency works may experience in response to a flood equivalent to the 2024 Outburst Event (~80 $m^3$/s) and whether they would continue to function.

Natural Resources Canada (NRCAN) has been researching the decline of the Place Glacier and following the 2024 Outburst Event established pressure transducers at the bottom of the glacier (ice-marginal) lake to monitor lake levels. Based on conversations with NRCAN, their research indicates that for the immediate future, or until the Place Glacier retreats far enough back eliminating the lake, the ice-marginal lake will continue to pose a potential risk to the downstream communities from GLOFs.

Based on these unknowns and the flood hazards posed to the downstream communities SLRD further retained Stantec to complete the following tasks (the Project):

1. Assess debris flood risks associated with anticipated future outburst from the ice marginal lake situated on Place Glacier and develop emergency preparedness measures associated with these risks.
2. Develop conceptual designs and Class D (+-50%) opinion of probable cost estimates mitigate risks associated with debris floods propagated by an ice marginal lake outburst from the Place Glacier.

This report presents several conceptual designs to mitigate hazards associated with GLOFs, Class D opinions of probable cost for the concepts and an evaluation matrix of key considerations associated with the design, environmental, permitting, construction cost, and operation and maintenance costs for each of the concepts to support SLRD and other stakeholders with decision making. Information to support the SLRD with emergency preparedness is also included.

## 1.1 Scope of Work

The overall scope of the Project work includes the following:

- Refine the hydraulic model developed as part of Phase 1 to assess downstream hazards associated with the 2024 Outburst Event and inform emergency preparedness and conceptual mitigation designs associated with an GLOF from the Place Glacier.
- Develop conceptual designs and Class D (+-50%) opinion of probable cost estimates to mitigate risks associated with debris floods propagated by an GLOF from the Place Glacier.

## 1.2 Information Sources

The Project was completed based on the following digital resources provided by NRCAN and publicly available.

- Stage-discharge curves for the 2024 and 2025 Outburst Events, provided by NRCAN.
- Historical flow data collected by Water Survey of Canada (WSC).
- Bedrock geology, faults, terrain mapping, BC Digital Road Atlas, and Freshwater Atlas available from iMapBC.
- Google Earth Imagery (dated 2013, 2015, 2021).
- LiDAR digital elevation model available from LidarBC (dated 2016).
- LiDAR digital elevation model and aerial imagery collected by Stantec following completion of the 2024 emergency response works (dated November 2024).
- LiDAR digital elevation model collected by Hakai Institute following the 2025 ice-marginal lake GLOF (dated July 2025).
- Geologic and Hydrologic Hazard Assessment of District Lot 1251 Near Birken, BC (Baumann Engineering 2000)
- *Place Lake Outburst Flood Hazard Update* (NRCAN 2025).
- *Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment* (Stantec 2024a).
- *Place Creek Emergency Response Completion Report* (Stantec 2024b).
- *Place Creek Visual Hazard Assessment* (Stantec 2025a).
- *Place Glacier Hazard Assessment Report* (Stantec 2025b).

## 1.3 Design Guidelines, References, and Regulations

The following design guidelines and reference documents were reviewed as part of the conceptual options development and may be applicable to future detailed design associated with the selected concept:

- *Open Channel Hydraulics* prepare by V.T. Chow (1959).
- *Hydraulics of subglacial outburst floods: new insights from the Spring–Hutter formulation* prepared by Garry K.C. Clarke (2003).
- *Riprap Design and Construction Guide* prepared by BC Ministry of Environment, Lands and Parks (MELP 2000).
- *Dike Design and Construction Guide Best Management Practices for British Columbia* prepared by BC Ministry of Water Land and Air Protection (MWLAP 2003).
- *Project Cost Estimating Guidelines, Version 01.02* prepared by BC Ministry of Transportation and Infrastructure (MOTI 2013).
- *Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures)* prepared by BC Ministry of Environment (MOE 2014).
- *Water Sustainability Act, Dam Safety Regulation (B.C. Reg. 40/2016)* prepared by Government of British Columbia (BC 2016).
- *Guide to Bridge Hydraulics, Third Edition* prepared by Transportation Association of Canada (TAC 2025).
- *Legislated Dam Safety Reviews in BC* prepared by Engineers & Geoscientists British Columbia (EGBC 2023).
- *Dam Safety Guidelines 2007 (2013 Edition)* prepared be Canadian Dam Association (CDA 2013).
- *Engineering and Design: Retaining and Flood Walls* prepared by USACE (1989).
- *Engineering and Design: Hydraulic Design of Flood Control Channels* prepared by USACE (1994)
- *Engineering and Design: Design and Construction of Levees* prepared by USACE (2000).

The list of Environmental related design references and guidelines included the followings:

- *Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians & Reptiles* prepared by BC Ministry of Environment, Lands and Parks (MELP 1998).
- *Best Management Practices for Amphibians and Reptiles in Urban and Rural Environment in British Columbia* prepared by BC Ministry of Water, Land and Air Protection (MWLAP 2004).
- *Guidelines for Raptor Conservation during Urban and Rural Land Development in British Columbia* prepared by BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO 2013).
- *Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development* prepared by Government of British Columbia (BC 2014).
- *Requirements and Best Management Practices for Making Changes In and About A Stream in British Columbia* prepared by Government of British Columbia (BC 2022).
- *British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture* prepared by BC Ministry of Water, Land, and Resource Stewardship (MWLRS 2025).
- *Land Development Guidelines for the Protection of Aquatic Habitat* prepared by Department of Fisheries and Oceans Canada (DFO 1992).
- *Interim code of practice: End-of-pipe fish protection screens for small water intakes in freshwater* prepared by Department of Fisheries and Oceans Canada (DFO 2020).
- *Measures to protect fish and fish habitat* prepared by Department of Fisheries and Oceans Canada (DFO 2025a).
- *Standard: In-Water Site Isolation* prepared by Department of Fisheries and Oceans Canada (DFO 2025b).

- *Avoidance Guidelines for Protection of Migratory Birds* prepared by Environment and Climate Change Canada (ECCC 2023).
- *General Nesting Period of Migratory Birds* prepared by Environment and Climate Change Canada (ECCC 2024).

# 2 Background

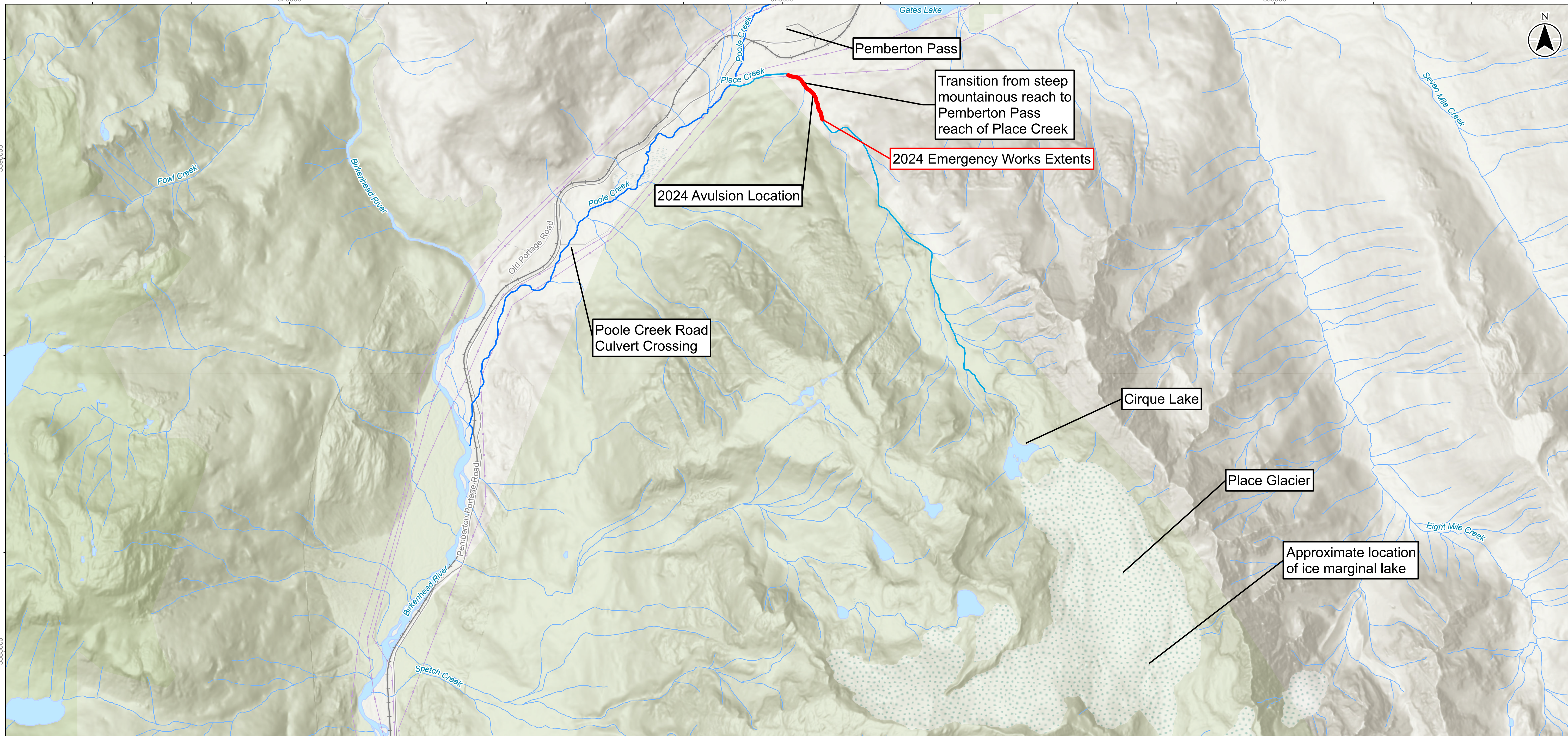
A detailed background of the 2024 and 2025 Outburst Events, emergency response activities, and subsequent hazard assessments conducted by Stantec are detailed in previous Stantec reports (2024a, 2024b, 2025a, 2025b). The following sections provide pertinent details from these reports that are applicable to the Project scope. Figure 2-1 presents key locations associated with the Project and discussed throughout this report.

## 2.1 Location

The Place Creek area is underlain by two major rock types: metamorphic rock (mainly argillite and phyllite) belonging to the upper Triassic age (200 million years old), Hurley Formation, and Cretaceous-aged (70 million years old) granite rock of the Mt. Rohr formation, part of the Coast Plutonic Complex. The metamorphic rock predominates in the valley bottom along the Gates River and the slopes of Birkenhead Peak to the north, whereas Gates Peak to the south is composed of both metamorphic and some granite rock. In prehistoric times at least one large rock avalanche came down to the valley floor from Gates Peak and formed the natural dam behind which Gates Lake now lies (Baumann Engineering 2000).

Place Creek watershed is bounded by Cirque Peak, Mt. Olds, Mt Oleg, and Gates Peak with a north-east aspect and peak elevation of approximately 2520 m. Place Creek originates from several glacial lakes within Place Glacier, situated in a hanging valley (cirque) between the peaks detailed above. The channel then extends down the mountainous slope through steep, incised gulleys before transitioning to meandering planform along an alluvial fan located on the shallower valley bottom slope referred to as Pemberton Pass.

The Pemberton Pass is the divide between the Lillooet River watershed (containing Poole Creek) and the Fraser River watershed (containing Gates Lake and Gates River). A historical map from 1914 (City of Vancouver 1914) indicates that a portion of Place Creek (referred to as Summit Creek) flowed northeast and discharged into Gates Lake (referred to as Summit Lake). Subdivision drawings from 2004 (SLRD 2004), a geotechnical report (Kontur 2023), and regional maps (BC Freshwater Atlas) indicate that Place Creek flowed to the southwest discharging into Poole Creek. It is unknown when Place Creek established its current alignment (i.e., flowing into Poole Creek); however, based on conversations with local Gates Lake and Poole Creek residents, Lílwat Nation members, and the SLRD this alignment has been existing in living memory and was the basis for developments along Poole Creek, Gates Lake, and Gates River.





- Place Creek
- Poole Creek
- Watercourse
- Road
- Local Street
- Resource Road
- Railway
- Transmission Line
- Waterbody

**Notes:**
1. Coordinate System: NAD 1983 CSRS UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3.Copy of World Topographic Map:
World Hillshade: Esri, NASA, NGA, USGS

THIS FIGURE IS NOT A FLOOD MAP AND IS NOT TO BE USED FOR DESIGN PURPOSES. THE DEBRIS FLOOD AND CLEARWATER FLOOD ASSESSMENT INCLUDED IN THIS STUDY IS NOT INTENDED TO ALIGN WITH EGBC GUIDELINES FOR LEGISLATED FLOOD HAZARD ASSESSMENTS OR FLOOD MAPPING.

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Stantec

Project Location:
Birken, BC

Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
**2-1** Project Location Map

Title
**2025 Outburst Event Flow Overview**

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## 2.2 2024 Outburst Event and Emergency Response Works

On July 22, 2024, a sudden and large volume of water flowed from Place Glacier into Place Creek. Based on information provided by NRCAN (2025), this sudden release of water was associated with a GLOF of the ice-marginal lake that forms on the upper reaches of the Place Glacier. In 2024, the lake grew to about 90,000 $m^2$ and reached an estimated depth of 36 m. On July 22, 2024, it drained over a period of 10–16 hours and conveyed $1.2 \times 10^6$ $m^3$ of water into Place Creek and mobilized 100,000 $m^3$ of sediment and debris from the upper reaches of the channel (2024 Outburst Event). The 2024 Outburst Event entrained further sediment and debris as it flowed down Place Creek precipitating in a debris flood event that deposited large volumes of sediment within Place Creek and along the Pemberton Pass. An avulsion[1] of the Place Creek channel occurred in response to the debris flood with the new alignment conveying the majority of Place Creek flow into the existing constructed drainage ditches and into Gates Lake (Stantec 2024a).

Stantec directed the implementation of emergency response works to alleviate immediate overland flooding hazards and conducted a qualitative debris flow and debris flood hazard assessment of the new and previous Place Creek alignments and the Place Creek watershed. The geohazard assessment determined that the threat to the public's safety from a direct landslide impact was relatively low; however, the debris flood assessment determined that the potential for further debris floods, more overland flooding as a result of extreme rainfall events, and the absence of quantitative hazard analyses immediate mitigative actions be taken (Stantec 2024a). For further details on the assessment please see the preliminary hazard assessment prepared by Stantec (2024a).

To mitigate the immediate hazard, SLRD further retained Stantec to develop an accelerated, field-based channel modification based on rudimentary hydrologic and channel capacity analyses to re-direct Place Creek back to the previous alignment and provide engineer of record services during construction. The following project criteria were established for the work:

- Channel modifications are to alleviate the immediate debris flood and flood hazards posed to the properties around Gates Lake and portion of Gates River immediately downstream of Gates Lake prior to the imminent extreme rainfall events generally experienced in the fall. The channel modifications are deemed "emergency response measures"; as such, no design life or design flow is associated with the channel modifications.
- Channel modification alignment to be restored in kind to the previous Place Creek alignment.
- Channel modification is to function as a pilot channel to promote re-establishment of the previous Place Creek alignment.
- Typical section for channel modification to be based on 1 in 2-year mean annual flow.
- Re-established embankment to tie into high ground at the upstream extent to reduce the potential for future avulsions.

[1] A rapid abandonment of a river channel and the formation of a new river channel.

- Flow to be diverted into channel modification and previous Place Creek alignment prior to September 15, 2024 (as requested by Department of Fisheries and Oceans during various meetings held in August 2024).

Based on these criteria Stantec developed a mitigative action concept that involved removing large woody debris jams within the previous Place Creek channel alignment, excavating a channel and re-establishing the previous Place Creek east embankment. Large boulders were sourced from the debris and placed along the east embankment to provide some form of erosion protection from high flow events. The channel works were completed on September 26, 2024, Figure 2-2 presents the record drawings of the constructed mitigative works (Stantec 2024b).


Stantec

500, 4515 Central Blvd
Burnaby, British Columbia V5H 0C6
www.stantec.com



Notes

1. POST-CONSTRUCTION SURFACE IS BASED ON OCT. 13, 2024 LIDAR COLLECTED BY ALPINE SOLUTIONS AVALANCHE SERVICES. BACKGROUND IMAGE COLLECTED ON NOV. 7, 2024 AND PROVIDED BY ALPINE SOLUTIONS AVALANCHE SERVICES. PRE-CONSTRUCTION AND PRE-DEBRIS FLOOD EVENT SURVEY/SURFACE INFORMATION WAS NOT AVAILABLE.
2. THE PURPOSE OF THE CHANNEL MODIFICATION AND RE-ESTABLISHED EMBANKMENT WAS TO ALLEVIATE THE IMMEDIATE DEBRIS FLOOD AND FLOOD HAZARDS POSED TO THE PROPERTIES AROUND GATES LAKE AND PORTION OF GATES RIVER IMMEDIATELY DOWNSTREAM OF GATES LAKE PRIOR TO THE IMMINENT EXTREME RAINFALL EVENTS GENERALLY EXPERIENCED IN THE FALL.THE CHANNEL MODIFICATIONS ARE DEEMED "EMERGENCY RESPONSE MEASURES"; AS SUCH, NO DESIGN LIFE OR DESIGN FLOW IS ASSOCIATED WITH THE CHANNEL MODIFICATIONS. DUE TO THE LOCATION, PHYSIOGRAPHY, AND GEOGRAPHY PLACE CREEK WILL LIKELY CONTINUE TO BE PRONE TO AVULSION AND LATERAL MIGRATION WITHOUT IMPLEMENTATION OF AN ENGINEER DESIGNED STRUCTURE THAT COULD PROVIDE LONG-TERM PROTECTION FROM DEBRIS FLOOD AND DEBRIS FLOW EVENTS.
3. THE SEAL AND SIGNATURE OF THE UNDERSIGNED ON THIS DRAWING CERTIFIES THAT THE DESIGN INFORMATION CONTAINED IN THESE DRAWINGS ACCURATELY REFLECTS THE ORIGINAL DESIGN AND THE MATERIAL DESIGN CHANGES MADE DURING CONSTRUCTION THAT WERE BROUGHT TO THE UNDERSIGNED'S ATTENTION. THESE DRAWINGS ARE INTENDED TO INCORPORATE ADDENDA, CHANGE ORDERS, AND OTHER MATERIAL DESIGN CHANGES, BUT NOT NECESSARILY ALL SITE INSTRUCTIONS.
   THE UNDERSIGNED DOES NOT WARRANT OR GUARANTEE, NOR ACCEPT ANY RESPONSIBILITY FOR, THE ACCURACY OR COMPLETENESS OF THE AS-CONSTRUCTED INFORMATION SUPPLIED BY OTHERS CONTAINED IN THESE DRAWINGS, BUT DOES, BY SEALING AND SIGNING, CERTIFY THAT THE AS-CONSTRUCTED INFORMATION, IF ACCURATE AND COMPLETE, PROVIDES AN AS-CONSTRUCTED SYSTEM WHICH SUBSTANTIALLY COMPLIES IN ALL MATERIAL RESPECTS WITH THE ORIGINAL DESIGN INTENT.
4. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS IF NOT OTHERWISE INDICATED. HORIZONTAL DATUM IS NAD83 (CSRS) Zone 10N, VERTICAL DATUM IS CGVD2013 (CGG2013a).

Client/Project
SQUAMISH-LILLOOET REGIONAL DISTRICT
PLACE CREEK CHANNEL REALIGNMENT

Project No.
111700815

Title
MITIGATION ACTION RECORD DRAWINGS

| Revision | Date |
|---|---|
| 0 | NOV/8/2024 |

| SCALE | Figure No. |
|---|---|
| SEE DRAWING | 1 |

Figure 2-2. Record Drawings of 2024 Mitigative Work (Stantec, 2024b)

## 2.3 2025 Outburst Event and Emergency Response Works

NRCAN installed a real-time monitoring equipment in the depression that the ice-marginal lake was expected to form on May 30, 2025. The equipment monitored water level, temperature, and water conductivity in hourly intervals. Based on satellite imagery the ice-marginal lake began to form sometime on or before May 27, 2025. On June 11, 2025, the lake depth was estimated to be 24 m and contained about 40% of the water that was impounded immediately prior to the 2024 Outburst Event (Figure 2-3)—NRCAN indicated that a GLOF should be anticipated when the lake deepened by another 4 m (i.e., reached about 50% of the 2024 lake volume) (NRCAN 2025).

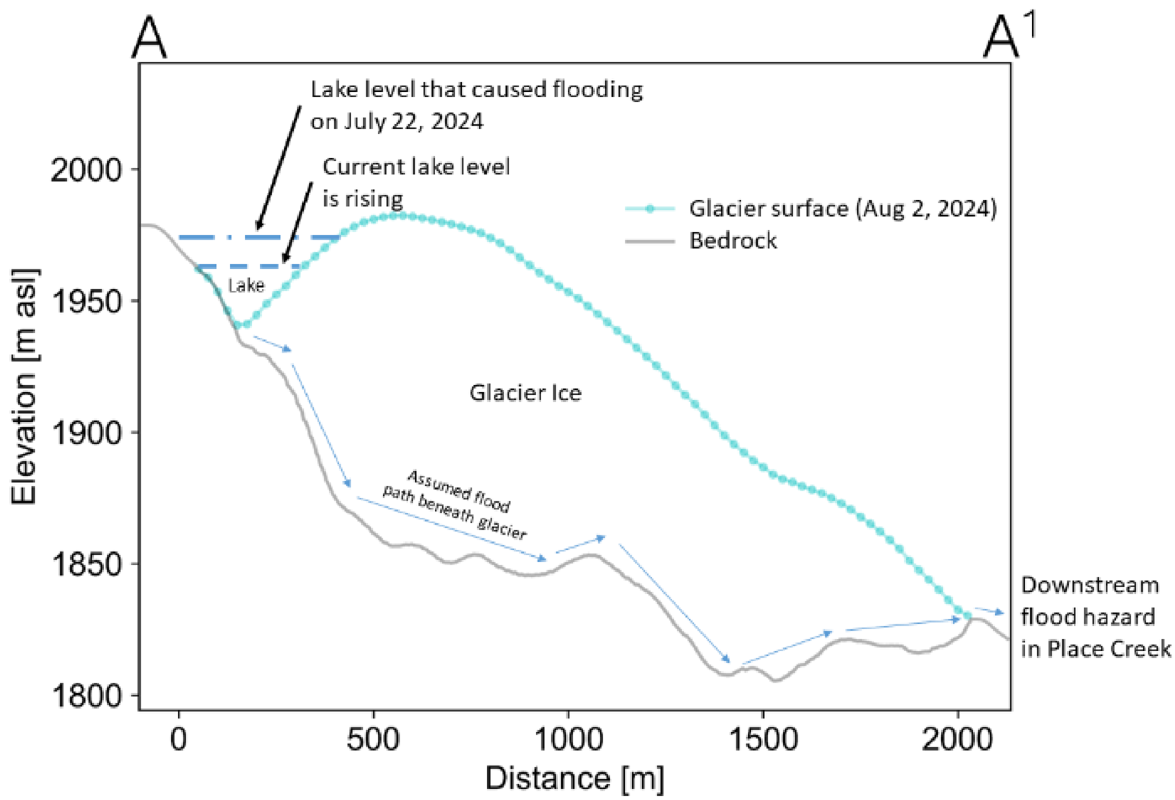


*Figure 2-3. Cross Section of Glacier Lake with June 11, 2025, Lake Level (NRCAN 2025)*

Based on the information provided by NRCAN, SLRD issued an open letter to the Ministry of Emergency Management and Climate Readiness (EMCR) and Ministry of Water, Lands, and Resource Stewardship (WLRS) on June 6, 2025, identifying the imminent hazard and requested EMCR and WLRS to take immediate action to communicate and address the risk posed by the anticipated GLOF (SLRD 2025).

From June 18 to 20, 2025, an GLOF occurred from the ice-marginal lake on the Place Glacier resulting in a debris flood event within Place Creek (2025 Outburst Event). NRCAN has been processing data from the monitoring equipment, and the data was made available to support the Project The data has not been validated by NRCAN and was provided to Stantec as preliminary data. Quality assurance and validation may result in change. The data was recorded from the bottom of Place Glacier, upstream of the cirque lake.

### 2.3.1 2025 Visual Hazard Assessment

To assess current hydrotechnical conditions (i.e., channel formation and morphology, bank erosion, channel scouring, bed material, debris jams, overland flood areas) and potential steep slope geohazards following the 2025 Outburst Event, and determine whether they pose an immediate hazard to public safety, Stantec (2025a) conducted the following visual assessments:

- July 4th, 2025: one geohazard specialist from Stantec conducted an aerial based visual assessment of the upper watershed of Place Creek immediately downstream of the ice-marginal lake; and
- July 8th, 2025: two hydrotechnical engineers from Stantec accompanied by one representative from SLRD conducted a ground based visual assessment of Place Creek extending from the upstream extent of the 2024 emergency response works downstream to the confluence with Poole Creek. The Poole Creek culvert crossing of Poole Creek Road and the road and rail bridge crossing of Pemberton Portage Road were also visually assessed.

Extents of the assessments are presented in Figure 2-4; a summary of key findings are provided below and in the Stantec report (Stantec 2025a).

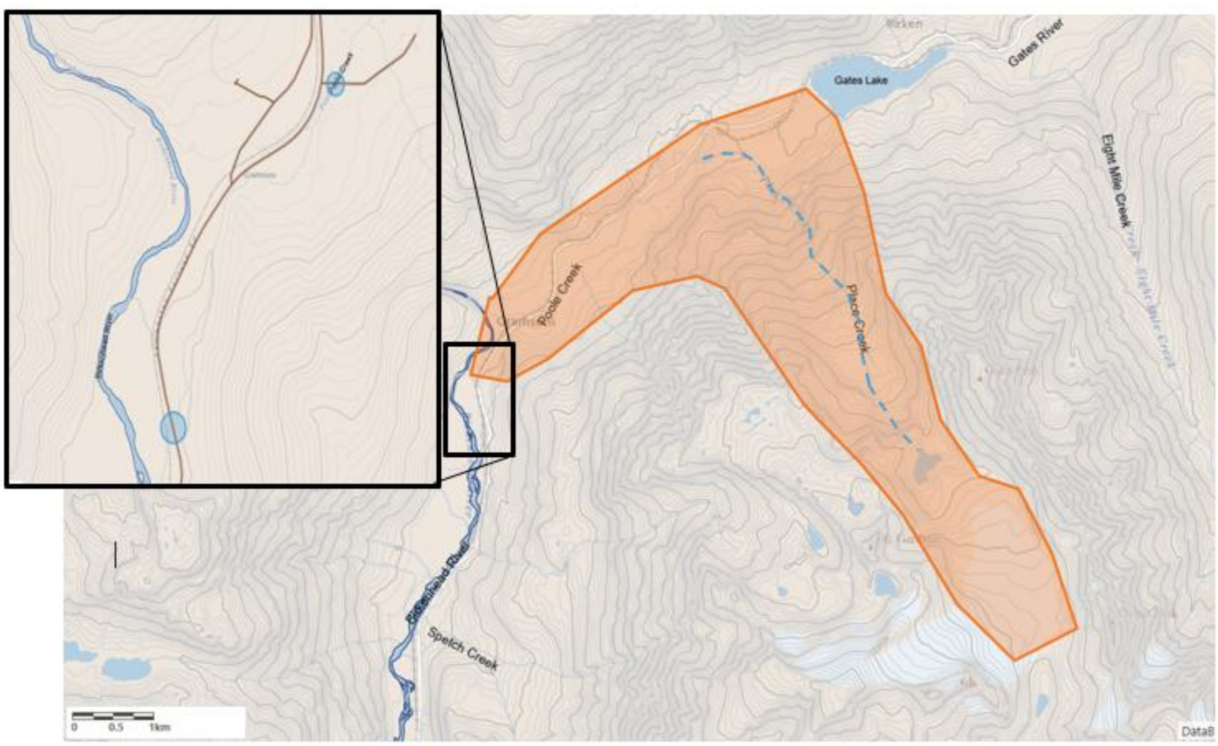


*Figure 2-4. Extents of Aerial (Orange Area) and Ground Based (Red Line and Solid Blue Circles) Visual Assessments*

The aerial based debris flow hazard assessment observed evidence of debris flows having occurred in the upper watershed immediately downstream of the Place Glacier. NRCAN has indicated to Stantec and

SLRD that now that the ice-marginal lake has gone through a GLOF, further meltwater is unlikely to refill the lake in 2025; rather, it will be conveyed downstream to Place Creek. NRCAN does not anticipate the lake refilling until 2026. In the absence of another GLOF there was observed to be low hazard of another debris flow event occurring in the immediate future (i.e., summer months).

The ground-based debris flood hazard assessment found that the 2024 emergency response works had been damaged as a result of the 2025 Outburst Event. Within the steep mountainous section near the upstream extent of the 2024 emergency response works, sections of the embankment riprap had failed, and the embankment had retreated back 2 to 3 m. At the location where the channel avulsed in 2024 only 2 to 3 m of crest width remain (Figure 2-5). Scouring of the bed occurred and the channel has incised down into the deposited 2024 sediments leaving the toe of the bank riprap undercut and perched in some locations.

Immediately upstream of where Place Creek transitions from the steep mountains section to the flatter Pemberton Pass region debris flood sediment had deposited filling the 2024 emergency works channel and flow transitioned from a single channel to a multi-channel planform. The riprap and embankment at the downstream extent of the mountainous section has been fully eroded with flow inundating the portion of forest adjacent to the channel during the GLOF; however, this area was dry at the time of the assessment (Figure 2-6).

Flow within the flatter Pemberton Pass section is largely within a single channel but secondary flood channels branch out from the main channel in places and convey small portion of flow or pooled water. Along this segment there was evidence of finer sediment being deposited and the channel incising into that material; however, it does not appear that flow avulsed from the main channel towards the lower BC Hydro right of way. Deposition of large woody debris was observed; however, no large log jams blocking the entire channel, similar to what was observed and removed in 2024, were present.

The culverts and bridges investigated were free from debris but there was evidence of resent backwatering upstream of the Poole Creek Road culvert crossing and site conditions indicated the culvert is undersized. Based on these observations, it was determined that the debris flow and debris flood hazards posed to the downstream communities was low (i.e., during the summer months prior to more extreme rainfall that historically occurs during the fall and winter).

*Figure 2-5. Riprap Failure and Embankment Retreat – Looking Upstream (June 8, 2025)*

*Figure 2-6. Erosion at Downstream Extent – Looking Upstream (June 8, 2025)*

A differential map comparing the 2025 LiDAR to the post-construction LiDAR from 2024 (Figure 2-7) confirms the observations recorded during the visual assessment, where red represents aggradation[2] and blue represents degradation[3]. Moreover, the differential map visualizes in red the location where Place Creek transitions from the steep mountains section to the flatter Pemberton Pass region and where debris flood sediment had deposited, filling the 2024 emergency works channel.

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[2] Channel aggradation refers to the accumulation of sediment in a river channel, which occurs when the supply of sediment exceeds the capacity of the channel to transport it.
[3] Channel degradation refers to the loss of material from a streambed caused by channel scour, resulting in a lowering of the streambed and/or widening of the channel.

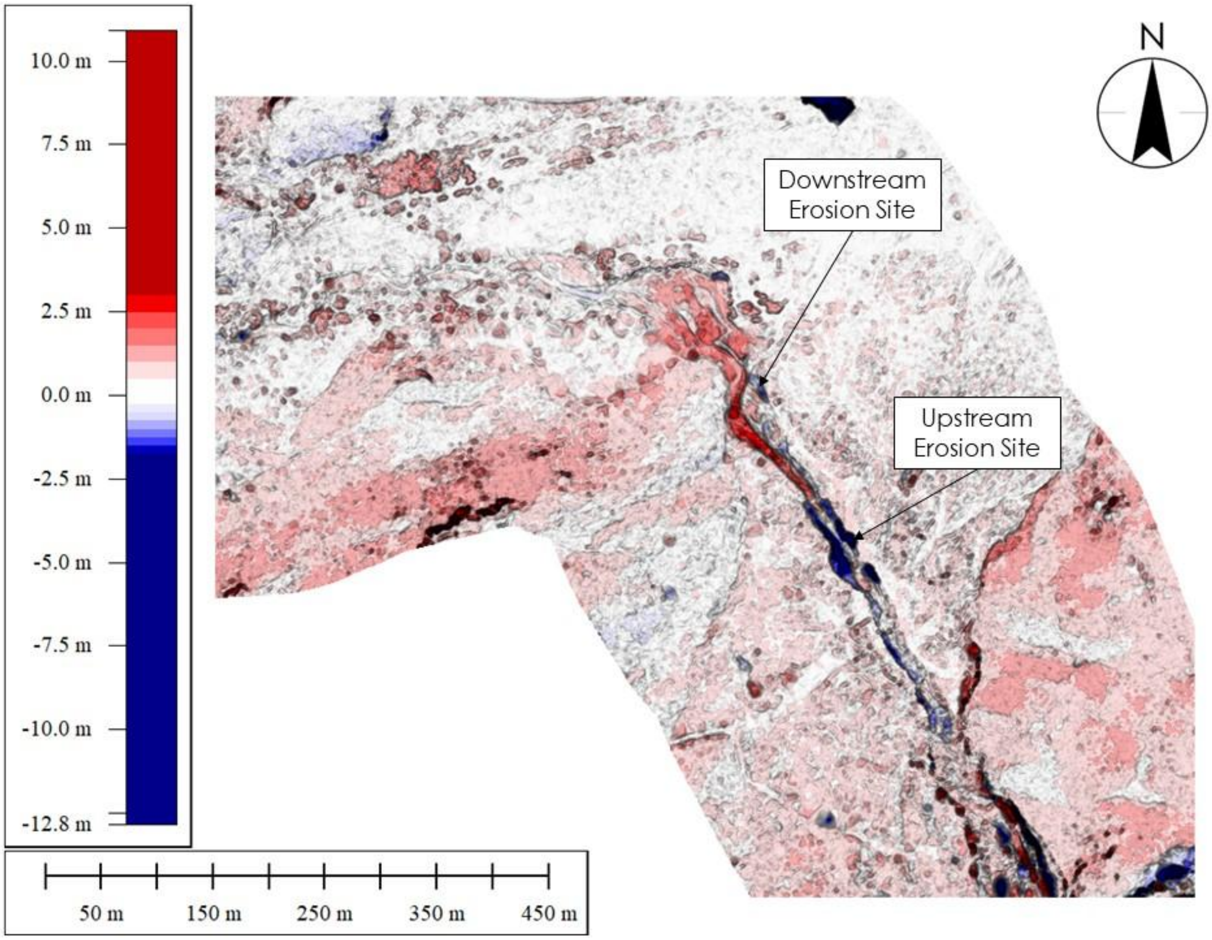


*Figure 2-7. Differential Map Comparing 2024 and 2025 LiDAR*

## 2.3.2 2025 Debris Flow and Flood Hazard Assessment

### 2.3.2.1 Summary of Assessment

The fall (i.e., September to November) 2025 hydrotechnical conditions and potential geohazards were assessed to determine whether they pose immediate hazards to the local population. It was determined that the debris flow risk was negligible when assessing public safety on paved roads and within residential buildings. Based on hydraulic modelling of the 2025 Outburst Event, private lands between Gramsons and Birken that are adjacent to Poole Creek are exposed to flood hazards during the event; however, higher-level hazard areas are contained within the creek banks and floodplains are generally safe for people, vehicles and buildings. Results indicate that the community upstream of the culvert crossing at Poole Creek Road is exposed to higher hazard levels that pose unsafe conditions for people and vehicles with the area immediately upstream of the culvert being vulnerable to structural damage.

Fall clearwater and debris flood flows that are representative of a 1 in 200-year return period flood (i.e., a flood with the probability of occurring in any given year of 0.5%) were also assessed using the hydraulic model and current channel and bank conditions. The resulting hazard of the fall flood scenarios was similar to that of the 2025 Outburst Event.

GLOFs propagating from the ice-marginal lake located on Place Glacier are anticipated to occur on an annual basis until the glacier recedes far enough to eliminate the depression where the ice-marginal lake forms. Hydraulic modelling demonstrated that the GLOF experienced in 2025 is equivalent to a 1 in 200-year return period fall flood event. The communities adjacent to Place Creek and Poole Creek may be subject to flood hazards associated with a 1 in 200-year return period flow magnitude (or greater) on a yearly basis.

As a result of the 2025 Outburst Event, the re-established embankment and riprap at the site where the Place Creek flow diverted away from Poole Creek to Gates Lake occurred in 2024 has been damaged. Continued exposure of this damaged portion of embankment to glacial outburst events may result in further erosion and eventual breach of the embankment causing flow to route back towards Gates Lake (avulsion). Repairing the 2024 emergency response works would provide temporary mitigation from a potential avulsion in response to a GLOF similar in magnitude to the 2025 Outburst Event; however, it is unknown whether it could provide mitigation from a larger GLOF similar in magnitude to the 2024 Outburst Event. A conceptual design and opinion of probable cost was prepared for the re-establishment of damaged 2024 emergency response works along Place Creek in response to the 2025 Outburst Event. As GLOFs are anticipated to occur on an annual basis, a more robust, longer-term option was recommended to be considered. If a longer-term option cannot be implemented prior to the anticipated 2026 GLOF (historically between June and July), Stantec recommends that the emergency response works be re-established no later than May 2026.

#### 2.3.2.2 Clearwater, Debris Flood, and 2025 Outburst Event Flows

Place Creek and Poole Creek clearwater and debris flood flows that were estimated as part of the Phase 1 work are detailed in Table 2-1 and Table 2-2, respectively. The hydrograph of the 2025 Outburst Event provided by NRCAN is presented in Figure 2-8.

The clearwater flows were estimated for two locations: i) outlet of Place Creek; ii) Poole Creek at the confluence with Place Creek. For the fall months (September–November), the monthly mean maximum daily discharge (MMMDD) was calculated for both locations using the maximum daily flow from each month for each year of continuous record. For the month of June, the monthly mean discharge (MMD) was calculated for Poole Creek by averaging the discharge values for the entire month for each year of continuous record. Clearwater flows corresponding to typical return period floods (i.e., 1 in 2.5-year, 5-year, 10-year, and 200-year) were estimated for both locations, and debris flood flows were estimated for the 1 in 200-year return period (Stantec 2025b).

*Table 2-1. Estimated Clearwater Flows used for the Project ($m^3/s$)*

| Return Period (Year) | September | October | November | Sept-Nov | June |
|---|---|---|---|---|---|
| | | **Place Creek** | | | |
| MMMDD | 3.49 | 2.44 | 1.07 | 3.92 | - |
| 1 in 2.5-year | 3.23 | 1.96 | 0.66 | 3.67 | - |
| 1 in 5-year | 4.95 | 2.95 | 1.25 | 5.74 | - |
| 1 in 10-year | 6.64 | 3.96 | 2.06 | 7.82 | - |
| 1 in 200-year | 13.88 | 9.16 | 8.90 | 12.89 | - |
| | | **Poole Creek** | | | |
| MMMDD | 2.89 | 1.99 | 0.85 | 3.22 | - |
| MMD | - | - | - | -- | 1.43 |
| 1 in 2.5-year | 2.68 | 1.61 | 0.52 | 3.01 | - |
| 1 in 5-year | 4.12 | 2.41 | 1.00 | 4.73 | - |
| 1 in 10-year | 5.53 | 3.23 | 1.65 | 6.44 | - |
| 1 in 200-year | 11.44 | 7.38 | 7.22 | 10.51 | - |

*Table 2-2. Estimated Debris Flood Flows ($m^3/s$)*

| Return Period (Year) | September | October | November | Sept-Nov |
|---|---|---|---|---|
| | | **Place Creek** | | |
| 1 in 200-year | 19.43 | 12.82 | 12.46 | 18.05 |
| | | **Poole Creek** | | |
| 1 in 200-year | 16.02 | 10.33 | 10.11 | 14.71 |

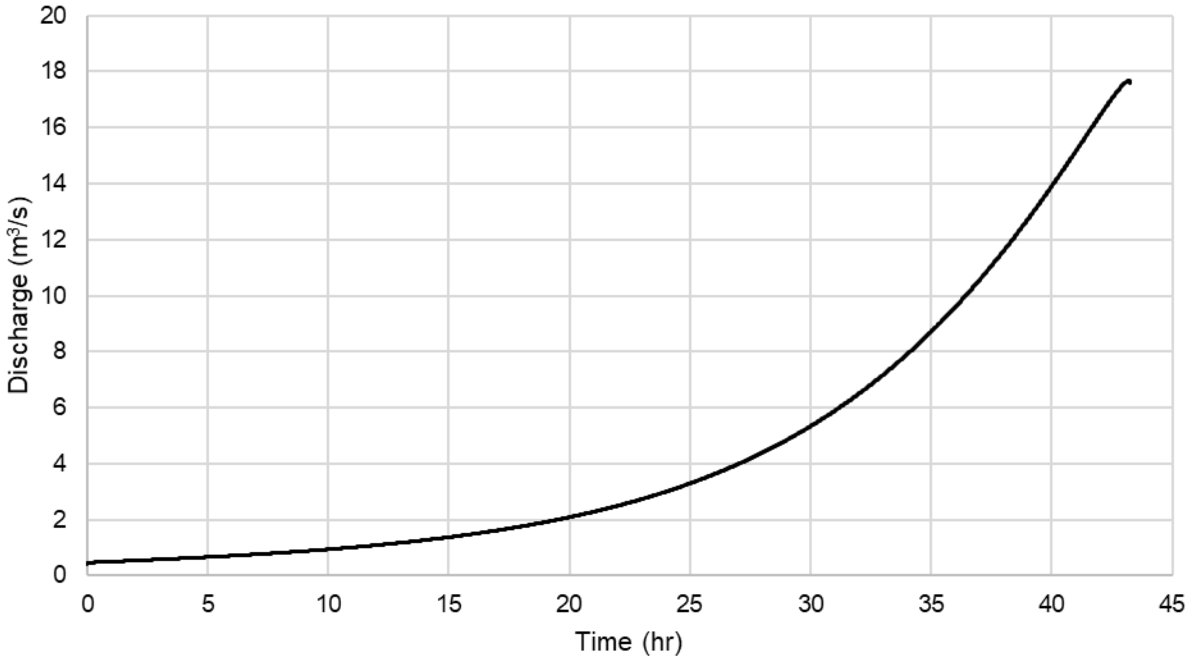


*Figure 2-8. 2025 Outburst Event Hydrograph*

### 2.3.2.3 Hydraulic Model

A two-dimensional (2D) hydraulic model utilizing the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis Software (HEC-RAS version 6.6) was developed to assess flood hazards associated with the 2025 Outburst Event, and 1 in 200-year return period Place and Poole Creek flows. The HEC-RAS models used user-defined inputs for the surface topography, surface roughness, and flow hydrograph to simulate the flood scenarios. The following sections provide a summary of the model development, model efficiency, and inform emergency preparedness.

#### *2.3.2.3.1 Model Terrain*

The 2D model terrain was prepared using RAS Mapper, a tool with geospatial capabilities included with HEC-RAS. RAS Mapper simulates and visualizes terrain models to help analyze hydraulic models and visualize results (USACE 2025). The terrain was developed based on post 2024 emergency response works LiDAR and overlaid with post 2025 Outburst Event LiDAR. As culvert and bridge information, other than the Poole Creek Road culvert, was unknown/unavailable for the Project the terrain was modified to remove the road embankments and project the upstream channel geometry through the embankment, connecting to the downstream channel. Figure 2-9 presents the model terrain and perimeter for the model extents.

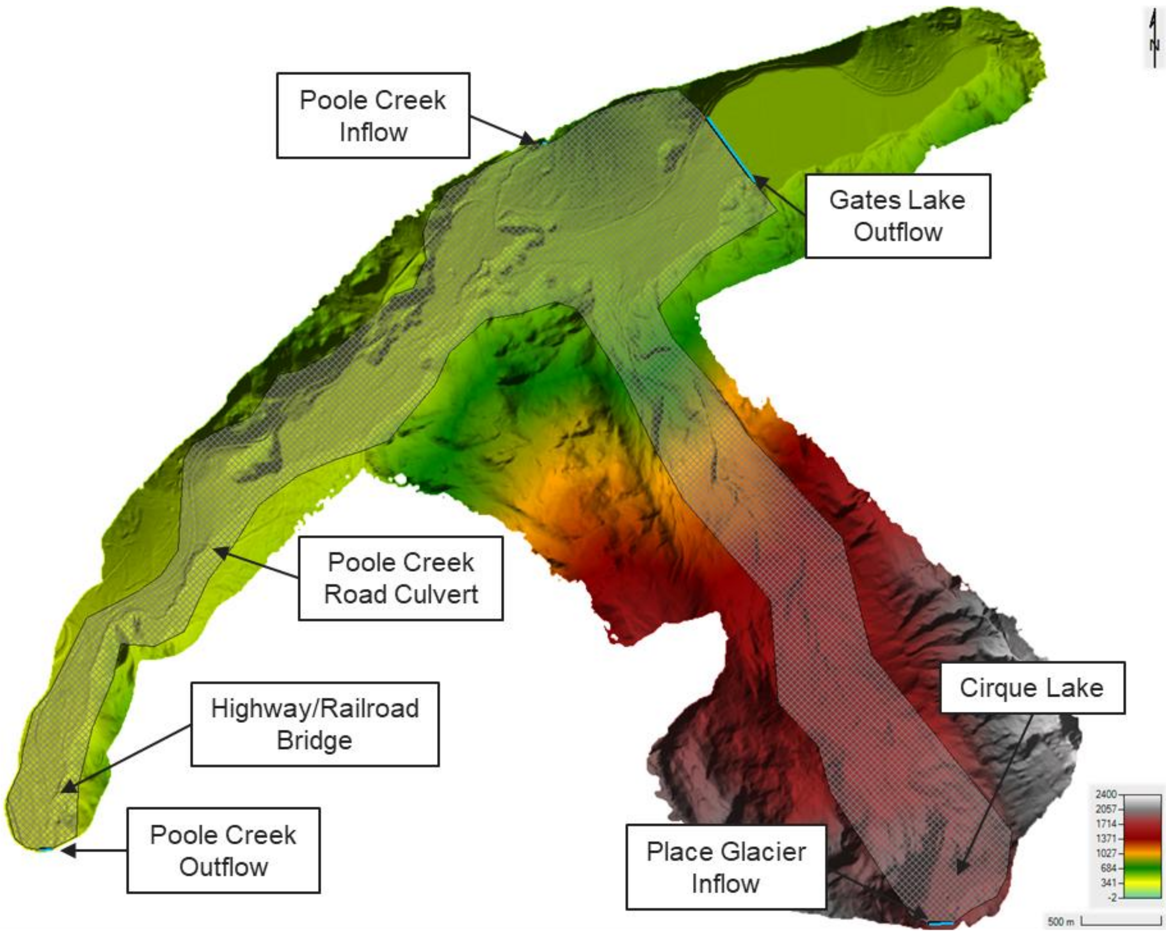


*Figure 2-9. HEC-RAS Model Setup*

Ground elevations within the HEC-RAS 2D model range from the Place Glacier inflow at 1816 m to the Poole Creek outflow at 378 m. The flow path distance between the Place Glacier inflow and Poole Creek outflow is approximately 10.8 km.

#### *2.3.2.3.2 Surface Roughness*

Surface roughness for the HEC-RAS 2D model were classified based on the land cover conditions and assigned corresponding Manning’s n values. Creek channels were delineated and assigned Manning’s n values based on Chow (1959). The floodplain and surrounding ground surfaces were classified based on the North American Environmental Atlas – Land Cover 2020 map (CEC 2024). Manning’s n values were assigned based on National Land Cover Database (NLCD) land cover type and HEC-RAS 2D manual values (USACE 2025). Table 2-3 presents the land cover conditions and corresponding Manning’s n values.

*Table 2-3. Manning's n for Model Land Cover Conditions*

| Land Cover Condition | Manning's n Value |
|---|---|
| Place Creek – Upper Mountainous | 0.055 |
| Place Creek – Lower Mountainous | 0.045 |
| Poole Creek | 0.040 |
| Temperate or Sub-Polar Needleleaf Forest | 0.150 |
| Mixed Forest | 0.120 |
| Temperate of Sub-Polar Shrubland | 0.080 |
| Temperate of Sub-Polar Grassland | 0.040 |
| Barren Lands | 0.030 |
| Urban and Built-up | 0.080 |
| Water | 0.035 |
| Snow and Ice | 0.035 |

Model calibration for the surface roughness was not possible as detailed channel bathymetry and hydrometric data were not available for Place Creek and Poole Creek. Some model validation was provided by comparing the results from the 2025 Outburst Event model with the visual observations collected by SLRD during the event and field observations of high-water marks collected by Stantec during the visual hazard assessment.

#### 2.3.2.4 Flood Hazard Rating

Flood hazard curves are based on a combination of flow depth and velocity. Different flood hazard curves exist for people, vehicles, and buildings. Thresholds for people's stability in floods depend on limiting depths and velocities. The limiting depth for adults is 1.2 m whereas the limiting depth for children is 0.5 m. The limiting velocity for both children and adults is 3 m/s (Smith, Davey and Cox 2014). Combining the limiting depth and velocities produces flood hazard curves for people. Similarly, with vehicles, the limiting depth differs depending on vehicle size and the flood hazard curve is produced with a limiting velocity of 3 m/s. Lastly, buildings flood hazard curves fall under two categories: light structures or all structures. The limiting depth (measurement taken from above the floor) for a light structure is 2 m whereas the limiting depth for all structures is 4 m; and the corresponding limiting velocities are 2 m/s and 4 m/s, respectively (Smith, Davey and Cox 2014).

Combining the aforementioned elements, flood hazard curves can be produced that relate to the vulnerability of a community with floodwater Table 2-4. Figure 2-10 details which stability thresholds from individual flood hazard curves defined the limit for each flood hazard class and Table 2-5 summarizes the corresponding limiting parameter values.

*Table 2-4. Flood Hazard Classification Defining Limits*

| Hazard Vulnerability Classification | Depth | Velocity |
|---|---|---|
| H1 | Vehicle Stability – Small Car | Building Stability - Light Building |
| H2 | People Stability – Children<br>Vehicle Stability – Large 4WD | Building Stability - Light Building |
| H3 | People Stability - Adults | Building Stability - Light Building |
| H4 | Building Stability - Light Buildings | Building Stability - All Buildings |
| H5 | Building Stability - All Buildings | Building Stability - All Buildings |
| H6 | None | None |

*Table 2-5. Flood Hazard Risk Classification Summary*

| Hazard Vulnerability Classification | Description | Classification Limit | Limiting Depth (D, m) | Limiting Velocity (V, m/s) |
|---|---|---|---|---|
| H1 | Generally safe for vehicles, people and buildings | DV ≤ 0.3 | 0.3 | 2.0 |
| H2 | Unsafe for small vehicles | DV ≤ 0.6 | 0.5 | 2.0 |
| H3 | Unsafe for vehicles, children and the elderly | DV ≤ 0.6 | 1.2 | 2.0 |
| H4 | Unsafe for vehicles and people | DV ≤ 1.0 | 2.0 | 2.0 |
| H5 | Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure | DV ≤ 4.0 | 4.0 | 4.0 |
| H6 | Unsafe for vehicles and people. All building types considered vulnerable to failure | DV > None | None | None |

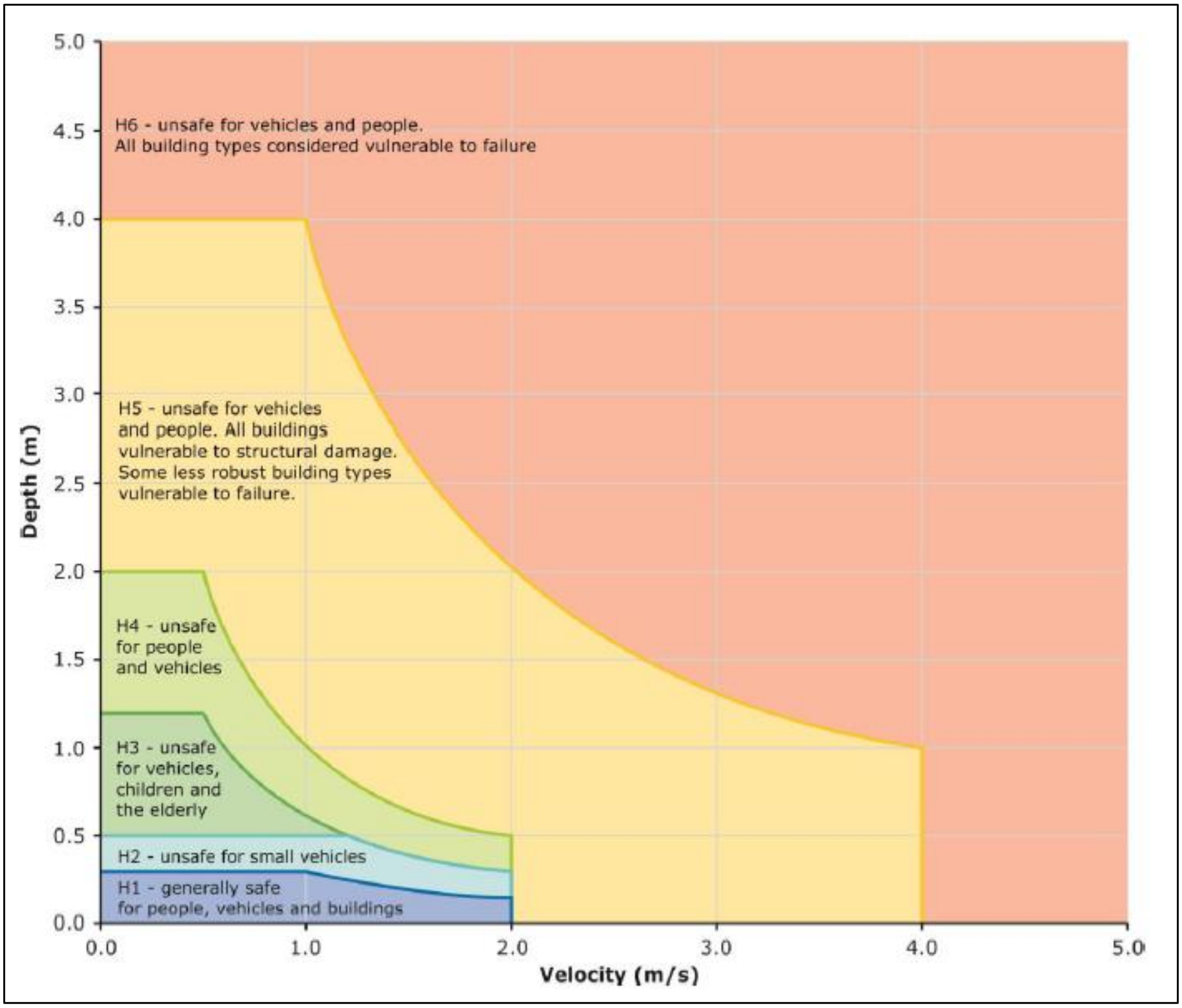


*Figure 2-10. Flood Vulnerability Classification Based on Flood Depth and Velocity (Smith, Davey and Cox 2014)*

# 3 Hydraulic Assessment – 2024 Outburst Event

The HEC-RAS model setup discussed in Section 2.3.2.3 was refined to further improve model efficiency. Many of the previous model parameters were transferred, with the exception of the model perimeter and geometry.

## 3.1 Model Geometry

Previous HEC-RAS modelling results consolidated the modelling into a single geometry and simulation. This setup resulted in long computation times to complete simulations which reduced model efficiency. To improve the model efficiency the HEC-RAS 2D model was subdivided into three sequential models. The three models are summarized in Table 3-1.

*Table 3-1. HEC-RAS 2D Model Geometries*

| Model Geometry | Upstream Model Extents | Downstream Model Extents |
|---|---|---|
| 01 – Upper Place Creek | Cirque Lake | Downstream of Channel Avulsion |
| 02 – Lower Place Creek | Upstream of Channel Avulsion | Upstream of Confluence with Poole Creek |
| 03 – Poole Creek | Upstream of Confluence with Poole Creek | Downstream of Pemberton Portage Rd and Railroad Crossings |

The model meshing has been further refined to improve computation time and reduce instabilities and fluctuations of the results. The mesh cell size was set to 3 m along the primary flow path and generated as hexagons to better represent the directional changes the flow path takes. Breaklines along the Place Creek and Poole Creek alignments were maintained from the previous HEC-RAS modelling, but additional breaklines were drawn at sections along the creeks to generate flow hydrographs to use a boundary conditions. Refinement regions were included when areas needed either increased or decreased mesh resolution. Figure 3-1, Figure 3-2, and Figure 3-3 present the three model geometries.

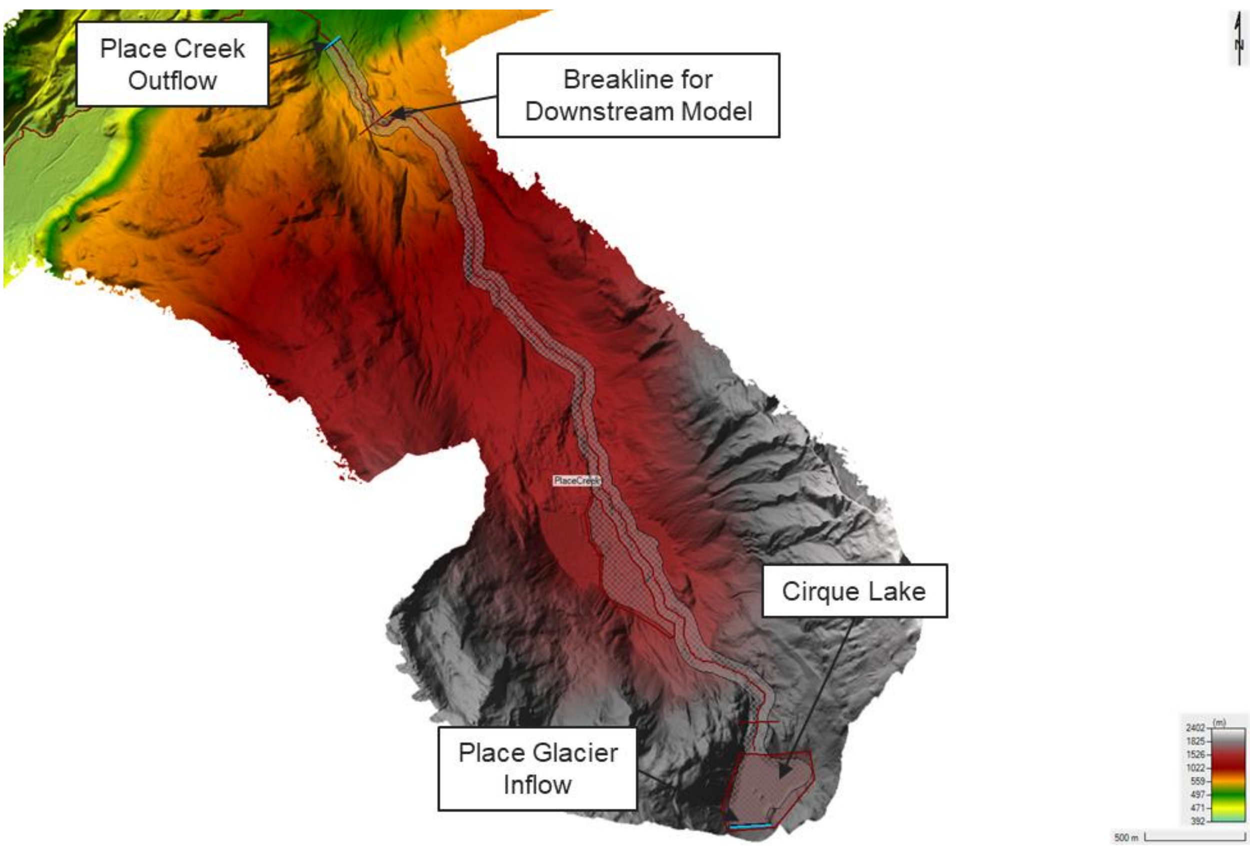


*Figure 3-1. Upper Place Creek Model Setup*

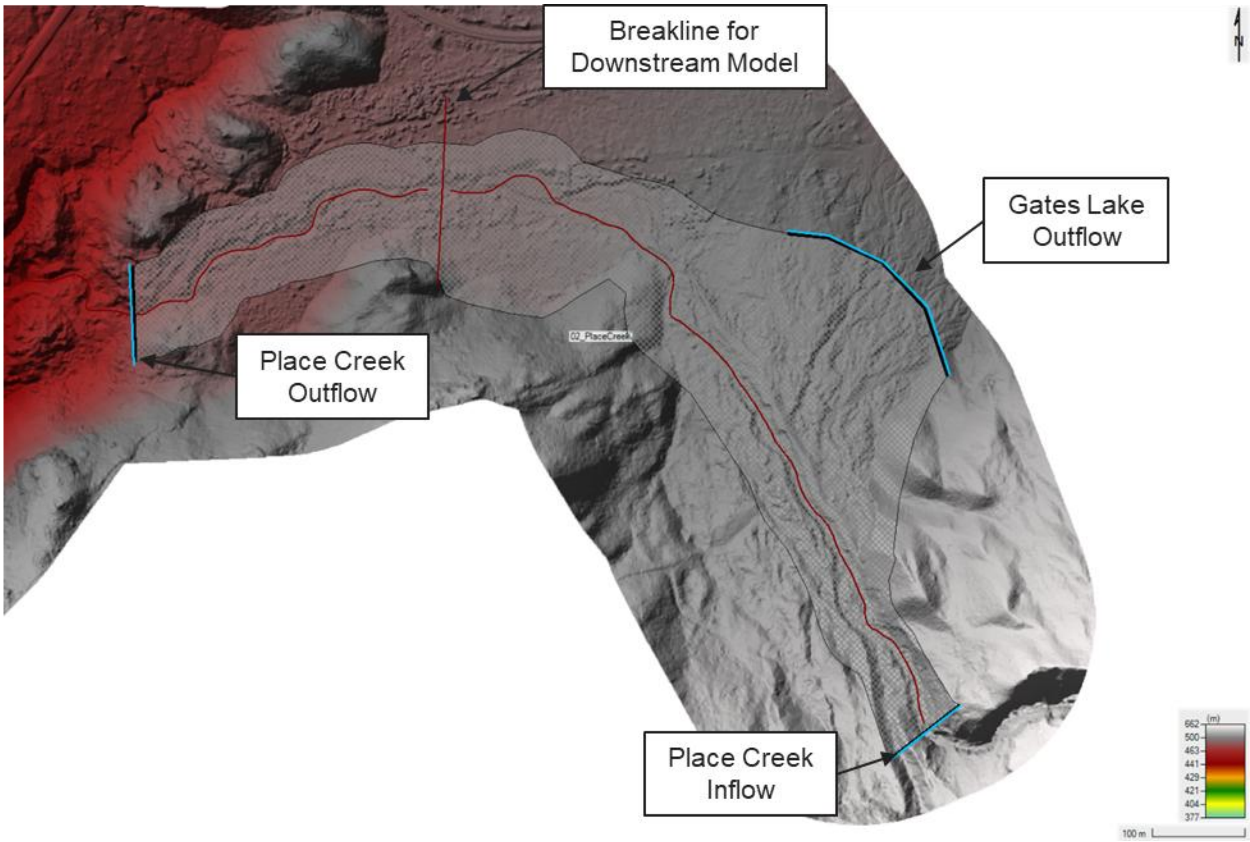


*Figure 3-2. Lower Place Creek Model Setup*

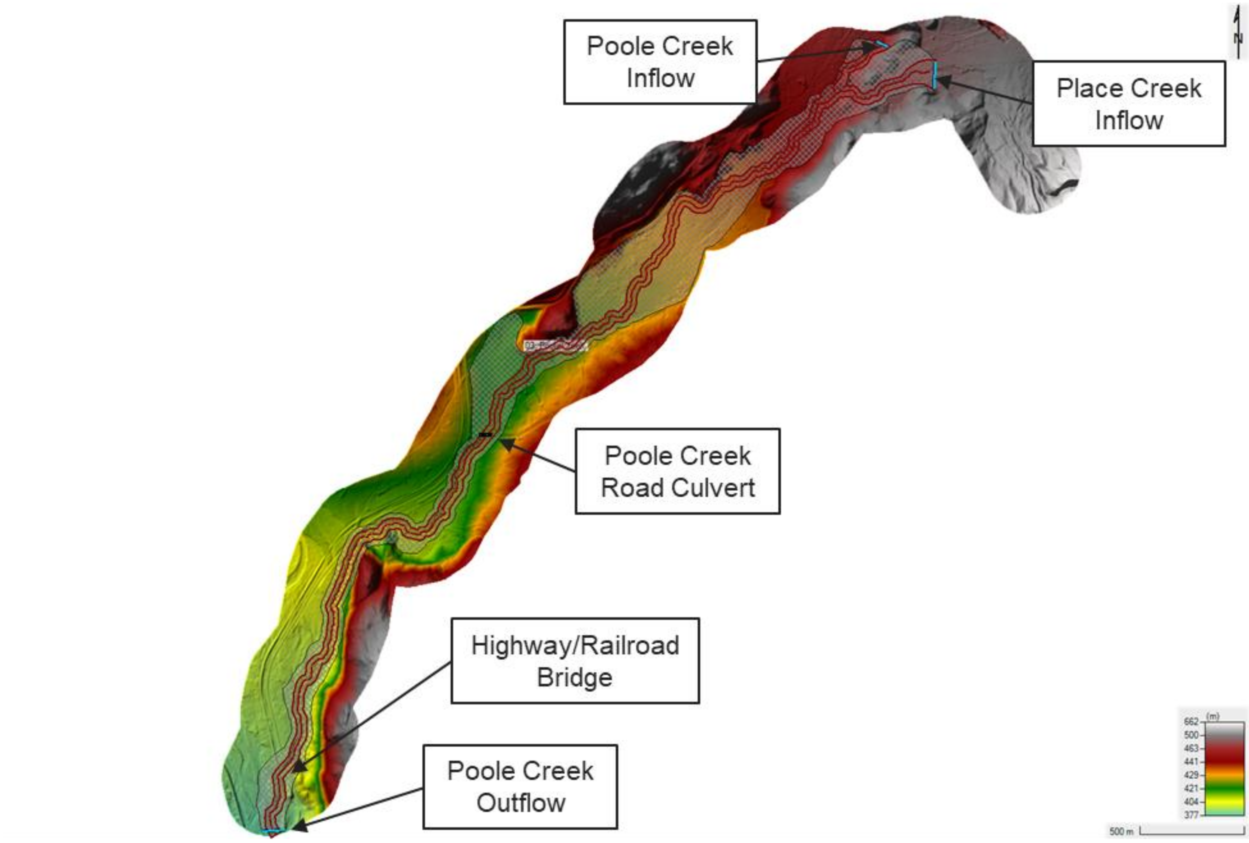


*Figure 3-3. Poole Creek Model Setup*

## 3.2 Boundary Conditions

The inflow boundary condition for the Upper Place Creek model was set as the flow hydrograph for the 2024 Outburst Event. For each sequential HEC-RAS model, the inflow boundary condition was set as the measured flow hydrograph from the breakline in the upstream model. The inflow boundary condition for Poole Creek was set as the MMD of 1.43 $m^3$/s.

Figure 3-4 presents the modelled flow hydrograph used for the 2024 Outburst Event. The hydrograph was developed by scaling the shape of the 2025 Outburst Event to align with the 2024 ice-marginal lake volume (1,200,000 $m^3$) and outburst duration (16 hours) estimated by NRCAN. The 2024 Outburst Event flow hydrograph has a peak discharge of approximately 80 $m^3$/s.

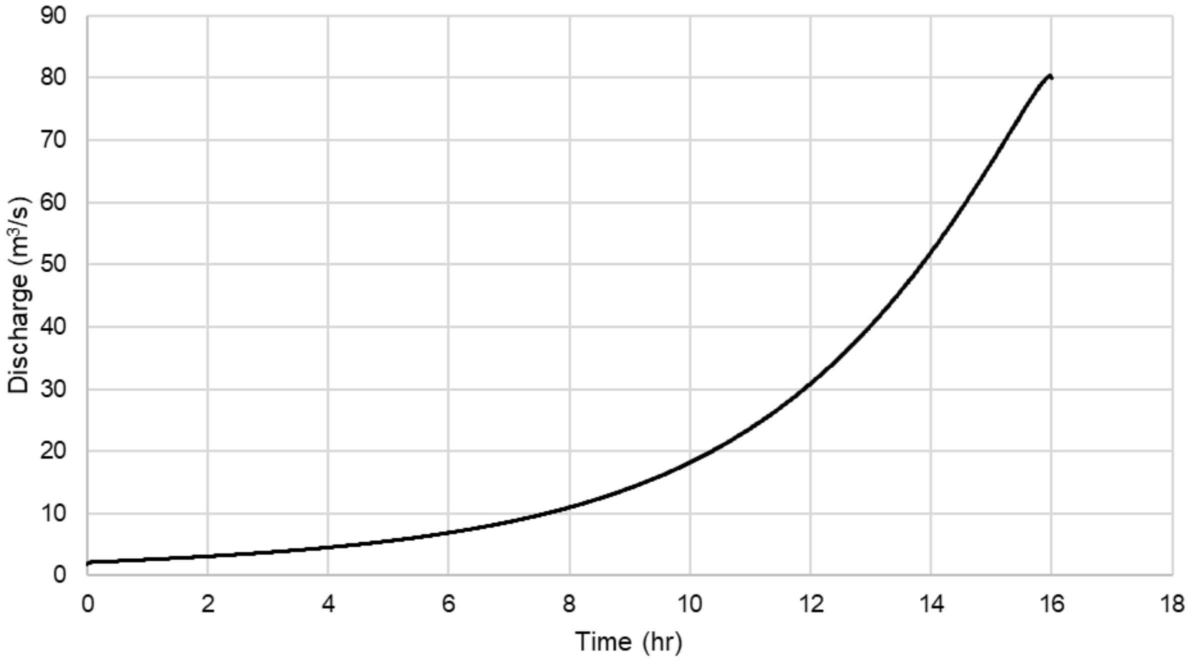


*Figure 3-4. 2024 Outburst Event Hydrograph*

## 3.3 Results

Water depths and velocities associated with the three sequential modelled simulations were used to develop the hazard map for the 2024 Outburst Event. Appendix A presents the 2024 Outburst Event hazard maps.

### 3.3.1 Performance of 2024 Emergency Response Works

The 2024 emergency response works, that were completed following the 2024 Outburst Event, were designed to re-establish the pre-2024 Outburst Event Place Creek embankment, reduce the potential for further bank erosion, and reduce the risk of an avulsion towards Gates Lake. The HEC-RAS model results demonstrated that the 2024 emergency response works would contain flows with the magnitude of the 2024 Outburst Event; however, the embankment would likely be damaged due to the extreme hydraulics (velocities upward of 9 m/s). The resiliency of the emergency response works can not be modelled using the HEC-RAS software. The HEC-RAS model assumes a static terrain, where geomorphic changes that may occur during a flood event are not simulated. Stantec's previous assessments of the 2025 Outburst Event (2025a, 2025b) found that portions of the 2024 emergency response works experienced erosion – an GLOF with a similar magnitude of flow to the 2024 Outburst Event would likely result in more significant damage of the 2024 emergency response works than what was observed from the 2025 Outburst Event.

The modelled discharge through the section of Place Creek where the emergency response works were terminated did not overtop the creek banks. However, further downstream prior to where Place Creek drops steeply down from the Pemberton Pass to the confluence with Poole Creek, flow overtops the right bank and is conveyed through the BC Hydro right of way before flowing down the steep transition and discharging into Poole Creek approximately 350 m upstream of the confluence with Place Creek.

### 3.3.2 Flood Risk to Human Life and Property

The model results indicate that a glacial outburst flood with a magnitude equal to the 2024 Outburst Event will pose a flood hazard to private lands between Gramsons and Birken that are adjacent to Poole Creek. The higher-level hazards are generally contained within the creek banks and floodplains. However, due to the culvert constraint at the Poole Creek Road, the community upstream of the culvert crossing is exposed to H4 flood hazards levels that are “unsafe for vehicles and people”, with “buildings vulnerable to structural damage.” The culvert crossing is assessed to be overtopped during the 2024 Outburst Event, for a duration of 12 hours.

Upstream of the Poole Creek highway/railroad bridge crossing, the creek banks are overtopped; however, flow does not overtop the road or rail embankments, and all flow is routed through the bridge openings[4]. The community upstream of the bridge crossing is exposed to low flood hazard levels that are “unsafe for vehicles, children and the elderly.”

### 3.3.3 Comparison to Previously Modelled Events

The comparison of the modelled events include the 2024 Outburst Event, 2025 Outburst Event, and Post-2025 Outburst Event 200-year Fall Clearwater Flow. The following observations are consistent between all the modelled results:

- Discharge through Place Creek did not overtop the 2024 emergency response works but overtopped the right bank downstream where Place Creek drops steeply down from the Pemberton Plateau to the confluence with Poole Creek.
- H4 and above flood hazards are generally contained within the creek banks and floodplains.
- The culvert crossing at the Poole Creek Road does not provide sufficient capacity to pass these flows resulting in backwatering upstream and inundating properties.

The culvert crossing at Poole Creek Road consistently backwaters up Poole Creek and inundates the upstream community resulting in high flood hazard levels. The culvert did not overtop during the 2025 Outburst Event but overtops for both the 2024 Outburst Event and Post-2025 Outburst Event 200-year Fall Clearwater Flow. Although upsizing the culvert may reduce the flood hazard classification for the upstream community, there would potentially be a transfer of risk to communities downstream of the culvert crossing. Further assessment should be completed to assess this risk as part of any future culvert replacement design work.

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[4] Bridge structures are not included within the model – further assessment would be required to determine whether the low chord elevation of the bridges would interact with flows.

## 3.4 Assumptions and Limitations

The following assumptions and limitations are associated with the hydraulic model:

- Results from this assessment are based on LiDAR only and do not incorporate detailed bathymetric data of the channel – this may result in more conservative flood depths and extents as depending on flow conditions at the time of LiDAR collection the "channel bed" may be higher than actual conditions.
- The terrain was modified to remove culverts and bridges along Poole Creek other than the Poole Creek Road culvert. The Poole Creek Road culvert invert elevations and culvert length were not publicly available and therefore were estimated based on visual observations.
- The results do not include freeboard and should not be used to develop flood construction levels (FCLs).
- Model terrain is static and does not account for geomorphic changes that may occur during a flood event (i.e., channel avulsion, aggradation or degradation of the bed, large woody debris jams, etc.).
- HEC-RAS modelling of the 2024 Outburst Event was limited to the diffusion wave equation solver. This equation solver was selected as it has a faster computation time compared to the shallow water equation solver. For future modelled scenarios, the shallow water equation solver should be used for applicability with the Place Creek and Poole Creek flow characteristics.
- The 2024 and 2025 Outburst Event hydrographs provided by NRCAN are modelled based on *Hydraulics of Subglacial Outburst Floods: New Insights for the Spring-Hutter Formulation* (Clarke 2003).
- Model calibration and accurate validation of the model was not possible due to the mentioned limitations and lack of hydrometric data available along Poole Creek or Place Creek.
- The NRCAN outburst hydrograph data has not been validated by NRCAN and was provided to Stantec as preliminary data. Quality assurance and validation may result in change.
- The hydraulic assessment is not intended to align with EGBC guidelines for flood hazards assessments of flood mapping and is not intended to be used for design purposes. Legislated flood hazard assessments and flood mapping require extensive bathymetric/topographic surveys and site-specific hydrological analyses be completed to inform deterministic hydraulic models that generate water surface elevations, water depths, and velocities. Geomorphic assessments are also encouraged for the development of flood hazard assessments as the potential for lateral migration of the channel should be considered when determining what fluvial hazards exist at the select site. These robust assessments are time intensive and costly; however, they are important for residents, property and landowners, development consultants, planners, Approving Authorities, and local governments, as well as provincial and federal government ministries. Many of these parties require and rely upon these assessments for determining flood construction levels and authorizing building and development permits.

# 4 Conceptual Design Options Development

To mitigate the potential annual flood hazard posed to the communities within the Project scope, Stantec has assessed various concepts and approaches to either: i) mitigate the potential for the ice-marginal lake to propagate to a depth/volume that is greater than the 2025 Outburst Event; ii) mitigate the potential for an avulsion of Place Creek and re-direction of flow towards Gates Lake. The following sections detail: i) key considerations and criteria that are used for the development of the conceptual options; ii) the proposed conceptual options; and iii) an evaluation matrix to compare the options to one another and support SLRD with selection of an option to be progressed to detailed design.

## 4.1 Development of Design Options

The conceptual designs presented in this report were selected based on a combination of feasibility, effectiveness, environmental sensitivity and alignment with the Project's scope and timeline. The following are key criteria, considerations, and limitations that were identified and used to guide development of conceptual options:

- Accessibility to site was a key limitation when determining design options. The topography of Place Glacier/Creek is characterized by steep, mountainous terrain, that is difficult to access. The upper cirque lakes, Place Glacier, and ice-marginal lake are located in a hanging valley which can not be accessed by land based vehicular means. Concepts shall be based on assumption that access to the ice-marginal lake for construction or maintenance purposes would be via. helicopter only.
- An GLOF from the ice-marginal lake is anticipated to occur on an annual basis between mid-June to mid-July. Therefore, any design option shall be implemented by mid-June 2026 and be in operation until the glacier recedes a sufficient distance that the ice-marginal lake no longer forms.
- The ice-marginal lake is located at a geodetic (GD) elevation of approximately 1950 m and exposed to severe winter conditions. Concepts shall either allow for mobilisation and de-mobilisation on an annual basis or be designed to handle the severe winter weather (freezing temperatures, high winds, snow loads)
- The Place Glacier is receding on an annual basis and therefore the location and geometry of the ice-marginal lake will constantly be changing. Concepts shall not be static and be adaptable to the changing ice-marginal lake geometry and conditions.
- Hydraulic modelling completed by Stantec and conditions observed during and following the 2025 Outburst Event indicate that flood hazards posed to the communities within the Project scope are generally low for a GLOF with a flow magnitude equivalent to the one experienced during the 2025 Outburst Event. Therefore, concepts that are based on management of the ice-marginal lake level shall limit ice-marginal lake depths to 15 m. All other concepts shall be based on the 2024 Outburst Event hydrograph.
- Concepts shall not transfer flood hazard to properties currently not exposed to glacial outburst as defined by Stantec's Phase 1 and current Project studies.
- Concepts shall not increase the flood hazard rating at structures as defined by Stantec's Phase 1 and current Project studies. Concepts should minimize the potential for increases in flood hazard rating at all other locations within the Project scope.
- Concepts should consider environmental impacts associated with future glacial loss; specifically, loss of year-round cold-water source relied upon for fish spawning and rearing habitat within downstream watercourses.
- Concepts should limit operation and maintenance requirements and SLRD administration requirements.

The development of design options was informed by an interdisciplinary team of hydrotechnical, geotechnical, structural, and process engineers, avalanche explosive specialists, and environmental professionals with input provided by NRCAN's glaciologist. Hydrotechnical engineers led the hydraulic modelling and flood hazard assessments. Geotechnical engineers contributed expertise in assessing the feasibility of constructing the permanent structures based on slope stability and terrain constraints. Structural engineers provided input on proposed infrastructure and maintenance implications. Process engineers were consulted to assess the operational feasibility of pump-based solutions, including fuel equipment. Environment professionals provided input on environmental considerations and permitting logistics. Avalanche explosives specialists provided input on feasibility of explosive related options. NRCAN's glaciologist provided input with respect to glacier outburst mechanisms and information they have collected of the Place Glacier that may support conceptual option development. This integrated approach allowed for a holistic evaluation of design options. The options were also developed in consultation with the SLRD, and Indigenous communities. The conceptual options reflect concerns around environmental stewardship, land use impacts, and the need for timely action ahead of anticipated future GLOFs.

The following concepts were considered as part of the Project:

**Option 1** – Install a siphon in the ice-marginal lake and convey flow into the Joffre Creek catchment OR overtop of the glacier into the Place Creek catchment

**Option 2** – Install pumps in the ice-marginal lake and pump into the Joffre Creek catchment OR overtop of the glacier into the Place Creek catchment

**Option 3** – Drill a conduit through the bedrock adjacent to the glacier extending from the ice-marginal lake downstream to the upper cirque lake and into Place Creek

**Option 4** – Construct a dam at the outlet of the lower cirque lake to impound glacier outburst flows and control flow rates released into Place Creek

**Option 5** – Use explosives to fracture open the conduit within the ice-marginal lake where annual GLOFs propagate.

The following sections provide details for each of the options presented above and discusses key engineering, environmental, opinion of probable cost, and operation and maintenance considerations with respect to the Project criteria, considerations, and limitations detailed above. Several options were found to not be feasible and therefore detailed assessment and opinion of probable cost were not developed.

For all Options it is recommended to also repair the 2024 emergency response works in 2026. Details on these required repairs are included in Section 4.2.3 and costs for this have been included in the OPC of each of the options.

## 4.2 Opinion of Probable Cost

For each of the concepts deemed feasible, a Class D opinion of probable costs (OPC) was developed. A Class D OPC has an uncertainty of -30% to +50% (ACEC 2022). The cost basis and assumptions used to derive the OPCs have been defined herein. We have assumed the work will be administered with a general contractor engaged to perform all activities and consulting services for engineering design, environmental permitting, environmental monitoring, and construction review services during construction. Detailed OPCs for each of the conceptual options is provided in Appendix B.

### 4.2.1 Project Engineering, Environmental, and Contingency Costs

Project costs include fees associated with project management, planning, engineering, and environmental design and construction supervision (soft costs). The project cost also includes contingencies to account for uncertainties associated with the project scope:

- Design refinements as engineering progresses.
- Changes in equipment, material and labour costs.
- Extra work (within reason) not related to design refinements.
- Increase/decrease in qualities.
- Fuel costs and surcharges.
- Escalation and currency effects.

The following uncertainties cannot be accounted with any degree of certainty:

- Changes in project scope, objectives, or operating criteria resulting in changes to the product resulting from stakeholder and third-party consultation.
- Changes in government policies and regulations.

Soft costs associated with design and environmental permitting are assumed to be 15% of the total construction cost. Costs associated with environmental monitoring and engineering quality assurance during construction are assumed to be 12% of the total construction cost. In addition, OPCs presented below are based on the following assumptions:

- Material and labour unit prices are based on information and projects managed by Stantec. Contingency included within the OPC does not account for potential future tariffs impacts on unit rates.

### 4.2.2 Unit Costs

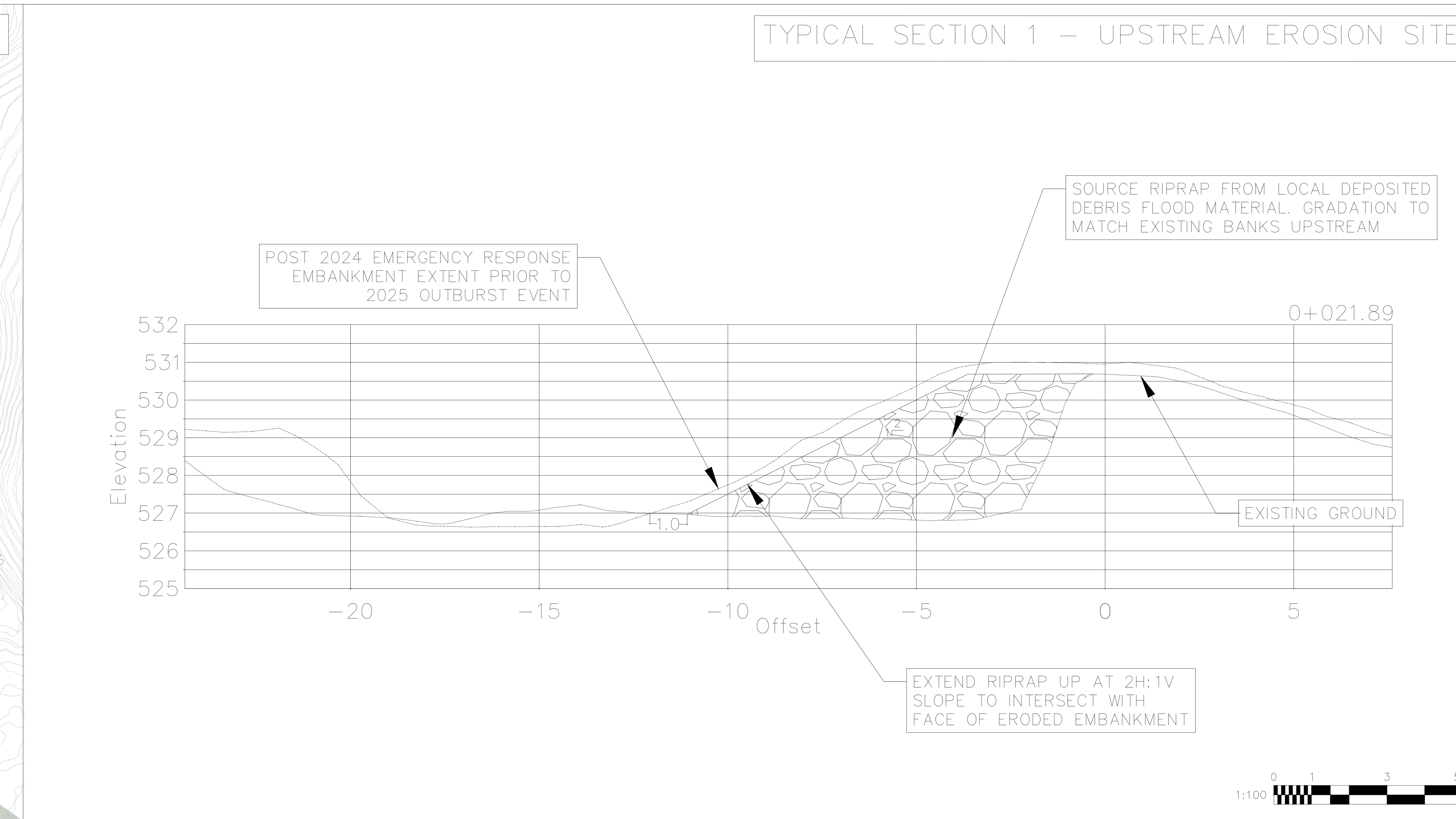
Unit costs used in the OPC (Table 4-1) utilize rates from the 2024 emergency response works (Stantec 2024a) and rates based on previous Stantec projects and discussions with providers.

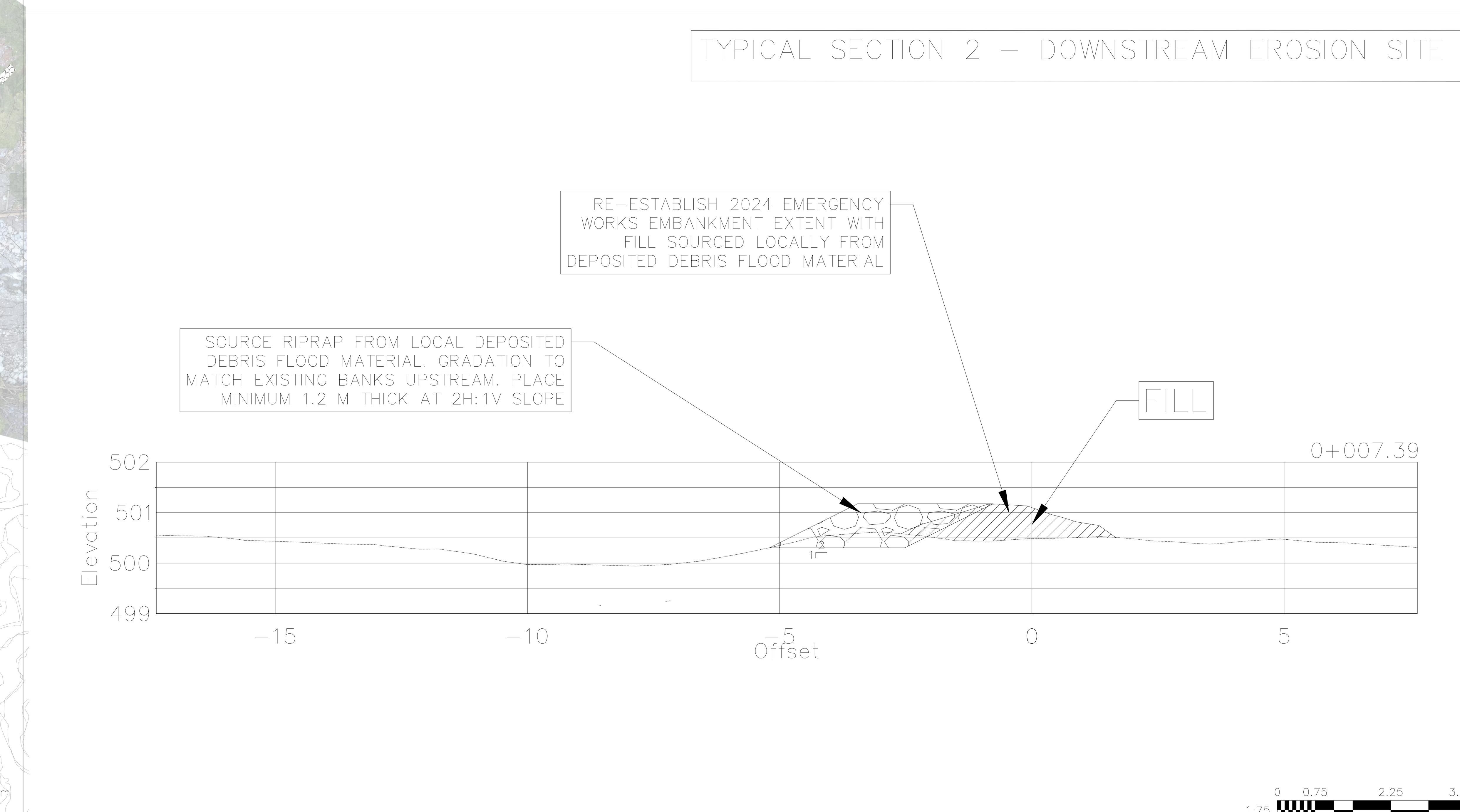
Table 4-1. Summary of Unit Costs

| Cost Item | Description of Item | Unit Rate |
|---|---|---|
| Mobilisation and Demobilisation for Land Based Vehicle Options | Excavator for establishing access route and site closure | $20,000 |
| Class 500-kg Riprap | Excavate, Source, & Place 500 kg Riprap (Riprap sourced from debris flood deposits adjacent to site, includes 1 x 210, 1 x 300 Excavator) | $565 / hr |
| Fill Material | Excavate, Source, & Place Fill (Fill sourced from debris flood deposits adjacent to site, includes 1 x 210, 1 x 300 Excavator) | $565 / hr |
| 8" Layflat hose | Material Cost Only, 210 m long segments | $13,500 ea |
| Diesel Generator, 30 kVa | Material Cost Only | $50,000 ea |
| Electrical, Control, Instrumentation | Material Cost Only | $300,000 ea |
| Diesel Tanks (1000 L) | Material Cost Only | $6,000 ea |
| Helicopter | Equipment and Operator | $6,700 / hr |
| Generator Diesel | Material Only | $2 / L |
| Explosives Expenses | Source and Place explosives. Assumes 4 hours A-star helicopter time spread over three days from either Whistler or Pemberton | $16,408 ea |
| Gabion Basket Filled with Rock | Material and Supply | $721 / $m^3$ |
| Labourer | Price per hour of service | $75 / hr |

### 4.2.3 Common Work for All Options

For all options, the 2024 emergency response works need to be repaired in 2026. This includes re-establishing the damaged embankments and riprap protection with granular material and stones sourced from local deposited debris flood material at the upstream and downstream erosion sites. The gradation of the riprap should match the existing banks upstream of the erosion site. At the upstream erosion site, the riprap shall be placed 1 m offset from the bank toe, starting from the existing ground elevation up at a 2H:1V slope to intersect with the face of the eroded embankment. At the downstream erosion site, the 2024 emergency embankment is to be re-established with fill sourced locally from deposited debris flood material and armoured with a layer of riprap. The riprap shall be placed at a minimum thickness of 1.2 m at a 2H:1V slope along the re-established embankment. This reach of Place Creek would be exposed to extreme velocities and debris during outburst flows. The size of riprap required to remain stable during the 2024 Outburst Event would be on the order of MOTT Class 4,000 kg riprap which is not readily available, extremely difficult to transport and handle, and cost prohibitive. It is anticipated that Option 1 through 4 would be reduce the potential for yearly maintenance and repair of the 2024 emergency response works, while Option 5 would likely require yearly repair and maintenance. A figure presenting the design concept is provided in Figure 4-1.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Notes

1. POST-CONSTRUCTION SURFACE IS BASED ON OCT. 13, 2024 LIDAR COLLECTED BY ALPINE SOLUTIONS AVALANCHE SERVICES. BACKGROUND IMAGE COLLECTED ON NOV. 7, 2024 AND PROVIDED BY ALPINE SOLUTIONS AVALANCHE SERVICES. PRE-CONSTRUCTION AND PRE-DEBRIS FLOOD EVENT SURVEY/SURFACE INFORMATION WAS NOT AVAILABLE.
2. THE PURPOSE OF THE CHANNEL MODIFICATION AND RE-ESTABLISHED EMBANKMENT WAS TO ALLEVIATE THE IMMEDIATE DEBRIS FLOOD AND FLOOD HAZARDS POSED TO THE PROPERTIES AROUND GATES LAKE AND PORTION OF GATES RIVER IMMEDIATELY DOWNSTREAM OF GATES LAKE PRIOR TO THE IMMINENT EXTREME RAINFALL EVENTS GENERALLY EXPERIENCED IN THE FALL.THE CHANNEL MODIFICATIONS ARE DEEMED "EMERGENCY RESPONSE MEASURES"; AS SUCH, NO DESIGN LIFE OR DESIGN FLOW IS ASSOCIATED WITH THE CHANNEL MODIFICATIONS. DUE TO THE LOCATION, PHYSIOGRAPHY, AND GEOGRAPHY PLACE CREEK WILL LIKELY CONTINUE TO BE PRONE TO AVULSION AND LATERAL MIGRATION WITHOUT IMPLEMENTATION OF AN ENGINEER DESIGNED STRUCTURE THAT COULD PROVIDE LONG-TERM PROTECTION FROM DEBRIS FLOOD AND DEBRIS FLOW EVENTS.
3. THE SEAL AND SIGNATURE OF THE UNDERSIGNED ON THIS DRAWING CERTIFIES THAT THE DESIGN INFORMATION CONTAINED IN THESE DRAWINGS ACCURATELY REFLECTS THE ORIGINAL DESIGN AND THE MATERIAL DESIGN CHANGES MADE DURING CONSTRUCTION THAT WERE BROUGHT TO THE UNDERSIGNED'S ATTENTION. THESE DRAWINGS ARE INTENDED TO INCORPORATE ADDENDA, CHANGE ORDERS, AND OTHER MATERIAL DESIGN CHANGES, BUT NOT NECESSARILY ALL SITE INSTRUCTIONS.
   THE UNDERSIGNED DOES NOT WARRANT OR GUARANTEE, NOR ACCEPT ANY RESPONSIBILITY FOR, THE ACCURACY OR COMPLETENESS OF THE AS-CONSTRUCTED INFORMATION SUPPLIED BY OTHERS CONTAINED IN THESE DRAWINGS, BUT DOES, BY SEALING AND SIGNING, CERTIFY THAT THE AS-CONSTRUCTED INFORMATION, IF ACCURATE AND COMPLETE, PROVIDES AN AS-CONSTRUCTED SYSTEM WHICH SUBSTANTIALLY COMPLIES IN ALL MATERIAL RESPECTS WITH THE ORIGINAL DESIGN INTENT.
4. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS IF NOT OTHERWISE INDICATED. HORIZONTAL DATUM IS NAD83 (CSRS) Zone 10N, VERTICAL DATUM IS CGVD2013 (CGG2013a).

Client/Project
SQUAMISH-LILLOOET REGIONAL DISTRICT
PLACE GLACIER RISK ASSESSMENT

Project No.
111700836

Title
2025 EMERGENCY RESPONSE CONCEPTUAL DESIGN DRAWINGS

| Revision | Date |
|---|---|
| 0 | AUG/29/2025 |
| SCALE | Figure No. |
| SEE DRAWING | 1 |

Figure 4-1. Common Work / Option 5 Conceptual Figure

### 4.2.4 Option 1 – Install Siphon in Ice-Marginal Lake

A siphon is a conduit that is used to convey liquids upwards from a reservoir and then down to an elevation that is below the water surface elevation within the reservoir. Generally, this is achieved by forcing the liquid (via. suction or immersion) through the conduit to the desired lower elevation. Following this, flow will continue unaided. The limiting factor of a siphon is that due to capillary forces a liquid cannot be raised higher than 7 to 8 m from the reservoir level prior to being lowered. At elevation changes greater than this, water vaporizes, and the siphon ceases to function.

The elevation difference from the 15 m deep ice-marginal lake water surface (approximately 1971 m GD) to the crest of the glacier (2000 m GD, for conveying flow into Place Creek) or the crest of the mountain divide (1995 m GD, for conveying flow to Joffre Creek) are greater than 8 m. This option has therefore not been evaluated further.

### 4.2.5 Option 2 – Install Pumps in Ice-Marginal Lake

Option 2 involves installing a series of pumps within the ice-marginal lake to divert flow overtop of the crest of the glacier into the cirque lake and eventually into Place Creek; or overtop of the crest of the mountain divide and into the Joffre Creek watershed and eventually into Joffre Creek. Immersible pumps would be mounted to a floating raft which would then be situated within the centre of the ice-marginal lake and hoses would then extend either over the glacier or the mountain divide to convey the pumped flow. An example of what this would look like is provided in Figure 4-2.

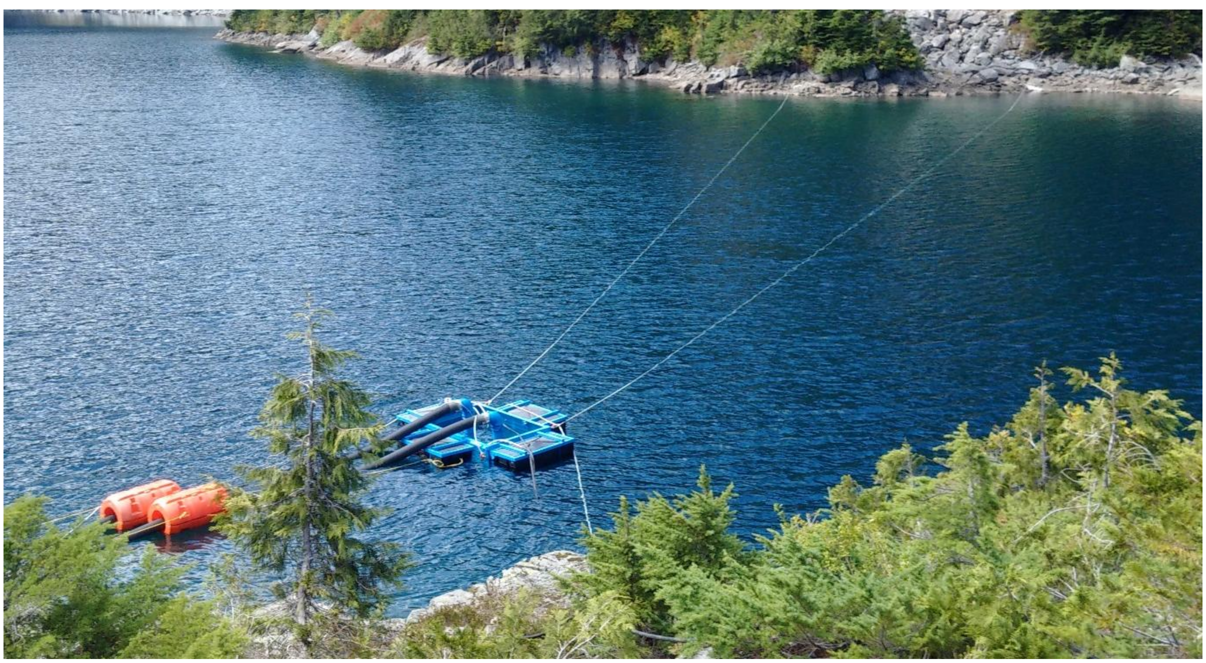


*Figure 4-2. Example of immersible pumps mounted to a floating raft (Image provided by Canadian Dewatering Ltd)*

A diesel generator would be required to power the pumps and would need to be located adjacent to the ice-marginal lake on competent ground (i.e., stable rock, prepared wooden pad, etc.). The crest of the glacier and the mountain divide have a similar elevation; however, the lateral distance from the ice-marginal lake to the glacier crest is approximately 400 m; while the distance from the ice-marginal lake to the crest of the mountain divide is approximately 210 m. Based on this, the optimal pumping scenario would be to pump flow over the mountain divide into the Joffre Creek catchment. Further assessment of this option is based on this optimal pumping scenario. Figure 4-3 presents the general concept of Option 2.

### Engineering and Environmental Considerations

In order to determine the construction OPC a detailed assessment of pump requirements and associated materials has been completed. Further engineering design tasks would include developing detailed design drawings and a design basis report to support environmental permitting requirements and emergency funding applications.

Option 2 does not require a permanent structure, nor the requirement for a structure to be decommissioned. The ice-marginal lake is located on a glacier, forms seasonally, and is not fish bearing. Based on these considerations the environmental permit requirements would be limited. For planning purposes it is assumed that a notification to the Ministry of Water, Land, and Resource Stewardship (WLRS) under Section 11 of the Water Sustainability Act would be required. A request for a review from the Department of Fisheries and Oceans (DFO) under the Fisheries Act may also be required. As part of the ongoing Project work SLRD and Stantec have worked closely with the Lílwat Nation and N'Quatqua Nation; however, formal consultation would be required as part of the environment permitting process. The reliance and magnitude of diesel required for this option would result in significant volumes of greenhouse gas emissions being produced. As greenhouse gas emissions and associated climate change is likely contributing to the rapid decline of the Place Glacier this option does not align with environmental stewardship and glacial heath Project considerations.

### Construction Feasibility

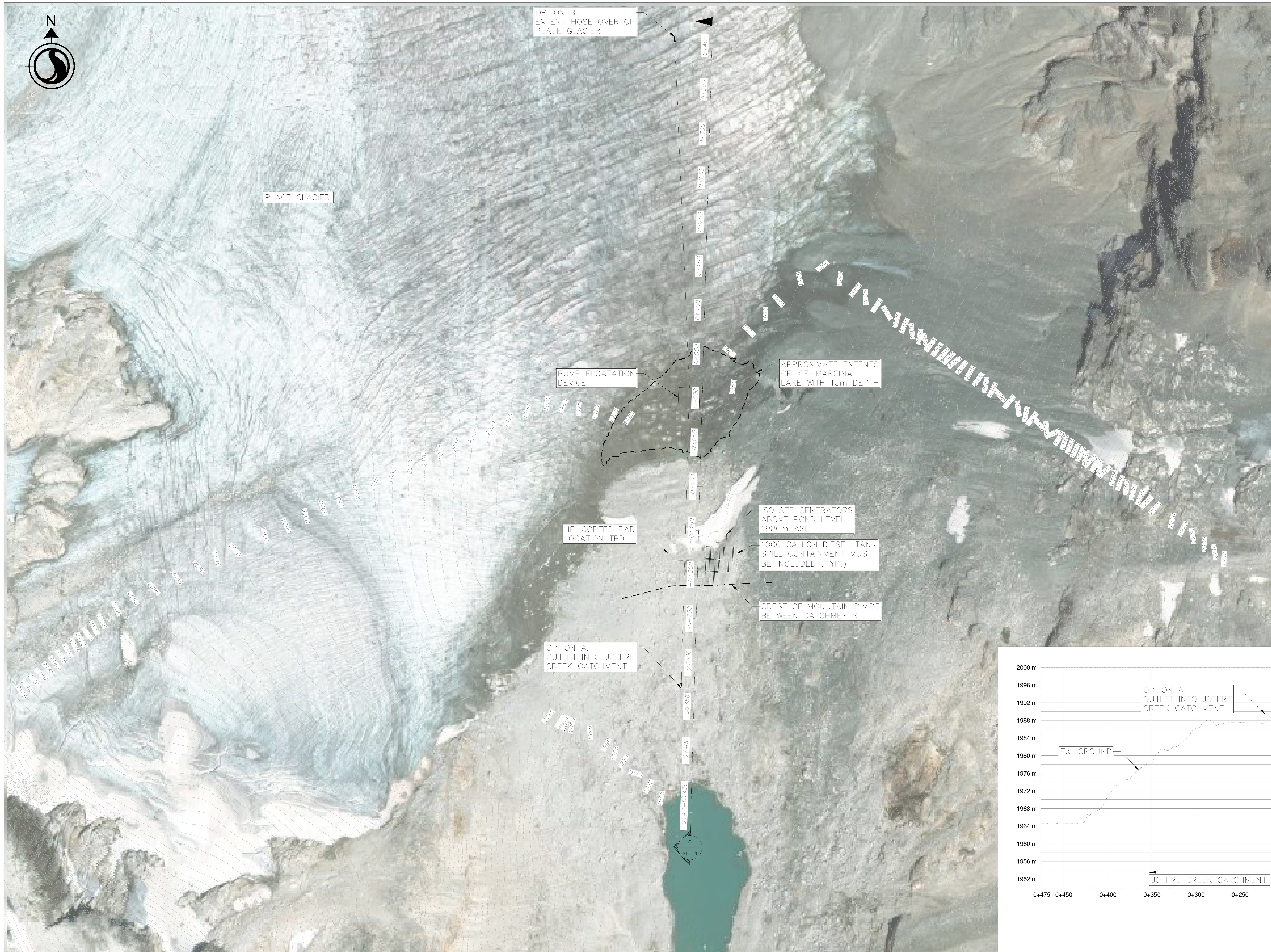
The primary constraint for this option is helicopter lifting capacity. Stantec confirmed with a Vancouver-based helicopter company that the largest, readily available commercial helicopter has a lifting capacity of 2,500 lbs at elevations required to bring equipment to the ice-marginal lake. This limitation restricts the generator size to approximately 30 kVa and consequently the maximum pump size to about 10 kW. NRCAN has estimated that the ice-marginal lake forms at a flow rate of 1 $m^3/s$; therefore, to maintain the lake depth at 25 m the pumping scheme would require a similar capacity. To achieve this flow rate with 10kW pumps, approximately 36 individual pumps and 17 generators would be required. The diesel consumption is estimated to be 136 L/h and fuel would need to be replenished once every seven hours operating continuously day and night. Larger diesel fuel tanks could be sourced to extend this period; however, even if extended to once daily sourcing helicopters at this frequency during the peak wildfire fighting season would be challenging. The pumps are only effective if their capacity matches the ice-marginal lake forming inflow; therefore, reliance on helicopters for fuel and maintenance poses a risk to the efficacy of this option.

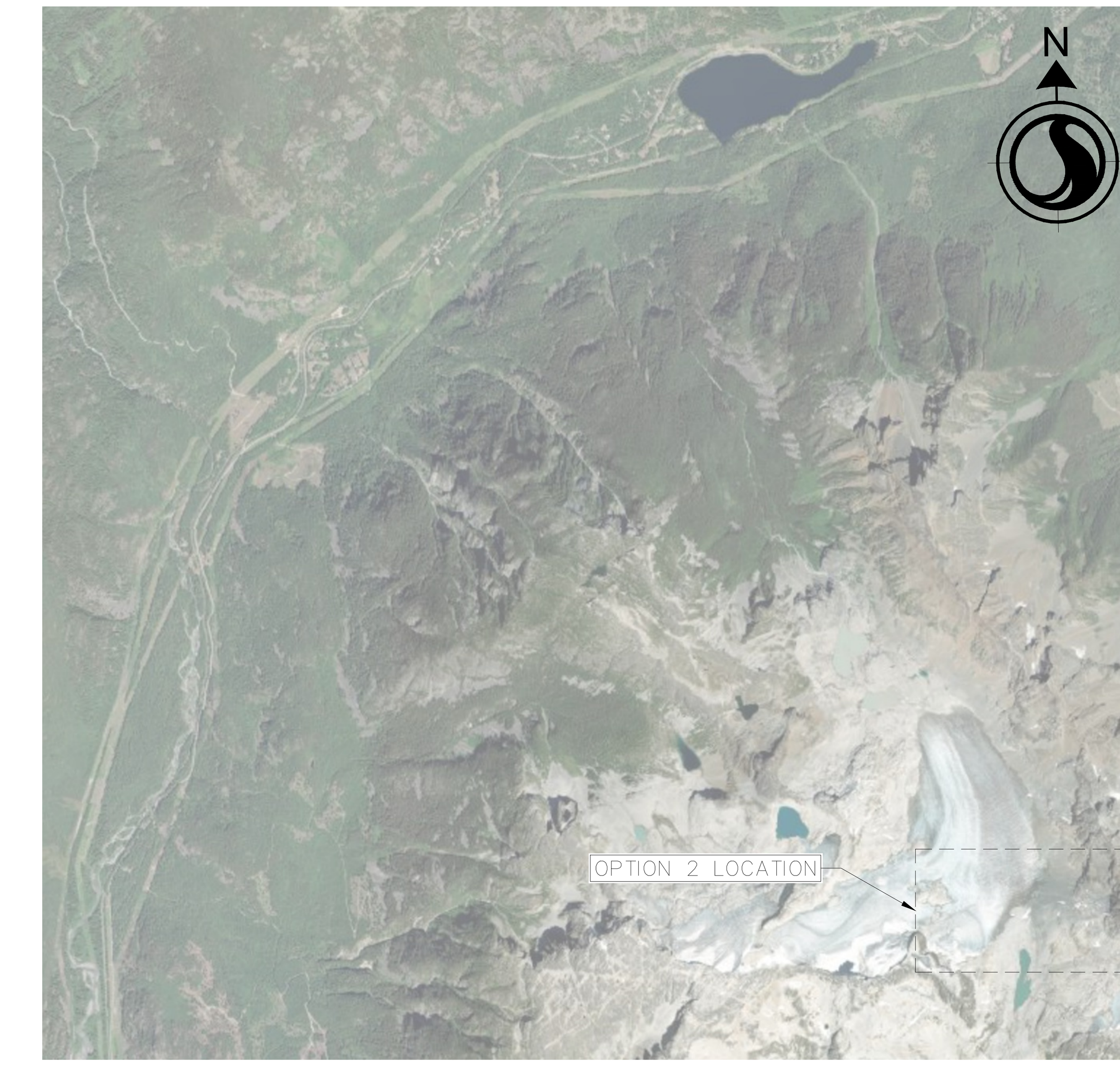
### OPC Consideration

Due to the limitations with helicopter lift capacity and the requirement for 36 pumps and 17 generators, helicopter hours required to mobilize and demobilize the equipment and refuel the generators the construction cost for Option 2 is prohibitive. For 2026, the OPC for designing, permitting, and constructing (including environmental supervision and engineering quality assurance) Option 2 is $19,517,000. For subsequent years where design and permitting is not required the cost would be $16,160,000. The number of years which the ice-marginal lake will pose a flood hazard is unknown and highly dependant on yearly climate and glacial melt trends; however, if we assume the mitigation would be required for a period of 8 years the total cost would be $148,794,000. It is assumed that nominal repairs to the 2024 emergency response works would be required with this option and therefore an annual cost to repair these works has not been carried in the OPC.

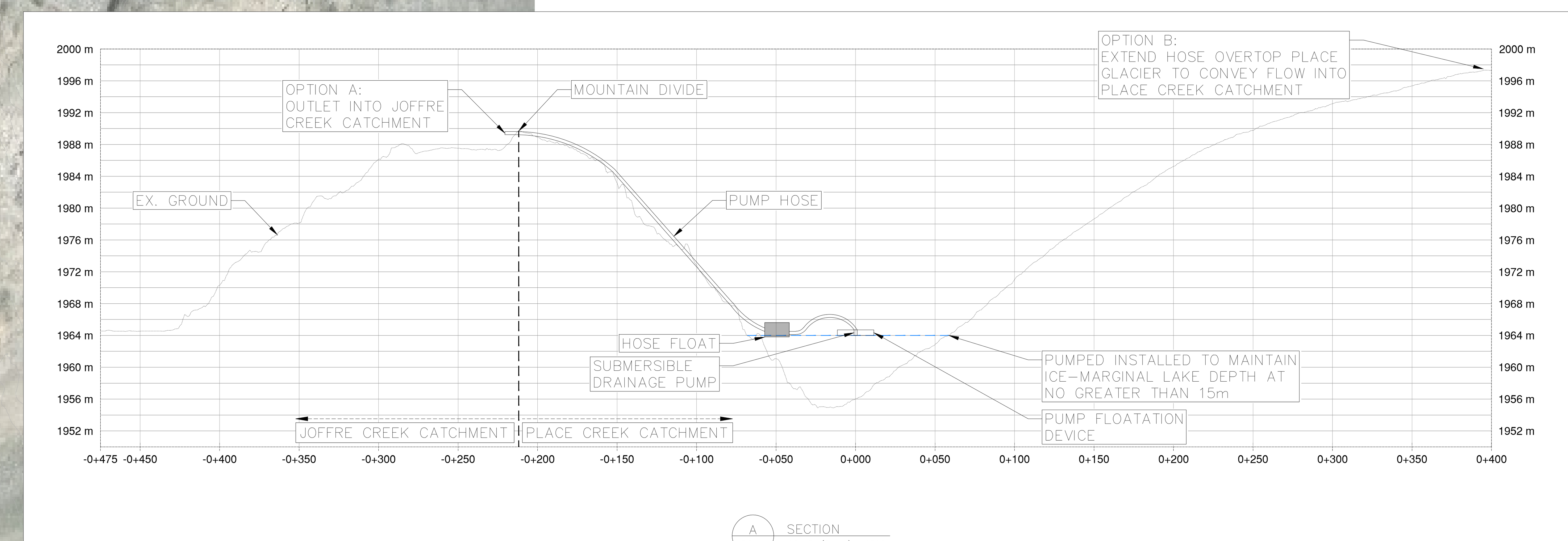
### Operation and Maintenance Consideration

Option 2 would only be in place for the months where the ice-marginal lake forms and would be fully removed each year. Therefore, there would be minimal operation and maintenance requirements outside of annual maintenance of the generators and pumps. Costs associated with replacing the pumps, generators, and hose lines has not been considered. It is assumed that nominal repairs to the 2024 emergency response works would be required with this option.




PROJECT KEY MAP

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2. CONCEPT INCLUDED WITHIN THIS DRAWING IS FOR EMERGENCY RESPONSE PURPOSES ONLY. CONCEPT WAS PREPARED WITHOUT POST-EVENT LiDAR AND BASED ON CURSORY HYDROTECHNICAL ENGINEERING ASSESSMENT LIMITED TO VISUAL OBSERVATIONS, REVIEW OF AVAILABLE STUDIES PROVIDED BY SLRD AND PRELIMINARY HYDROLOGIC ANALYSIS. NO HYDRAULIC MODELING, GEOMORPHIC ANALYSIS, OR DEBRIS FLOOD MODELLING WAS COMPLETED TO INFORM THIS CONCEPT - ACTUAL LAYOUT OF WORKS WILL BE FIELD-FIT BASED ON EXISTING CONDITIONS AT TIME OF CONSTRUCTION. THE PURPOSE OF THE CONCEPT INCLUDED WITHIN THIS DRAWING IS TO MITIGATE IMMEDIATE FLOOD HAZARDS ASSOCIATED WITH PLACE CREEK POSED TO THE COMMUNITY OF BIRKEN, BC FOLLOWING THE JULY 21, 2024 EVENT. FOR FURTHER DETAILS ON THE QUALITATIVE HAZARD ASSESSMENT THAT INFORMED THIS CONCEPT SEE "rpt_Gates_Prelim_Hazard_v0.pdf" - Stantec, 2024.
3. CONTOURS DISPLAYED @ INTERVALS OF 5m.
4. CONTOURS BASED ON LiDAR COLLECTED ON 08/02/2024.

0 25 75 125m
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Client/Project

SQUAMISH-LILLOOET REGIONAL DISTRICT
PLACE GLACIER CONCEPTUAL DESIGNS

Project No.
111700836

Title

OPTION 2
INSTALL PUMPS IN ICE-MARGINAL LAKE

| Revision | Date |
|---|---|
| 0 | DEC/03/2025 |
| SCALE | Figure No. |
| 1:2500 | 1 |

Figure 4-3. Option 2 Conceptual Figure

### 4.2.6 Option 3 – Drill Conduit Through Bedrock Adjacent to Glacier

Option 3 involves trenchless drilling of a conduit through the bedrock adjacent to the glacier extending from the location where the ice-marginal lake forms downstream to the upper cirque lake. This would prevent the ice-marginal lake from forming by providing a means for meltwater to circumvent the depression where the ice-marginal lake forms. Due to the mechanical nature of trenchless installations, a significant amount of heat can be released during the drilling or tunneling process, which is not recommended for installation through solid ice as it would likely aggravate the issue of the glacier melting. As such, the conduit alignment would need to be situated within the underlying bedrock. Based on information provided by NRCAN, the conduit alignment would likely be greater than 1 km, which would require the use of a maxi-HDD rig installation to complete. Maxi-HDD rigs generally weigh around 40 metric tons, which far exceeds the maximum lift capacity of available helicopters. As such, the proposed conduit trenchless installation would require a suitable access road that can accommodate a semi-trailer truck with a flatbed to the entry location. Since this is not possible, this constraint generally precludes the use of trenchless means for installing a gravity fed conduit to drain the ice-marginal lake. Note that in addition to the access road, there would also need to be sufficient working area at both the entry and exit to support the installation, approximately 100 m x 50 m working area. Additionally, as the glacier recedes the location of the ice-marginal lake may also move – this may result in conduit becoming perched above the ice-marginal lake and no longer being effective. For these reasons this option has therefore not been evaluated further.

### 4.2.7 Option 4 – Construct Dam at Outlet of the Cirque Lake

Option 4 involves constructing a permanent dam at the outlet of the cirque lake. NRCAN's research indicated that the 2024 ice-marginal lake contained 1,200,000 $m^3$ of water—during the 2024 Outburst Event this volume of water was drained within approximately 16 hours. The topography of the depression where the cirque lake is located has sufficient volume to impound this volume of water if a dam were constructed at the outlet of the lake. Based on the topography and the 2024 Outburst Event hydrograph the required dam height may be upwards of 7 m. Detailed hydraulic modelling would be required to refine this value and for design purposes. The dam could potentially be comprised of gabion baskets (i.e., rectangular wire baskets filled with rocks) and this would allow for seasonal flow to be conveyed through the voids of the structure while impounding outburst flows. The dam structure would need to incorporate a sufficiently sized weir opening to limit downstream flows to no greater than the 2025 Outburst Event flow. A spillway structure would also be required to convey weir flow away from the structure. It is assumed that the foundation of the dam would be bedrock; however, detailed assessment of the foundation material would be required for design purposes. If gabion baskets are not feasible due to the height and associated weight of the dam; concrete blocks or cast-in-place concrete could be alternatives; however, they would need to include a pipe outlet to convey seasonal flows and may not be feasible depending on the foundation, cost, and maintenance requirements. Figure 4-4 presents the general concept of Option 4.

#### Engineering and Environmental Considerations

Design and implementation of this option must comply with the BC Dam Safety Regulation (DSR) (B.C. Reg. 40/2016). The DSR outlines requirements related to dam classification, design, construction, operation, and maintenance. Dams exceeding low consequence classification are subject to stringent provision, including preparation, review, and update of an Operations, Maintenance, and Surveillance (OMS) manual; preparation of a Dam Emergency Plan; and periodic Dam Safety Reviews by a qualified professional. Minor dams that are less than 7.5 m high and impound less than 10,000 $m^3$ of water are exempt from the regulation. Additionally, operation of the dam and safety reviews should adhere to EGBC guidelines for *Legislated Dam Safety Reviews in BC* and CDA *Dam Safety Guidelines.*

To develop the design of the dam, detailed geotechnical studies would be required to assess the proposed foundation which may require drilling of boreholes. Depending on the depth of the cirque lake, a computational fluid dynamics (CFD) hydraulic model may be required to assess the wave hydraulics propagated by the outburst flow and what forces they would apply to a dam structure. At minimum, a three-dimensional (3D) hydraulic model would be required to assess riverine hydraulics associated with an GLOF at the proposed structure. These forces and hydraulics (velocity and depth) would govern the design of the dam structure, specifically what mass would be required to resist the outburst flow forces and what the associated dimensions of the dam (i.e., crest elevation, bottom width, top width) would be. Results from the hydraulic modelling would also be required to design the weir opening through the dam that would be sized to regulate flow through the dam structure to no greater than the 2025 Outburst Event. Development of a dam option would need to follow the requirements of the DMA discussed above. Designing and permitting a dam requires years to complete and could not be ready in time for the anticipated 2026 Outburst Event.

As a dam would be a permanent structure within the active watercourse, rigorous environmental permitting would be required. At minimum the following environmental permits may be required:

- Federal Level:
  - Fisheries Act Authorization (FAA).
  - Request for Review (RfR).
- Provincial Level:
  - Lands Act – License of Occupation
  - Wildlife Act.
  - Water Sustainability Act – Section 11 Change Approval.
  - Forest and Range Practices Act.

The Place Glacier provides a year-round source of cold water that spawning fish rely upon in downstream watercourses. Once the Place Glacier disappears, this source of cold water through the summer and early fall months would be impacted. Construction of a dam would help impound greater volumes of cold water within the cirque lake which would help to offset the potential loss of cold water during the summer months once the glacier is gone.

## Construction Feasibility

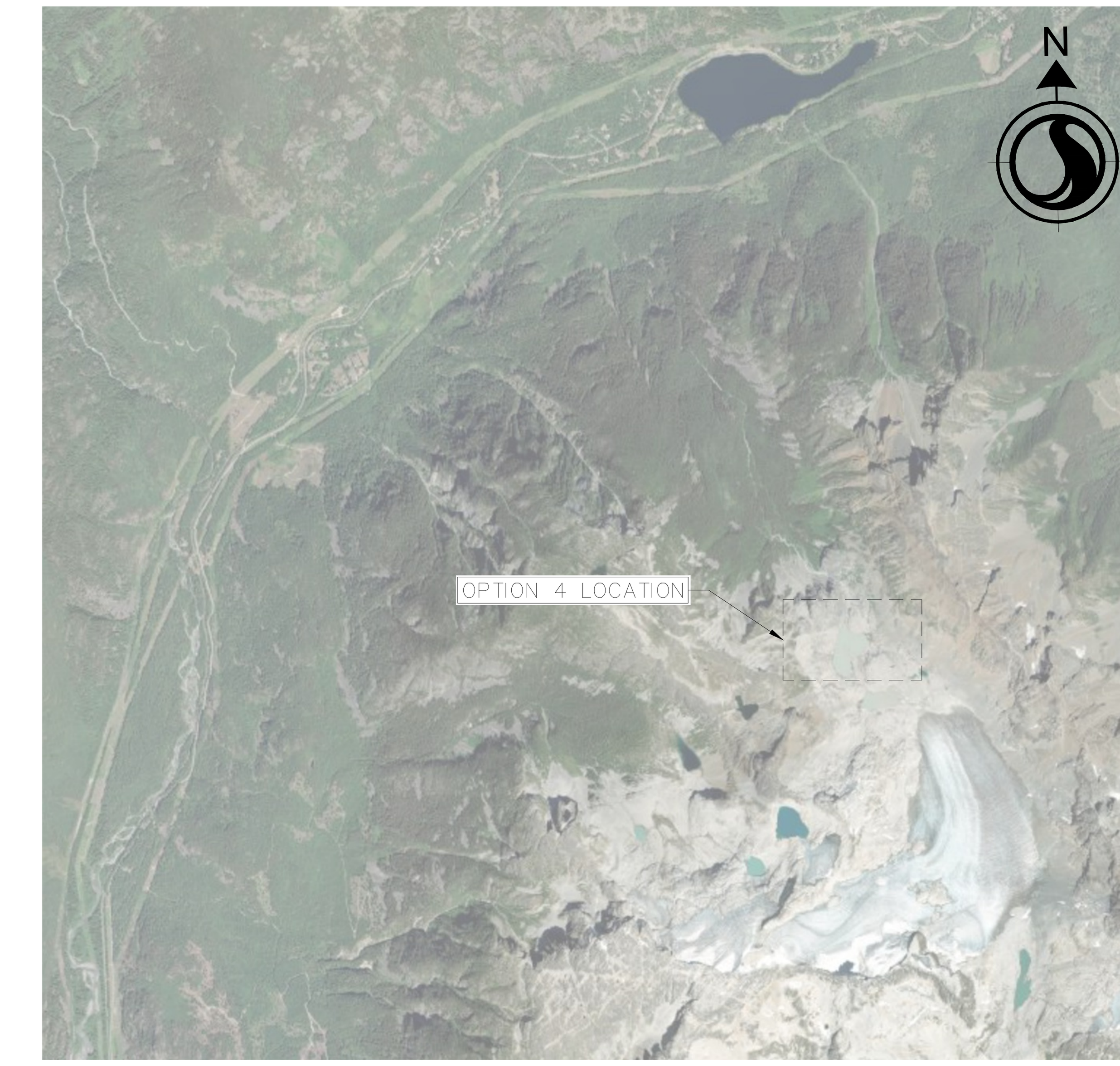
Construction of the dam will pose significant environmental and economic challenges. As the cirque lake is not accessible by land-based vehicles, all construction equipment and materials would need to be transported via. helicopter. This would only allow for mini excavators to access the proposed dam location which may make construction of any dam not feasible. If the foundation improvements are required, this would be time-intensive and costly due to the limited size of machinery that could access the site. If suitable rock to fill the gabion baskets is available at the lower cirque lake this would help mitigate these challenges.

## OPC Consideration

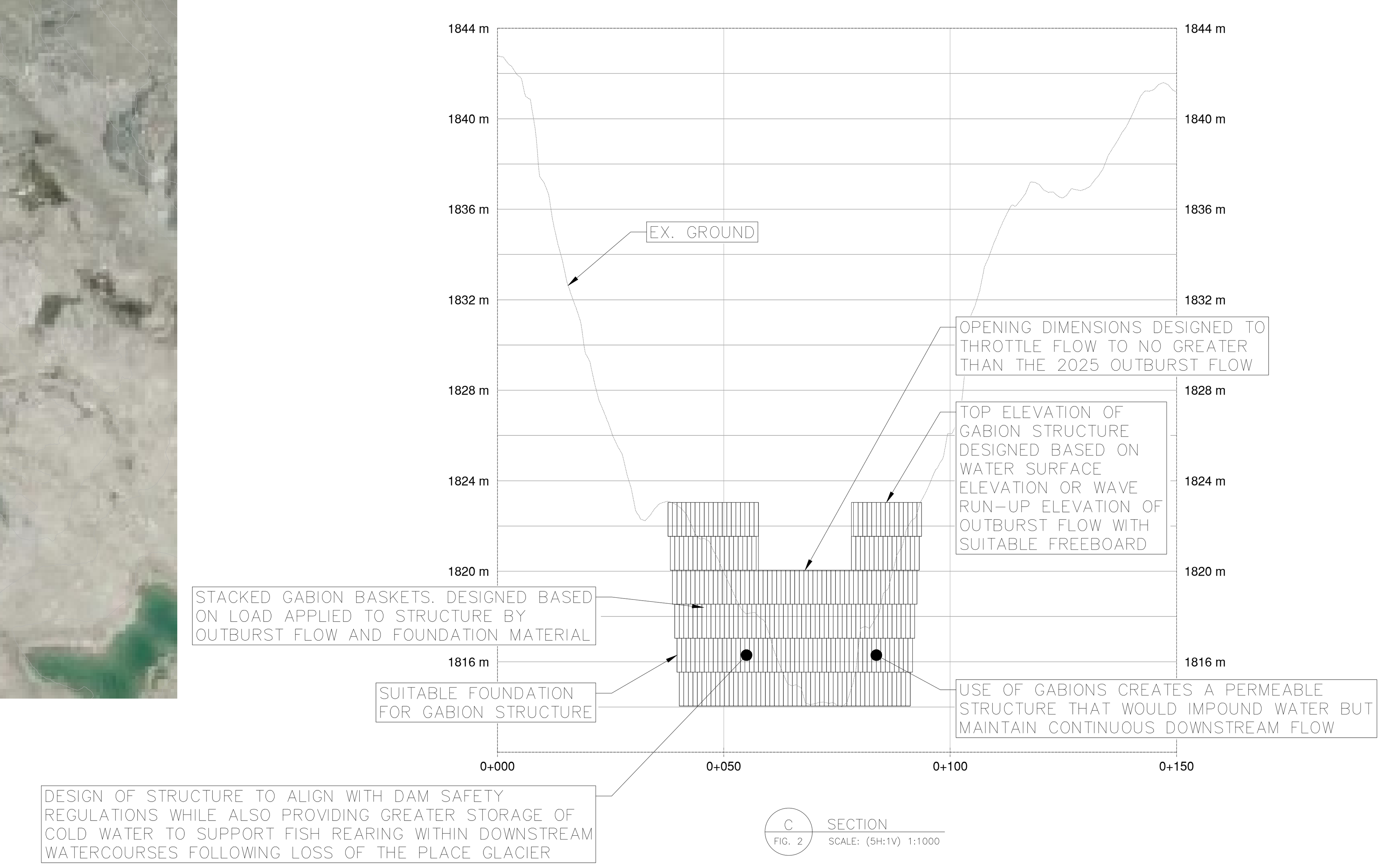
Due to the limitations with helicopter lift capacity and the reliance upon helicopters to supply all of the equipment and materials to the proposed dam site the construction cost for Option 4 is prohibitive. For 2026, the OPC for designing, permitting, and constructing (including environmental supervision and engineering quality assurance) Option 4 is $51,342,000. Long term operation and maintenance costs and required dam safety operational assessments would be depending on the dam classification and frequency/magnitude of GLOFs but may be on the order of $100,000 per year over the design life of the structure. Decommissioning of the structure would be required at the end of its design life – the cost associated with this is dependent on future construction rates which cannot be determined at this time. Assuming a structure design life of 50 years the total OPC for Option 4 would be on the order of $56,342,000. It is assumed that nominal repairs to the 2024 emergency response works would be required with this option and therefore an annual cost to repair these works has not been carried in the OPC.

## Operation and Maintenance Consideration

Operation and maintenance requirements will be dependent on the ultimate dam design and classification. Frequency and requirement of safety reviews would also be dependent on the dam design and classification. Magnitude and frequency of repairs to the structure would be dependent on the frequency and magnitude of the GLOFs. SLRD would be responsible for administrating operation and maintenance of the dam and would bear the cost associated with this. It is assumed that nominal repairs to the 2024 emergency response works would be required with this option.


PROJECT KEY MAP

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3. CONTOURS DISPLAYED @ INTERVALS OF 5m.
4. CONTOURS BASED ON LiDAR COLLECTED ON 08/02/2024.

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Client/Project
SQUAMISH-LILLOOET REGIONAL DISTRICT PLACE GLACIER CONCEPTUAL DESIGNS

Project No.
111700836

Title
OPTION 4 CONSTRUCT DAM AT OUTLET OF LOWER CIRQUE LAKE

| Revision | Date |
| --- | --- |
| 0 | DEC/03/2025 |
| SCALE | Figure No. |
| 1:2000 | 2 |

Figure 4-4. Option 4 Conceptual Figure

### 4.2.8 Option 5 – Repair the 2024 Emergency Response Works and Use Explosives to Fracture Open Conduit

Hydraulic modelling of the 2024 Outburst Event indicates that flood hazard levels posed to the public and structures are similar in magnitude to those from the 2025 Outburst Event along the majority of the Project extents. The community upstream of the Poole Creek Rd culvert crossing is exposed to large areas with a flood hazard rating of H3 – "unsafe for vehicles, children and the elderly" and areas of hazard rating H4 – "unsafe for people and vehicles" while the area immediately upstream of the culvert is exposed to flood hazard rating of H5 – "vulnerable to structural damage". During the 2024 Outburst Event the severity of the hazard rating does not increase; however, larger area are exposed to these higher hazard ratings with more structures within the H5 bounds.

Option 5 provides a hybrid approach to mitigating the glacial outburst flood hazard to the communities within the Project scope. The first element would be repairing 2024 emergency response works that were damaged due to the 2025 Outburst Event – discussion on this is presented in Section 4.2.3. It is assumed that this approach would require yearly maintenance to repair lengths of the 2024 emergency response works that sustain damage from ongoing GLOFs; however, it is constructible prior to the anticipated 2026 Outburst Event and ultimately would provide similar flood hazard mitigation as the other options at a more feasible cost.

To further mitigate the flood hazard from GLOFs, Option 5 would include using explosives to fracture open a conduit within the glacier where the ice-marginal lake forms. Controlled blasting could modify the seasonal snow cover, firn, or surface glacial ice to change meltwater retention or redirect flow into more optimal and stable pathways. Strategic charges may also assist in initiating drainage by compromising key hydrologic divides before uncontrolled failure occurs. In addition, explosives could be used to remove ice blocks or debris that impede outflow or contribute to damming within the lake or channel system.

#### Explosive Feasibility

Explosive energy attenuates very differently across seasonal snow cover, firn, and glacial ice because of their contrasting densities and pore structures. The explosives typically used in avalanche control work have varying velocities of detonation (VOD). Higher-velocity cast boosters deliver strong shock fronts that are effectively coupled into firn and glacial ice, while ammonium nitrate fuel oil (ANFO) though reliable and cost-effective, has a lower detonation velocity and may couple less effectively unless well confined or placed directly against dense ice.

Other high velocity waterproof explosive types - such as emulsion cartridge with waterproof detonators could be used for operations under the lake water to displace the blockage or encourage early melt season flow pathways. Drilling directly into the glacial ice to position waterproof explosives at or near suspected flow pathway blockages could be an option to confine and impart blast energy into the ice structure.

The effectiveness of explosives in modifying drainage pathways depends on how well energy is transmitted into the specific medium:

The seasonal snow cover is low-density and highly porous, absorbing most shock energy through compaction of air spaces. Leading mainly to surface cratering and localized compaction, localized “craters” several meters wide (depending on charge size) are often observed after the explosives are deployed over seasonal snow cover. This means the potential value for using explosives on the seasonal snow cover is to create a series of craters that would induce a drainage flow pathway. Reconnaissance missions would identify viable targets where the seasonal snow cover is preventing drainage which are more likely to occur early in the melt season (May–early July). ANFO is the recommended explosive type for this strategy.

Firn is denser, partially sintered snow that transmits energy better but still dissipates a meaningful portion of the blast. Charges can create shallow melt channels, voids, or fractures that may help direct meltwater or initiate small drainage features. Cast boosters provide better penetration and fracturing than ANFO, which disperses more energy through remaining pore space.

Glacial ice is dense, elastic, with low porosity, allowing shock waves to propagate more efficiently with limited attenuation. However, the higher density of the ice resists the initial blast wave more than for snow, unless the blast energy is confined or directed into the ice. Glacial ice has the potential to be the most responsive medium for drainage-related blasting due to the potential for fracture, however this requires that the blast energy be confined and directed into the ice structure. Both emulsion cartridges and cast boosters can generate radial fractures, controlled breaching, or structural weakening that may initiate or accelerate lake outflow. Cast boosters are especially effective for precise ice cleavage or opening thin ice dams near hydrologic divides. Energy propagation in ice allows for targeted modification of the lake boundary, potential outlet points, or shallow sub-ice channels.

Due to limited research on mitigative options for glacial outbursts, it is unknown how effective explosives will be with opening a conduit and ultimately regulating ice-marginal lake depths. To assess the feasibility of this approach an initial field program is proposed as a two-day operation with one additional contingency day to accommodate weather or access limitations. The proposed timing for these operations is early May which would allow for further explosive work to be implemented prior to the anticipated 2026 Outburst Event if results prove this approach is effective.

Day 1 – Aerial Reconnaissance and Target Identification

A helicopter-supported site visit will be completed to assess current glacier conditions, verify safe landing and travel zones, and identify potential explosive targets. The crew will collect spatial data, document ice thickness and surface features, and refine candidate locations for test charges.

Day 2 – Test Charge Deployment and Post-Blast Assessment.

Field charges will be deployed at the selected locations using approved priming, lighting, and deployment procedures. Following detonation, the team will conduct visual and instrumented observations to document blast effectiveness, ice response, and any resulting drainage pathways or structural changes.

Day 3 – Contingency

A third day is reserved for weather delays, access challenges, repeat testing if required, or post-blast investigation.

It is recommended that a robust emergency preparedness plan be established and followed as part of Option 5. See Section 5 for discussion on emergency preparedness.

### Engineering and Environmental Considerations

The majority of the engineering work required to develop a detailed design for Option 5 has already been completed as part of 2024 emergency response works and studies completed in 2025. Detailed design drawings would be developed along with a design basis memo to support permitting and funding applications.

Minor in-stream works would be required along a non-fish bearing reach of Place Creek; therefore, the environmental permit requirements would be limited—for planning purposes it is assumed that a notification to the Ministry of Water, Land, and Resource Stewardship (WLRS) under Section 11 of the Water Sustainability Act would be required. A request for a review from the Department of Fisheries and Oceans (DFO) under the Fisheries Act may also be required along. Construction would need to comply with Migratory Birds Convention Act (MBCA) and the Migratory Birds Regulations and an Occupant Licence to Cut (OLTC) may be required depending on site conditions at the time of construction.

As part of the ongoing Project work SLRD and Stantec have worked closely with the Lílwat Nation and N'Quatqua Nation; however, formal consultation would be required as part of the environment permitting process.

Table 4-2 presents relevant regulatory, safety and operational constraints for any Place Glacier operational explosives work.

*Table 4-2. Explosives related regulatory, safety and operational constraints.*

| Category | Requirements / Description |
|---|---|
| Regulatory Framework | • Compliance with federal Transportation of Dangerous Goods (TDG) regulations.<br>• Adherence to Natural Resources Canada – Explosives Regulation Division (ERD) requirements.<br>• Provincial compliance with WorkSafeBC and WCB occupational safety rules. |
| Emergency Plans & Documentation | • • Emergency Response Assistance Plan (ERAP) governs explosive-transport incidents.<br>• Activation steps, mandatory notifications, isolation zones.<br>• Roles for ERAP Coordinator, Technical Advisors, and response teams.<br>• Aligns with TDG Part 7.<br>• Procedures for spill response, damaged-package recovery, public-safety coordination, and post-incident reporting. |
| Personnel Training & Certification | • Required certifications: TDG, WCB Certified Blaster, TDG by Air (helicopter operations), WHMIS.<br>• Training on explosives contractor’s internal explosive-handling procedures. |
| Explosive Handling Procedures | • Controlled work areas and ignition-source exclusion zones.<br>• Mandatory PPE and clear communication during priming and lighting.<br>• Safe-handling practices per the Explosive Use Operational Plan. |

| Category | Requirements / Description |
|---|---|
| Transport Requirements | • Compliant vehicles, secure packaging, and controlled loading areas.<br>• Transport route planning.<br>• Documented inventories and chain-of-custody procedures. |
| Storage Requirements | • Explosives signed into certified and approved magazine.<br>• Continuous monitoring or deployment in approved operations. |
| Emergency Preparedness | • • First-aid capacity.<br>• Reliable communication systems.<br>• Readily deployable emergency-response equipment. |

## Construction Feasibility

As part of the 2024 emergency response works an access road was constructed along the associated reach of Place Creek. This access road was decommissioned following completion of the 2024 emergency response works by scattering large tree trunks along the crest of the road. To complete the non-explosives portion of Option 5 this access road would be re-established by clearing the previously placed large tree trunks and re-grading the surface as required to allow heavy equipment to access the portion of the 2024 emergency response works that require repair. It is anticipated that additional riprap required to repair the 2024 emergency response works can be sourced locally; however, if insufficient material is present this can be sourced from the Pemberton Concrete pit or a local pit operated by Lil̓wat Nation. Based on 2024 emergency response construction completion timelines it is assumed that these repairs would require three to four weeks to complete.

For completing the explosives portion of Option 5 a helicopter would be required to transport the explosives contractors' team and their equipment to site. It is likely that a small ice-coring drill would be required to position the explosive charges in place. It is assumed that two site trips, each three days in length, would be required to complete this work. The first trip would be the feasibility study discussed in the previous section, occurring in early May, while the second trip would be to implement the "design" explosive charges.

Of the options presented in this report, Options 5 is the simplest to construct.

## OPC Consideration

When considering both immediate and long-term operation and maintenance costs, the OPC for Option 5 is the lowest of all the options presented in this report as there is minimal reliance on helicopters. Rates and overall costs associated with repairing the 2024 emergency response works are well established, and the explosive related rates are well defined based on the explosive contractor's wealth of local experience.

For 2026 the OPC for engineering design, environmental permitting, and construction would be $481,350. It is assumed that the 2024 emergency response works are likely to sustain some damage in response to repeated, annual, GLOFs; therefore, Option 5 would likely have to be repeated on an annual basis. The number of years which the ice-marginal lake will pose a flood hazard is unknown and highly dependant on yearly climate and glacial melt trends; however, if we assume the mitigation would be required for a period of 8 years the total cost would be $3,676,650. This total cost is based on the conservative assumption that the annual cost to repair the channel in response to outburst events will be the same as the 2026 cost (i.e. $481,350); however it is anticipated that the explosives approach will significantly reduce, and potentially eliminate, the annual channel maintenance costs for 2027 and beyond. The total cost should be re-assessed once the effectiveness of the explosives approach has been evaluated following implementation in 2026.

Of the options presented in this report, Option 5 is the most cost effective.

### Operation and Maintenance Consideration

As discussed above, the size of riprap that would be required to remain stable during an GLOF with the same flow magnitude as the 2024 Outburst Event would be infeasible to source and place. It is also unknown what the magnitude of future GLOFs will be. For this reason, it has been proposed to take a similar approach to repairing the 2024 emergency response works as what was done for initially constructing them, i.e., source the largest riprap from within the locally deposited debris flood material and use that for the repairs. This may become depleted if extensive repairs are required on an annual basis – in this case MOTT Class 500-kg or 1000-kg (if available) could be sourced to supplement locally sourced material. For these reasons it is anticipated that annual repairs to the 2024 emergency response works would be required while the outburst hazard exists. As the explosives work doesn't require any permanent or temporary structures, there would be no maintenance works required; however, the two site visits and associated explosive activities would be required on the same annual schedule as the downstream repair works. It is also recommended that the LiDAR of Place Creek and Poole Creek be collected annually following the GLOF and an annual inspection be conducted by a qualified engineering professional to assess ongoing hazards posed to the communities within the Project scope.

## 4.3 Design Options Matrix

To evaluate the feasibility and suitability of the conceptual design options, each option was reviewed with input from hydrotechnical, geotechnical, structural, and process engineering disciplines to ensure that key design considerations such as site accessibility, long-term sustainability, regulatory constraints, and environmental sensitivity were thoroughly examined. Options 1 and 3 were excluded because both were deemed technically infeasible during the preliminary assessment. The matrix below summarizes the advantages and limitations of each feasible option, providing a comparative overview to support decision-making and prioritization of future works.

Option 2 provides a flexible means of mitigating the flood hazard posed by GLOFs; however, the cost (both initial construction, maintenance, and subsequent years of use) is high, requires heavy reliance on helicopters, and operational requirements to run 36 pumps and 17 generators over several months makes this option not feasible. Option 4 would provide long-term mitigation and potential environmental benefits; however, is technically complicated to design and maintain, cost prohibitive, and would require several years to permit and construct (i.e., outburst flood hazard would remain until approximately 2029).

Based on the considerations detailed in the sections above and within the design option matrix, Stantec recommends that Option 5 be progressed to detailed design and implementation prior to the anticipated 2026 Outburst Event along with the emergency preparedness procedures detailed in Section 5.

Replacement of the Poole Creek Road culvert would also reduce flood hazards to properties located upstream; however, the potential transfer of risk to downstream infrastructure (Pemberton Portage Road and railway bridges) would need to be assessed and accounted for in any replacement design.

| | Environmental and Engineering | | Economical | | Social | | Construction and Maintenance | |
|---|---|---|---|---|---|---|---|---|
| | **Pros** | **Cons** | **Pros** | **Cons** | **Pros** | **Cons** | **Pros** | **Cons** |
| **Option 2 – Install Pumps in Ice-Marginal Lake** | No permanent structures; minimal disturbance to glaciers or downstream habitat.<br><br>No need for decommissioning of the structure.<br><br>The lake that forms Place Creek headwaters is non-fish bearing.<br><br>Limited environmental permits required.<br><br>Limited engineering design required. | High diesel consumption for generators risking fuel spills and increasing greenhouse gas emissions.<br><br>Requires helicopter access for installation and fuel.<br><br>Need to confirm impacts to environmental flow needs/water levels in Place Creek. | Costs incurred only during glacier melt season. Can be determined on year-by-year basis.<br><br>Minimal operation and maintenance outside of annual maintenance to generators and pumps. | High costs are expected for helicopter mobilization and maintenance.<br><br>Limited by weight of generators. Cannot install one large pump due to weight of suitable generator. | Work is only required during glacier melt season.<br><br>No permanent structure, and no access required through private properties for construction and maintenance. | Public concern over emissions, reliance on helicopters, and working near the glacier. | No permanent structures.<br><br>Only required to be installed during glacier melt season. | Requires 36 pumps and 17 generators to meet water removal efficiency.<br><br>Pumps and generators will require yearly maintenance and storage area. Increased administration cost for SLRD. |
| **Option 4 – Construct Dam at Outlet of Cirque Lake** | Very likely to be effective at controlling flow. Future use for storing spring runoff and controlling summer flows.<br><br>Provides a year-round source of cold water and has the potential to provide cold water during future summer months once the glacier disappears. | Geotechnical analysis and construction are disruptive to the local environment.<br><br>Heavy reliance on helicopters for construction and decommissioning work once at the end of life.<br><br>Rigorous regulatory oversight by government.<br><br>Detailed and time intensive engineering assessment, design, and permitting requirements. Ongoing dam safety | Long-term solution that can also provide future water resources benefits. | Expected to be the highest cost option to construct and has a requirement to be maintained and decommissioned at the end of life.<br><br>If foundation improvements are required, it would be time-intensive and costly due to the limited size of machinery that could access the site. | Very likely to be effective at controlling flow.<br><br>Water resources benefit for fish habitat downstream. | Requires long-term management and maintenance in accordance with dam safety guidelines.<br><br>Concerns on disruption to the local environment.<br><br>Requires time to build before being put into effect.<br><br>Having a dam perched at high elevation in a known flood hazard area immediately above single family homes poses a safety concern. | Very likely to be effective at controlling flow.<br><br>High initial construction cost with lower annual operation and maintenance costs | Regulatory requirements including studies, design and approvals will take time. Estimate three years before implementation.<br><br>Proposed location of dam can only be accessed via. helicopter. Due to limited lift capacity of helicopters at high elevation, construction would need to rely on mini excavators that would greatly increase the construction time and cost. All |

| | Environmental and Engineering | | Economical | | Social | | Construction and Maintenance | |
|---|---|---|---|---|---|---|---|---|
| | **Pros** | **Cons** | **Pros** | **Cons** | **Pros** | **Cons** | **Pros** | **Cons** |
| | | assessment required over the dam design life. | | | | | | equipment and materials would also need to be delivered to site via. helicopter. |
| **Option 5 – Repair the 2024 Emergency Response Works and Use Explosives to Fracture Open Conduit** | Stabilize instream conditions within Place Creek.<br><br>Limited environmental permits required.<br><br>No permanent structures.<br><br>Majority of the engineering work required to develop a detailed design has already been completed as part of 2024 emergency response works and studies completed in 2025. | Construction and explosives are disruptive to the local environment.<br><br>Annual repairs are most likely required due to high velocity from GLOFs.<br><br>Efficacy of explosives to mitigate potential for the ice-marginal lake to form is unknown and would require some research and testing. | Expected to be the lowest cost.<br><br>Majority of the engineering work required to develop a detailed design has already been completed as part of 2024 emergency response works and studies completed in 2025.<br><br>Explosives work doesn't require any permanent or temporary structures so there would be no maintenance work required. | It is assumed that the emergency response works are likely to sustain damage in response to repeated, annual, GLOFs; therefore, repairs would likely have to be repeated on an annual basis.<br><br>Site visits and associated explosive activities would be required on the same annual schedule as the downstream repair works.<br><br>It is also recommended that LiDAR of Place and Poole Creek be collected annually following the GLOF and an annual inspection be conducted by a qualified engineering professional to assess ongoing hazards posed to the communities within the Project scope. | Rapid implementation before 2026 outburst.<br><br>Existing 2024 emergency response works have provided protection from the 2025 Outburst Event. | Aesthetics, public or Indigenous concerns on environmental impacts of use of explosives.<br><br>It is assumed that the emergency response works are likely to sustain damage in response to repeated, annual, GLOFs; therefore, repairs would likely have to be repeated on an annual basis.<br><br>Efficacy of explosives to mitigate potential for the ice-marginal lake to form is unknown and would require some research and testing. Public may potentially be exposed to a higher flood risk than other options due to this uncertainty. | Site access already exists to the 2024 emergency response works. It would be simple to reactivate the road and only require 3 to 4 weeks to complete the work.<br><br>Explosives work doesn't require any permanent or temporary structures so there would be no maintenance work required. | Extreme velocity events can still damage riprap protection. |

# 5 Emergency Preparedness

Given the annual occurrence of the GLOF, a proactive emergency preparedness plan is crucial to reduce risk to life, property, and infrastructure. As summarized in Section 3.3.2 the hazard classifications H3 (unsafe for vehicles, children, and elderly), H4 (unsafe for people and vehicles), and H5 (vulnerable to structural damage) were observed to impact communities directly upstream of the Poole Creek Road culvert crossing, under an GLOF. Hydraulic modelling indicates that during GLOFs greater than the 2025 Outburst Event it is anticipated that the Poole Creek Road culvert will surcharge, and flow will overtop the road for upwards of 12 hours. During this period, properties northeast of the crossing would be cut-off and inaccessible to emergency response services. Properties upstream of this location that rely on small access bridges or culvert crossings constructed and maintained by the property owner may also experience access limitations should these structures be damaged. Though hydraulic modelling indicates that Pemberton Portage Road bridge and the railway bridge crossing Poole Creek would not be overtopped during an GLOF, the erosion protection structures may be damaged from repeated exposure to these extreme hydraulic events, and the bridge substructure may be more vulnerable and require more maintenance from flood events. These hazards are expected to persist annually until the glacier recedes enough to eliminate the ice-marginal lake.

Stantec's Project team has developed conceptual options to help mitigate the flood hazard associated with annual GLOFs; however, having a monitoring system in place and well-defined emergency preparedness and response planning is crucial for mitigating the flood hazard posed to the public. NRCAN will be installing a real time pressure transducer to monitor water levels within the depression where the ice-marginal lake forms. This pressure transducer will monitor ice-marginal lake levels and allow for SLRD to forecast when certain "threshold" lake levels have been met which trigger emergency response actions.

Based on the visual observations and hydraulic modelling of the 2024 Outburst Event and 2025 Outburst Event, GLOFs propagating from ice marginal lake levels up to 24 m pose a hazard to people and structures; however, with adequate warning and preparation time the hazard would largely be mitigated and evacuation of the area not necessarily required. For GLOFs propagating from ice marginal lake levels greater than 24 m the hazard greatly increases, and emergency evacuation may be necessary, especially for the community upstream of the Poole Creek Road culvert crossing. Based on the studies completed to date and information provided by NRCAN, the following thresholds and emergency alerts shall follow established SLRD protocols:

- Low Hazard – when the ice-marginal lake begins to fill, an emergency alert issued to the impacted community identifying that the lake has begun to fill and that public should monitor SLRD communication services for further direction and alerts.
- Moderate Hazard – when the ice-marginal lake depth reaches 24 m, an emergency evacuation alert is issued to the impacted community identifying that the lake has reached a volume that may pose a hazard to people and structures and be ready to evacuate should an order be issued. The public should monitor SLRD communication services for further direction and alerts.

- High Hazard – when the ice-marginal lake depth reaches 30 m, an emergency evacuation order is issued to the community immediately upstream of the Poole Creek Road culvert crossing. The emergency alert would remain in place for the community further upstream, and the alert would be expanded to capture the properties on the south end of Gates Lake.

Model results indicate that the Pemberton Portage Road and railway bridge are not anticipated to be overtopped during an GLOF of similar magnitude to the 2024 Outburst Event. However, the low chord elevations of these bridges are unknown, and the structural resiliency to extreme hydraulic forces on an annual basis is also unknown. Given the limited alternative access roads to the communities located along Pemberton Portage Road, it is recommended that further assessment of flood hazards to these structures, with respect to GLOFs, be assessed.

# 6 Limitations and Liabilities

The conclusions in the Report titled Place Glacier Hazard Report – Conceptual Design Options Summary are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from the SLRD (the "Client") and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

This Report is intended solely for use by the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

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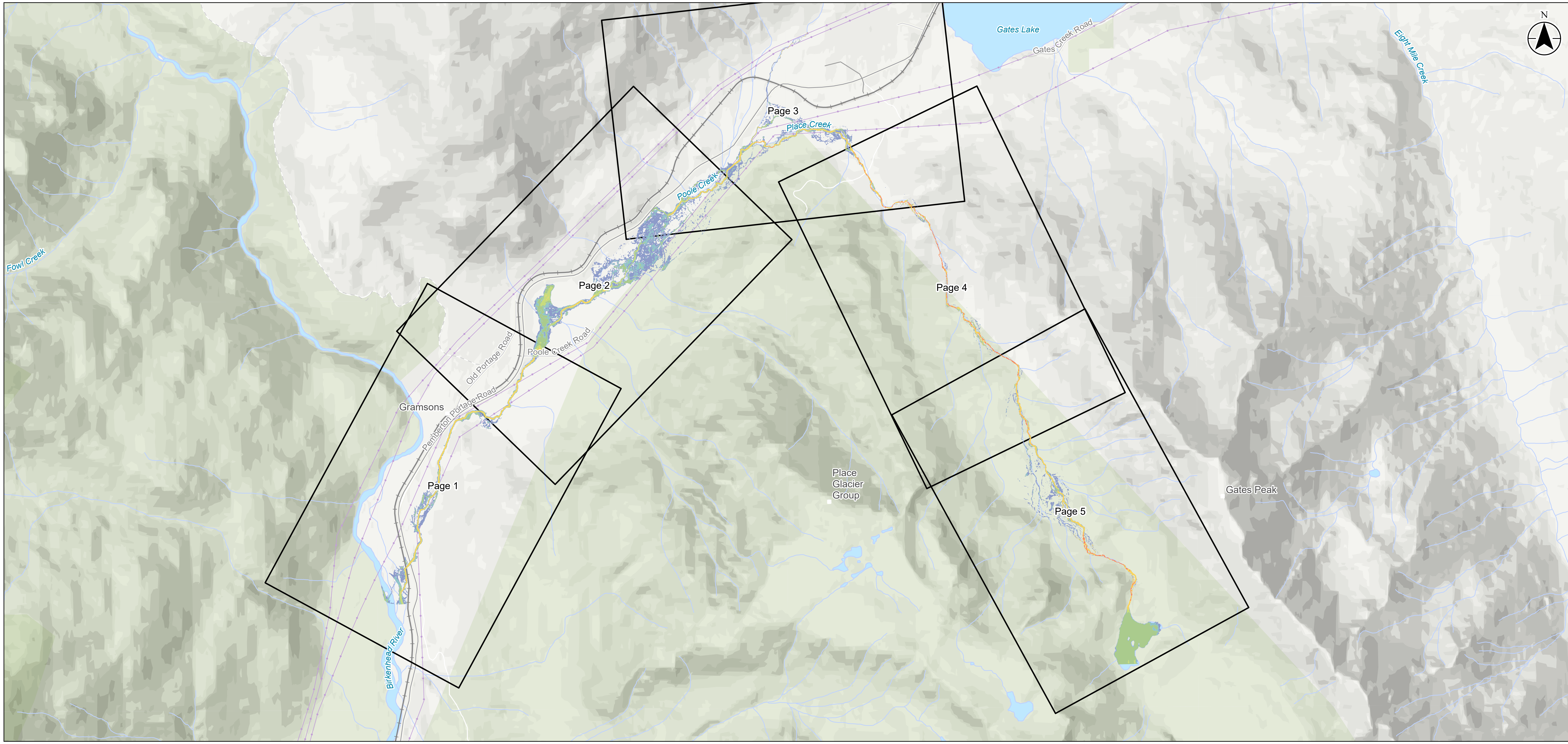
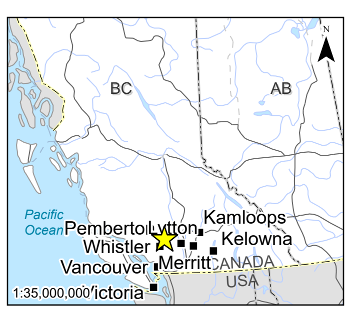
# Appendix A – 2024 Outburst Event Hazard Maps




- Road
- Local Street
- Resource Road
- Railway
- Transmission Line
- Watercourse
- Waterbody

**Hazard Rating**

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure.

THIS FIGURE IS NOT A FLOOD MAP AND IS NOT TO BE USED FOR DESIGN PURPOSES. THE DEBRIS FLOOD AND CLEARWATER FLOOD ASSESSMENT INCLUDED IN THIS STUDY IS NOT INTENDED TO ALIGN WITH EGBC GUIDELINES FOR LEGISLATED FLOOD HAZARD ASSESSMENTS OR FLOOD MAPPING.

0 0.5 1 km
1:30,000 (at original document size of 11x17)

Stantec

Project Location:
Birken, BC

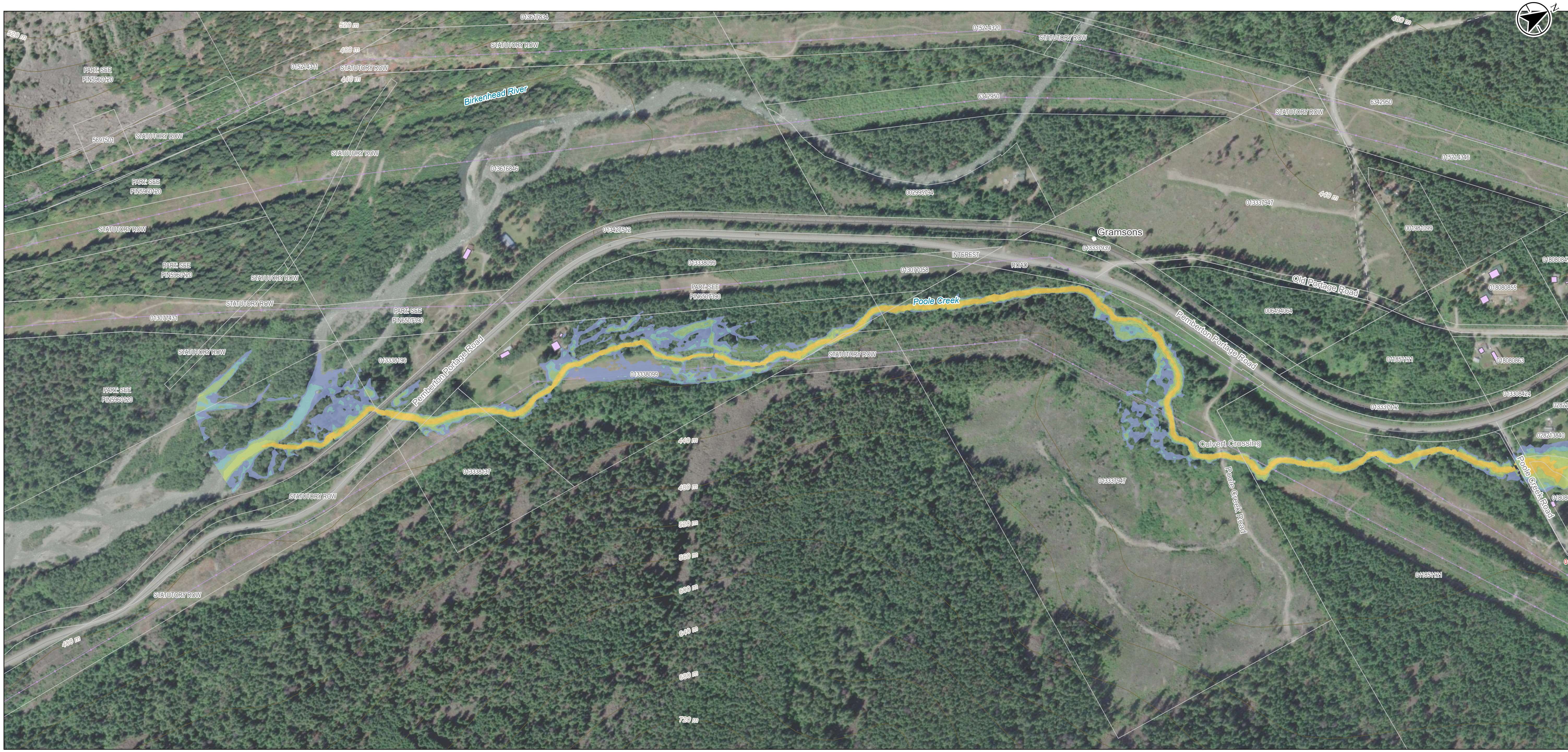
Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 20250911

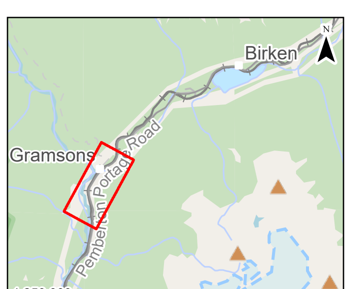
Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No.
**Appendix B**

Title
**2024 Outburst Event Flow Overview**

**Notes:**
1. Coordinate System: NAD 1983 CSRS UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3.World Topographic Map (with Contours and Hillshade) - no water, no labels:




- Road
- Local Street
- Resource Road
- Railway
- Transmission Line
- Topographic Contour
- Building or Structure

**Hazard Rating**

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
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Stantec

Project Location: Birken, BC

Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 2025

Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix B**

Page No. **1 of 5**

Title
**2024 Outburst Event Flow**

**Notes:**
1. Coordinate System: NAD 1983 CSRS UTM Zone 10N
2. Data Sources: DataBC, Government of British Columbia; Natural Resources Canada
3. OpenStreetMap: Map data © OpenStreetMap contributors, Microsoft, Facebook, Google, Esri Community Maps contributors, Map layer by Esri
World_Imagery: Vantor

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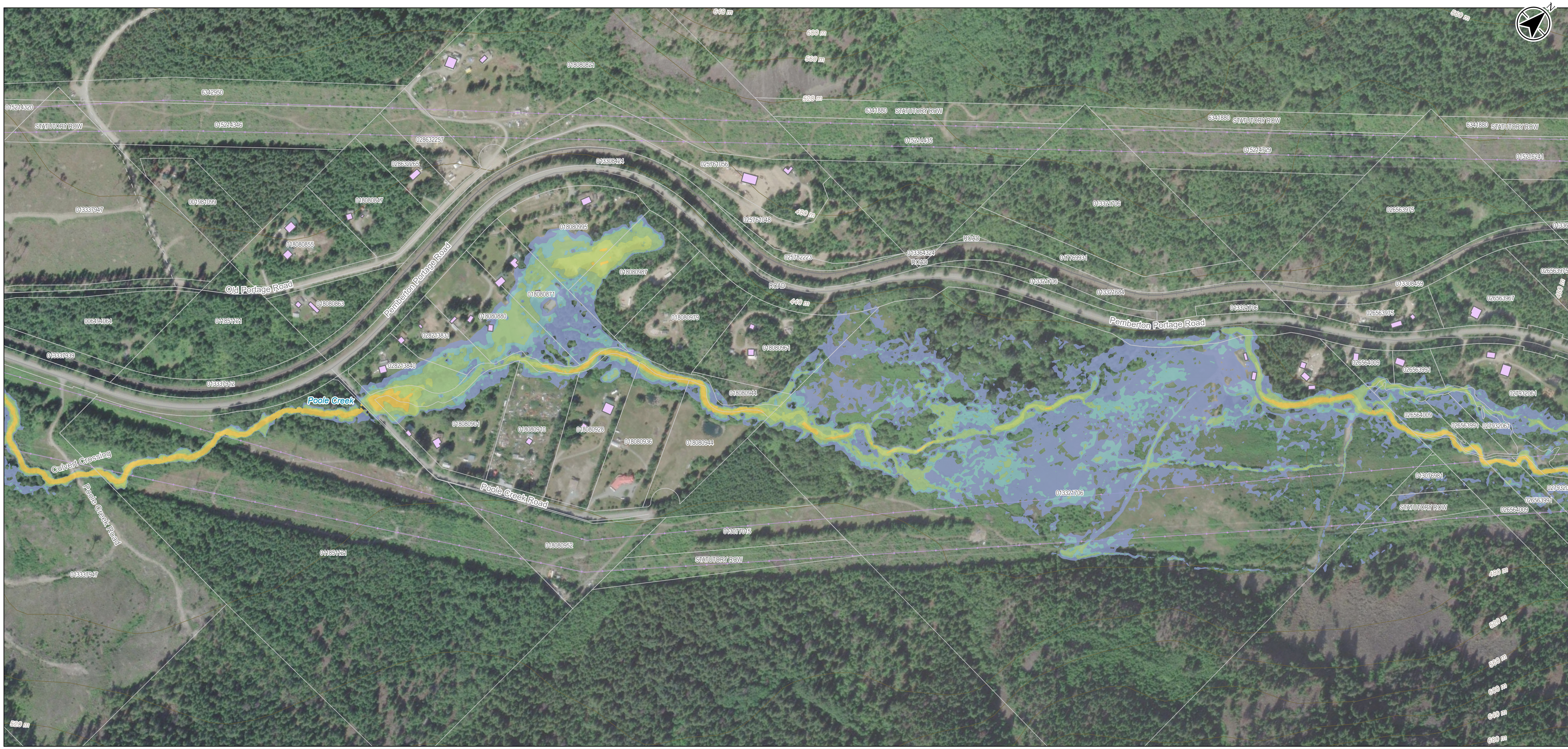


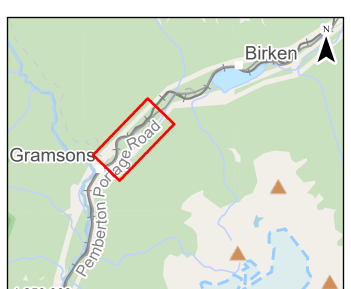


- Road
- Local Street
- Resource Road
- Railway
- Transmission Line
- Topographic Contour
- Building or Structure

**Hazard Rating**

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
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Stantec

Project Location: Birken, BC

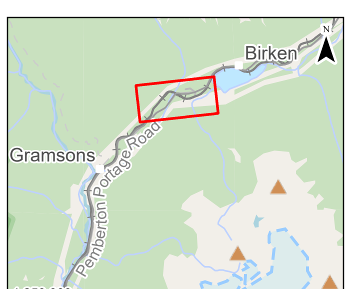
Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 2025

Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix B**

Page No. **2 of 5**

Title
**2024 Outburst Event Flow**


- Road
- Local Street
- Railway
- Transmission Line
- Topographic Contour
- Building or Structure

**Hazard Rating**

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Stantec

Project Location: Birken, BC

Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 2025

Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix B**
Page No. **3 of 5**

Title
**2024 Outburst Event Flow**



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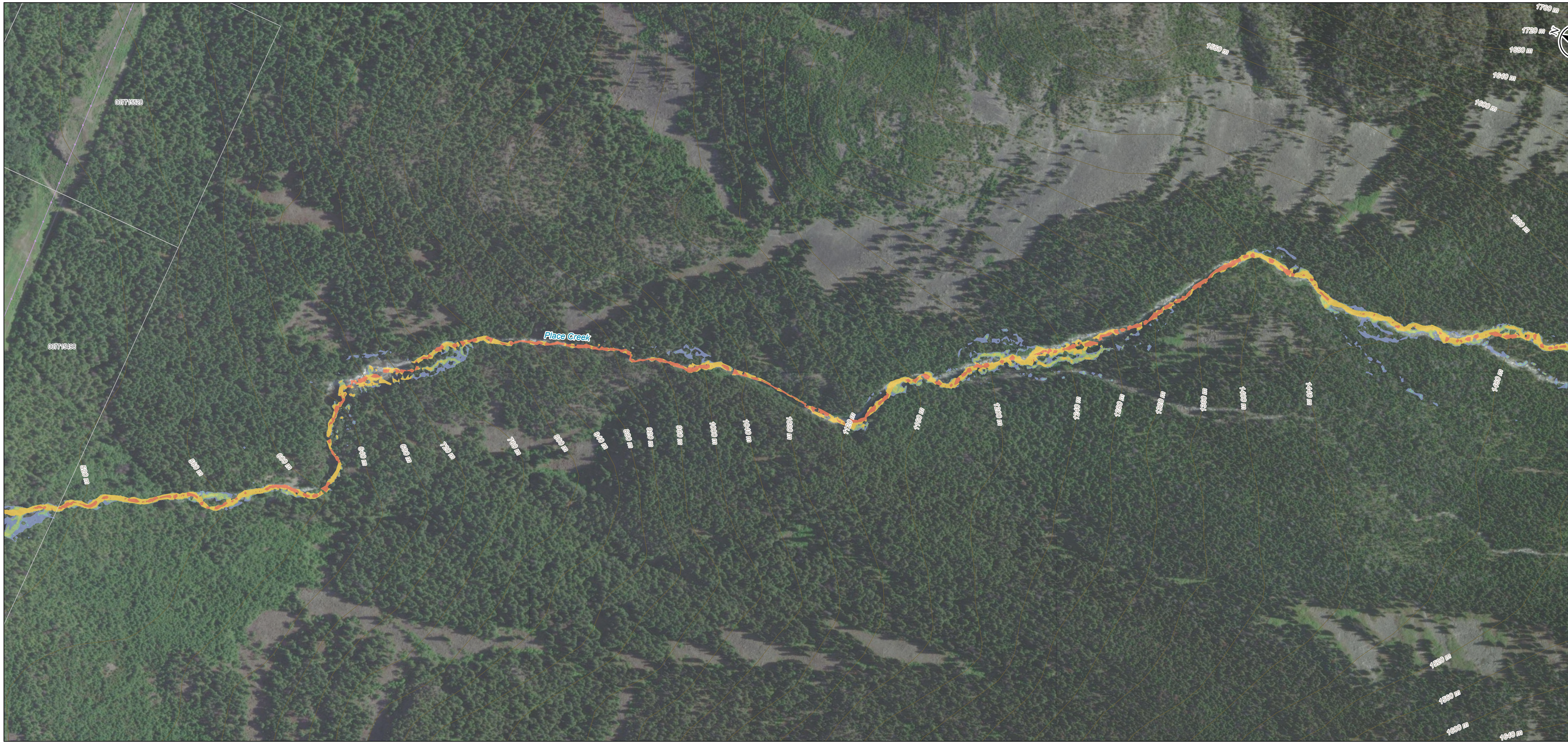


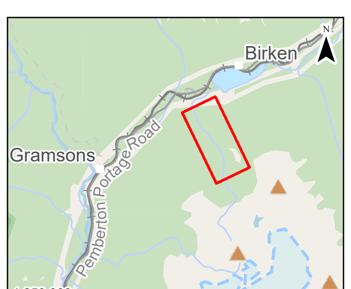


Transmission Line
Topographic Contour
Building or Structure

Hazard Rating

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Stantec

Project Location:
Birken, BC

Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 2025

Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No.
**Appendix B**

Page No.
**4 of 5**

Title
**2024 Outburst Event Flow**

**Notes:**
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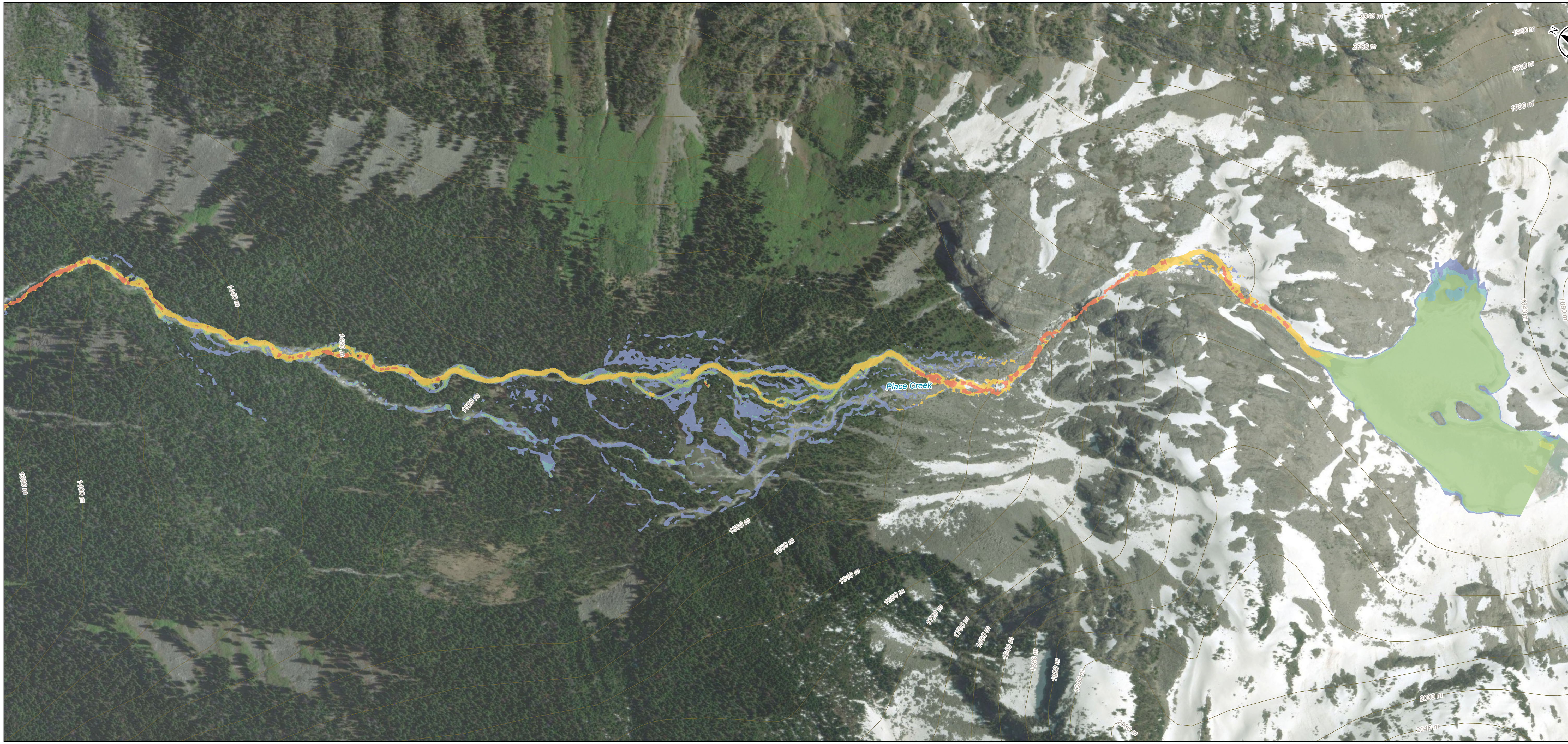
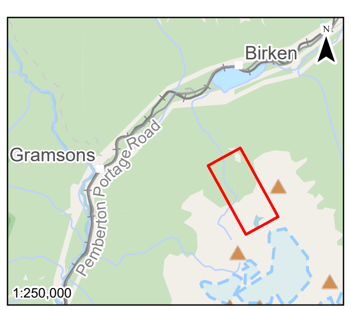
3.OpenStreetMap: Map data © OpenStreetMap contributors, Microsoft, Facebook, Google, Esri Community Maps contributors, Map layer by Esri
World_Imagery: Vantor

\\ca0183-pbagf01\workgroup\1232\projects\111700836\figures\reports\place_creek_hazard_maps\fig_111700836_place_creek_hazard_maps\fig_111700836_place_creek_hazard_maps.aprx Layout: fig_111700836_place_creek_2024_event_hazard_mapbook Map: Main Revised: 2025-12-01 Byjpoucher




Topographic Contour

Building or Structure

Hazard Rating

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World_Imagery: Vantor

Stantec

Project Location:
Birken, BC

Project Number: 111700836
Requested by RPARK 20251127
Prepared by JPOUCHER 20251201
Checked by GVASS 2025

Client/Project/Report
Squamish Lillooet Regional District
2024 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix B**

Page No. **5 of 5**

Title
**2024 Outburst Event Flow**

# Appendix B – Detailed Class D OPCs

# Opinion of Probable Cost Breakdown

SLRD - Place Glacier Conceptual Design Option 2

**Class D Opinion of Probable Cost**

**Schedule of Approximate Quantities and Unit Prices**

Project No: 111700836

Project Name: SLRD - Place Glacier Conceptual Design

**TOTAL CONSTRUCTION AND ENGINEERING AND ENVIRONMENTAL SUPERVISION COST ESTIMATES**

| Item# | Description of Work | Unit of Measure | Approx. Quantity | Unit Price | Extended Amount |
|---|---|---|---|---|---|
| | **PART A - CONSTRUCTION COST ESTIMATE** | | | | |
| **01** | **SECTION 1 - INSTALLATION** | | | | |
| 01.01 | Mobilization, Traffic Control, etc. | L.S. | 1 | $20,000 | $20,000 |
| 01.02 | Helicopter Hours (Taking Equipment Up) | Hour(s) | 94 | $6,700 | $629,800 |
| 01.03 | Helicopter Hours (Installation) | Hour(s) | 16 | $6,700 | $107,200 |
| 01.04 | Helicopter Hours (Diesel) | Hour(s) | 797 | $6,700 | $5,339,900 |
| 01.05 | Helicopter Hours (Removing Equipment) | Hour(s) | 94 | $6,700 | $629,800 |
| 01.06 | Electrical, Control & Instrumentation Cost | Each | 1 | $300,000 | $300,000 |
| | | | | **SubTotal** | **$7,026,700** |
| **02** | **SECTION 2 - MATERIALS** | | | | |
| 02.01 | Pumps 15hp | Each | 36 | $42,000 | $1,512,000 |
| 02.02 | 8" Layflat hose, 210m long | Each | 36 | $13,500 | $486,000 |
| 02.03 | Genset, 30KVa | Each | 17 | $50,000 | $850,000 |
| 02.04 | Diesel Tanks (1000 litre) | Each | 17 | $6,000 | $102,000 |
| 02.05 | Diesel Litres | Litre | 398208 | $2 | $796,416 |
| | | | | **SubTotal** | **$3,746,400** |
| **03** | **SECTION 3 - REPAIR 2024 EMERGENCY WORKS** | | | | |
| 03.01 | Construction for repairing the 2024 emergency works (see Option 5 OPC for detailed breakdown) | L.S. | 1 | $253,500 | $253,500 |
| | | | | **SubTotal** | **$253,500** |
| | | | | **Part A - SubTotal** | **$11,026,600** |
| | **PART B - ENGINEERING AND ENVIRONMENTAL SUPERVISION** | | | | |
| 03.01 | Engineering Design and Environmental Permitting | L.S. | 1 | L.S. | $1,653,990 |
| 03.02 | Environmental Monitoring and Engineering QA During Construction | L.S. | 1 | L.S. | $1,323,192 |
| | | | | **SubTotal** | **$2,977,200** |
| | **PART C - CONTINGENCY** | | | | |
| 04.01 | 50% | | | | **$5,513,300** |
| | **Total Construction Cost (Part A+ Part B + Part C)** | | | | **$19,517,100** |

## Opinion of Probable Cost Breakdown

SLRD - Place Glacier Conceptual Design Option 4

**Class D Opinion of Probable Cost**

**Schedule of Approximate Quantities and Unit Prices**

Project No: 111700836

Project Name: SLRD - Place Glacier Conceptual Design

**TOTAL CONSTRUCTION AND ENGINEERING AND ENVIRONMENTAL SUPERVISION COST ESTIMATES**

| Item# | Description of Work | Unit of Measure | Approx. Quantity | Unit Price | Extended Amount |
|---|---|---|---|---|---|
| | **PART A - CONSTRUCTION COST ESTIMATE** | | | | |
| **01** | **SECTION 1 - INSTALLATION** | | | | |
| 01.01 | Mobilization, Traffic Control, etc. | L.S. | 1 | $20,000 | $20,000 |
| 01.02 | Helicopter Hours (Taking Material and Excavator) | Hour(s) | 4068 | $6,700 | $27,255,600 |
| 01.03 | Helicopter Hours (Removing Excavator) | Hour(s) | 1 | $6,700 | $6,700 |
| 01.04 | Foundation Preparation | L.S. | 1 | $100,000 | $100,000 |
| | | | | **SubTotal** | **$27,382,300** |
| **02** | **SECTION 2 - MATERIALS** | | | | |
| 02.01 | Gabion Baskets | Cubic Metre | 1844.167 | $721 | $1,328,870 |
| 02.02 | Excavator - Class 1 | Hour(s) | 300 | $102 | $30,705 |
| | | | | **SubTotal** | **$1,359,600** |
| **03** | **SECTION 3 - REPAIR 2024 EMERGENCY WORKS** | | | | |
| 03.01 | Construction for repairing the 2024 emergency works (see Option 5 OPC for detailed breakdown) | L.S. | 1 | $253,500 | $253,500 |
| | | | | **SubTotal** | **$253,500** |
| | | | | **Part A - SubTotal** | **$28,995,400** |
| | **PART B - ENGINEERING AND ENVIRONMENTAL SUPERVISION** | | | | |
| 03.01 | Engineering Design and Environmental Permitting | L.S. | 1 | L.S. | $3,479,448 |
| 03.02 | Environmental Monitoring and Engineering QA During Construction | L.S. | 1 | L.S. | $4,349,310 |
| 03.03 | Survey | L.S. | 1 | $20,000.00 | $20,000 |
| | | | | **SubTotal** | **$7,848,800** |
| | **PART C - CONTINGENCY** | | | | |
| 04.01 | 50% | | | | **$14,497,700** |
| | **Total Construction Cost (Part A+ Part B + Part C)** | | | | **$51,341,900** |

# Opinion of Probable Cost Breakdown

SLRD - Place Glacier Conceptual Design Option 5

**Class D Opinion of Probable Cost**

**Schedule of Approximate Quantities and Unit Prices**

Project No: 111700836

Project Name: SLRD - Place Glacier Conceptual Design

**TOTAL CONSTRUCTION AND ENGINEERING AND ENVIRONMENTAL SUPERVISION COST ESTIMATES**

| Item# | Description of Work | Unit of Measure | Approx. Quantity | Unit Price | Extended Amount |
|---|---|---|---|---|---|
| | **PART A - CONSTRUCTION COST ESTIMATE** | | | | |
| **01** | **SECTION 1 - GENERAL** | | | | |
| 01.01 | Mobilization, Traffic Control, etc. | L.S. | 1 | $7,200 | $7,200 |
| 01.02 | Establish Access Route - 1 x 210, 1 x 300 Excavator | Hour(s) | 20 | $565 | $11,300 |
| 01.03 | Labourer | Hour(s) | 20 | $75 | $1,500 |
| | | | | **SubTotal** | **$20,000** |
| **02** | **SECTION 2 - RE-ESTABLISH EMBANKMENT UPSTREAM EROSION SITE** | | | | |
| 02.01 | Excavate, Source, & Place 500 kg Riprap (Riprap sourced from debris flood deposits adjacent to site, cost includes 1 x 210, 1 x 300 Excavator) | Hour(s) | 90 | $565 | $50,850 |
| 02.02 | Labourer | Hour(s) | 90 | $75 | $6,750 |
| | | | | **SubTotal** | **$57,600** |
| **03** | **SECTION 3 - RE-ESTABLISH EMBANKMENT DOWNSTREAM EROSION SITE** | | | | |
| 03.01 | Excavate, Source, & Place 500 kg Riprap (Riprap sourced from debris flood deposits adjacent to site, cost includes 1 x 210, 1 x 300 Excavator) | Hour(s) | 90 | $565 | $50,850 |
| 03.02 | Excavate, Source, & Place Fill (Fill sourced from debris flood deposits adjacent to site, cost includes 1 x 210, 1 x 300 Excavator) | Hour(s) | 90 | $565 | $50,850 |
| 03.03 | Labourer | Hour(s) | 180 | $75 | $13,500 |
| | | | | **SubTotal** | **$115,200** |
| **04** | **SECTION 4 - EXPLOSIVES WORK** | | | | |
| 04.01 | Excavate - 1 x 210, 1 x 300 Excavator | Hour(s) | 20 | $565 | $11,300 |
| 04.02 | Labourer | Hour(s) | 20 | $75 | $1,500 |
| | | | | **SubTotal** | **$12,800** |
| **05** | **SECTION 5 - SITE CLOSURE** | | | | |
| 05.01 | Feasibility Study | L.S. | 1 | $30,328 | $30,328 |
| 05.02 | Implementation of Design Explosives | L.S. | 1 | $30,328 | $30,328 |
| | | | | **SubTotal** | **$60,700** |
| | | | | **Part A - SubTotal** | **$266,300** |
| | **PART B - ENGINEERING AND ENVIRONMENTAL SUPERVISION** | | | | |
| 06.01 | Engineering Design and Environmental Permitting | L.S. | 1 | L.S. | $39,945 |
| 06.02 | Environmental Monitoring and Engineering QA During Construction | L.S. | 1 | L.S. | $31,956 |
| 06.03 | Survey | L.S. | 1 | $10,000.00 | $10,000 |
| | | | | **SubTotal** | **$81,900** |
| | **PART C - CONTINGENCY** | | | | |
| 07.01 | 50% | | | | **$133,150** |
| | **Total Construction Cost (Part A+ Part B + Part C)** | | | | **$481,350** |

Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

**Stantec Consulting Ltd.**
500-4515 Central Boulevard
Burnaby BC  V5H 0C6
stantec.com