Place Glacier Hazard Assessment Report

Debris Flood and Flow Hazards

Date:

October 16, 2025

Prepared for:

Squamish-Lillooet Regional District

Prepared by:

Stantec

Project/File:

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Stantec

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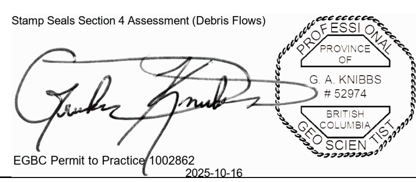

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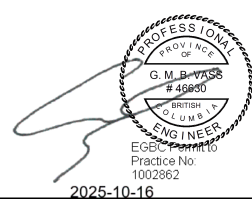

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Executive Summary

In 2024, Stantec Consulting Ltd. (Stantec) provided engineering and geohazard services to the Squamish-Lillooet Regional District (SLRD) to re-establish the Place Creek alignment following a debris flood initiated by a glacial lake (ice-marginal lake) outburst event from the Place Glacier. In 2025, the same lake experienced a rapid emptying causing a debris flood event within Place Creek (2025 Outburst Event). Portions of the re-established channel banks (part of the 2024 emergency response works) were damaged, and sediment deposited within the lower reaches of the channel which reduced freeboard and increased the potential for a re-direction of flow away from the Poole Creek catchment to the Gates Lake catchment (as happened in 2024). The Place Glacier hazard assessment is intended to assess the current hydrotechnical conditions and potential geohazards to determine whether they pose immediate hazards to the local population. Immediate debris flow and debris flood risk was assessed via numerical modelling.

Debris flows are a form of landslide that are typically shallow (< 3 m deep), gravity driven, very rapid to extremely rapid (> 3 m/s) and that surge downslope as turbulent flows. It was determined that the debris flow risk was negligible when assessing public safety on paved roads and within residential buildings.

Debris floods are hydraulicly driven, very rapid to extremely rapid flows of water, heavily charged with debris (up to 40% by volume) in which the stream bed is entirely mobilized for at least a few minutes (Church and Jakob 2020, Hungr, Leroueil and Picarelli 2014). Debris floods can be considered transitional between debris flows and clearwater floods. Clearwater flooding refers to flooding where the water carries low volumes of sediment and debris (typically less than 40% by volume). 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 (i.e. September to November) 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.

Glacial lake outburst events 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 demonstrates that the outburst event 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 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 re-direction of Place Creek flow 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 works would provide temporary mitigation from a potential avulsion in response to a glacial outburst event similar in magnitude to the 2025 Outburst Event; however, it is unknown whether it could provide mitigation from a larger outburst event similar in magnitude to the 2024 Outburst Event. A conceptual design and opinion of probable cost has been prepared for the re-establishment of damaged 2024 Emergency Works along Place Creek in response to the 2025 Outburst Event. As glacial lake outburst events are anticipated to occur on an annual basis it is recommended that a more robust, longer-term option be considered. If a longer-term option cannot be implemented prior to the anticipated 2026 glacial lake outburst (historically between June and July) it is recommended that the emergency works be re-established no later than May 2026.

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 (ice-marginal lake) outburst event from the Place Glacier. From June 18th to the 20th, 2025 the same lake situated on Place Glacier experienced a rapid emptying that caused a debris flood event within Place Creek (2025 Outburst Event). Based on photos provided by the Pemberton Valley Dyking District (PVDD) portions of the re-established channel banks (part of the 2024 emergency response works) were damaged and sediment deposited within the lower reaches of the channel reducing freeboard and increasing the potential for an avulsion and re-direction of flow away from the Poole Creek catchment to the Gates Lake catchment (as happened in 2024).

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 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 ice-marginal lake, the ice-marginal lake will continue to pose a potential risk to the downstream communities from outburst events.

Stantec was retained by SLRD to complete the following tasks (the Project):

1. Conduct a visual assessment of the Place Creek channel extending from the 2024 avulsion site downstream to the confluence with Poole Creek to assess current hydrotechnical conditions (i.e. channel formation and morphology, bank erosion, channel scouring, bed material, debris jams, overland flood areas) and potential geohazards and determine whether they pose immediate hazards to the local population.
2. Assess the immediate debris flood and debris flow risks[1] posed by the ice-marginal lake outbursts to the downstream communities of Birken; homes along Place Creek and Poole Creek; and Ministry of Transport and Transit (MOTT) culvert crossing of Poole Creek
3. Provide a Class D (+-50%) opinion of probable cost estimate and conceptual design for works required to mitigate immediate debris flood hazards posed by the current channel condition. This may include repair to the works constructed in 2024, dredging of the infilled channel, or other items identified as part of Stantec's assessment.

1.1 Scope of Work

The overall scope of the Project work includes the following:

[1] See Section 4 for details on what a debris flow is and Section 5 for what a debris flood is.

- Conduct a site assessment to identify potential geohazards and visually assess the channel to determine whether they pose an immediate hazard to the local population
- Conduct a partial risk assessment for shallow landslide hazards (debris flows) utilizing findings from the site assessment and Stantec's proprietary shallow landslide model, DebrisFlow Predictor
- Conduct a hazard assessment for flood and debris floods propagating from the 200-year return period rainfall driven fall flood; and the 2025 ice-marginal lake outburst event. This included:
    - Hydrological analysis to determine the 200-year return period rainfall driven fall clearwater flood
    - Analysis of bulking factor to determine the 200-year return period rainfall driven fall debris flood
    - Developing a two-dimensional (2D) hydraulic model utilizing HEC-RAS software of Place Creek and Poole Creek
    - Develop hazard maps to present the findings from the assessment.
- Develop one conceptual design option to mitigate the debris flood hazard posed by current channel and ice-marginal lake conditions. Concept would be limited to repairing the works constructed in 2024, dredging the infilled portion of the channel at the downstream extent of the 2024 works, or other conveyance enhancing items identified as part of the assessments. Development of a Class D (+-50%) opinion of probable cost and a single conceptual design figure are included within the scope.

1.2 Information Sources

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

- Stage-discharge curve of 2025 ice-marginal lake outburst event provided by NRCAN
- LiDAR digital elevation model and aerial imagery collected by Stantec following completion of the 2024 emergency response works (November, 2024).
- LiDAR digital elevation model collected by the Kakai Institute following the 2025 ice-marginal lake outburst event (July, 2025).
- LiDAR digital elevation data available from LidarBC.
- Historical flow data collected by Water Survey of Canada (WSC)
- Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment prepared by Stantec in 2024
- Place Creek Emergency Response Completion Report prepared by Stantec in 2024

- Place Creek Visual Hazard Assessment Letter Report prepared by Stantec in 2025
- Google Earth Imagery (2013, 2015 and 2021)
- Bedrock geology, faults, terrain mapping, BC Digital Road Atlas and Fresh Water Atlas available from iMapBC

2 Background

Figure 2-1 presents key locations associated with the Project and discussed throughout this report.

2.1 Pre-Event 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 year old), Hurley Formation, and Cretaceous-aged (70 million year 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 (Baumenn 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 outletted 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 outletting 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, Lil̓wat Nation members, and the SLRD this alignment has existing in living memory and was the basis for developments along Poole Creek, Gates Lake, and Gates River.

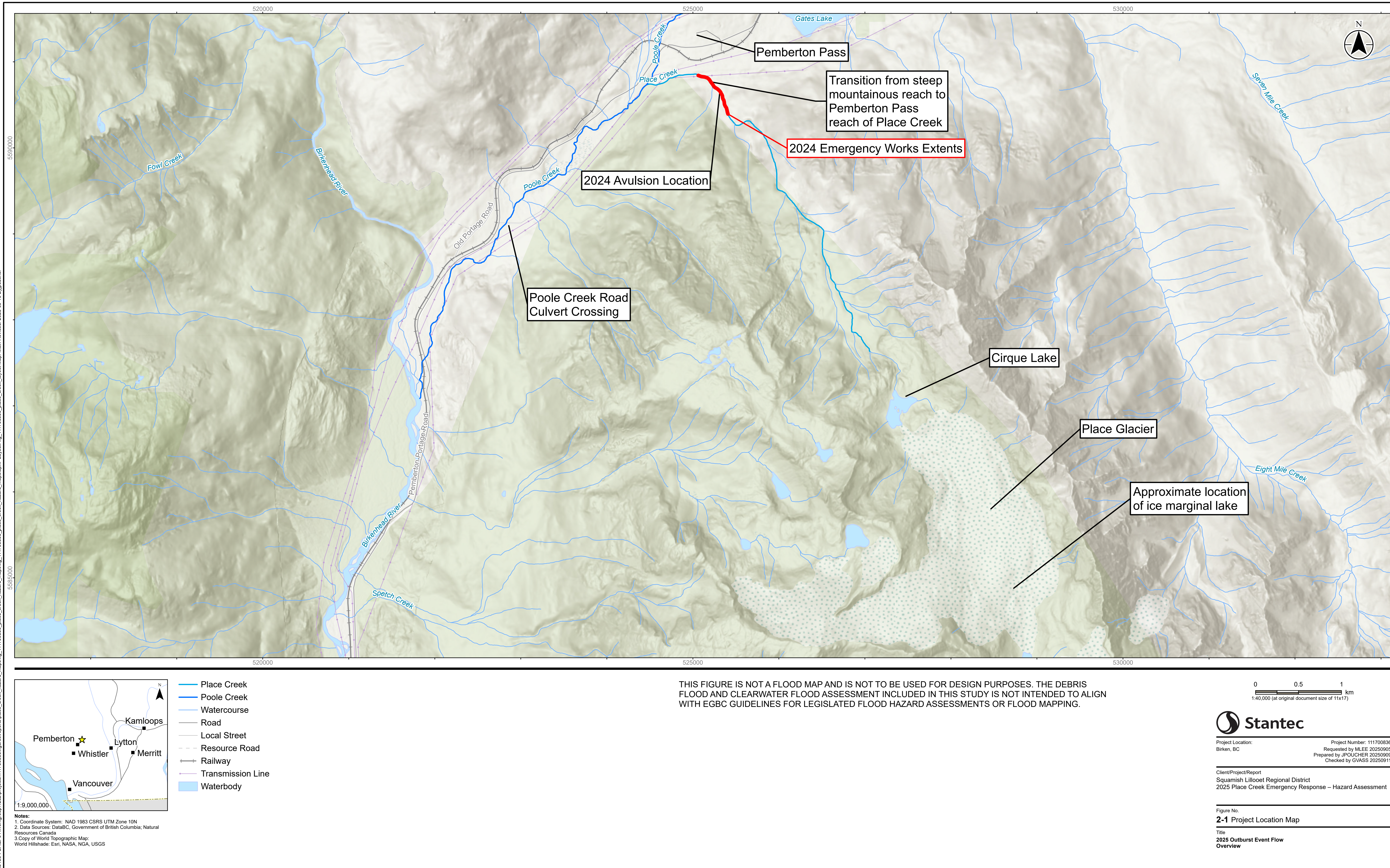

Figure 2-1. Project Location Map

2.2 2024 Event and Emergency Response Works

On July 22nd, 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 an 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 10-12 hours and conveyed $1.2x10^6$ 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). This 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[2] 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 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 results 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 based on previous Place Creek alignment.
- Channel modification is to function as a pilot channel to promote re-establishment of the previous Place Creek alignment.

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

- Typical section for channel modification to be based on 2-year mean annual flow.
- Re-established embankment to tie into high ground at the upstream extent to reduce the potential for future avulsions.
- 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).

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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 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, 2024)

2.3 2025 Event

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 an outburst event should be anticipated when the lake deepened by another 4 m (i.e. reached about 50% of the 2024 lake volume) (NRCAN, 2025).

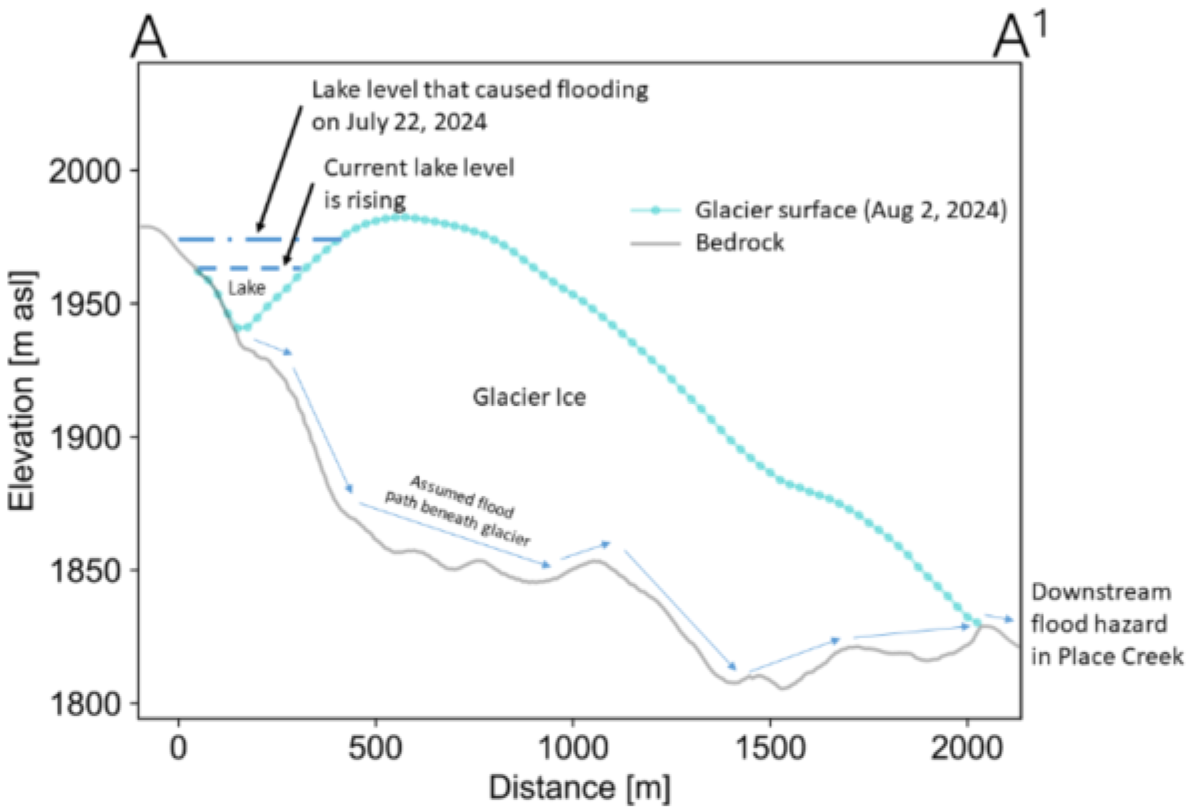

Figure 2-3. Cross section of ice surface and bed elevation of Place Glacier showing June 11, 2025, ice-marginal lake level (NRCAN, 2025)

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 outburst event (SLRD, 2025).

From June 18th to the 20th, 2025, an outburst event 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 Cirque Lake.

2.4 2025 Visual Hazard Assessments

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 (2025) 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 the report (Stantec, 2025) that details these assessments is appended to this document (Appendix A).

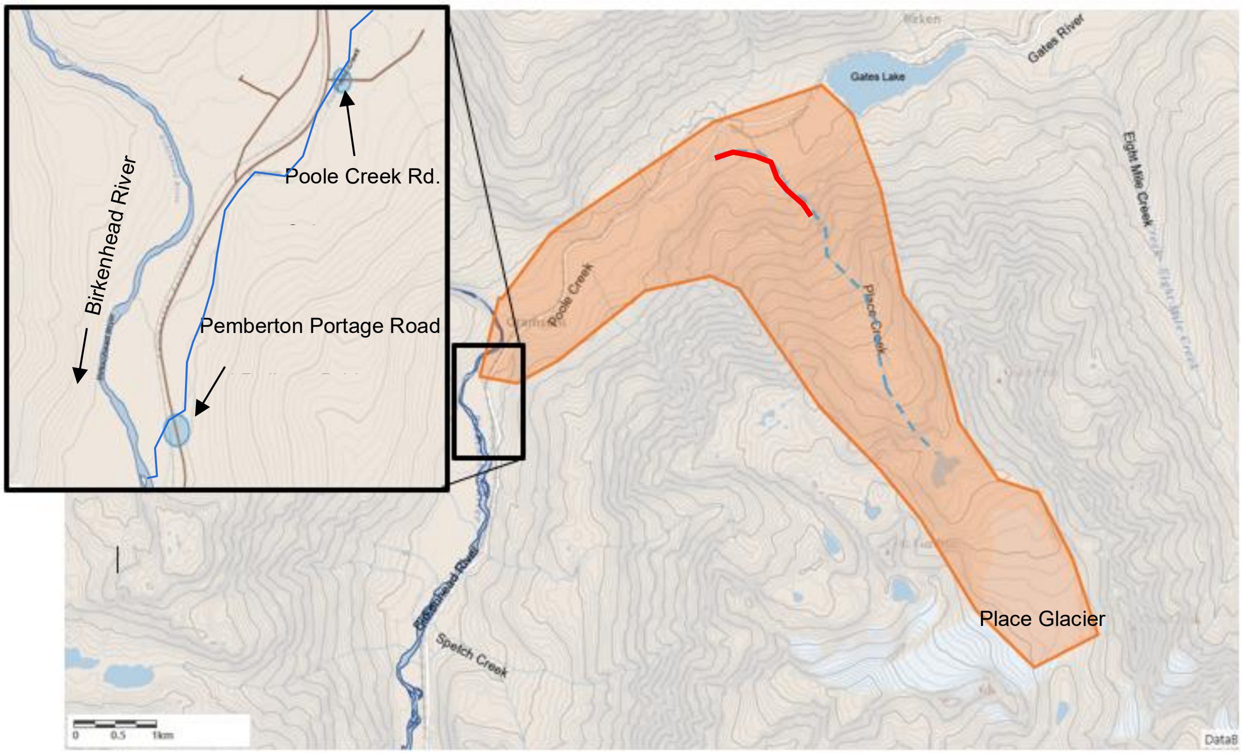

Figure 2-4. Extents of aerial (orange area) and ground based (red line and solid blue circles) visual assessments.

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 an outburst event, 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 outburst event 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 outburst event; 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, large log jams blocking the entire channel similar to what was observed and removed in 2024 was not observed.

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 there was low debris flow and debris flood hazards immediately posed to the downstream communities (i.e. during the summer months prior to more extreme rainfall that historically occurs during the fall and winter).

Figure 2-5. Riprap Failure & 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[3] and blue represents degradation[4]. 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.

[3] 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.
[4] 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.

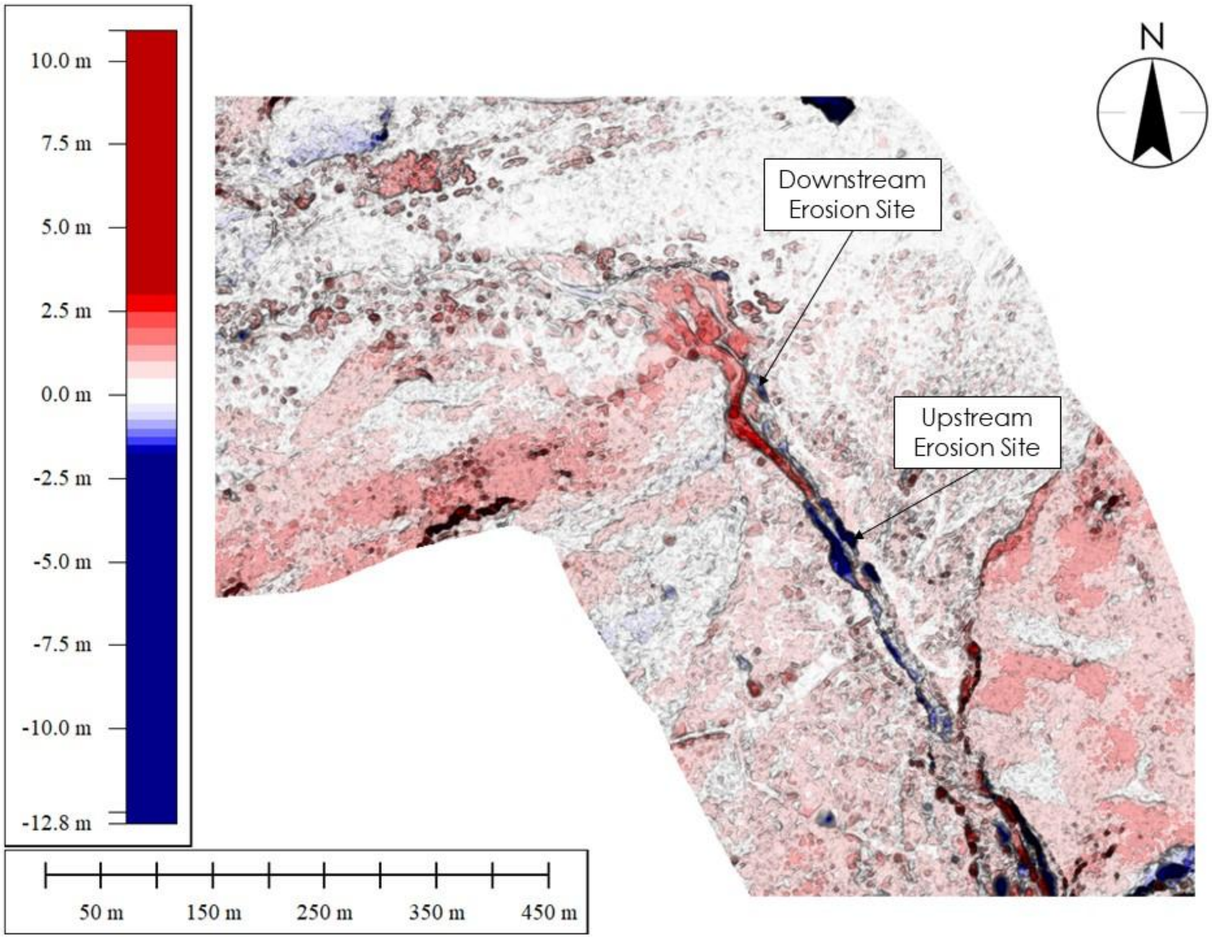

Figure 2-7. 2024-2025 LiDAR Differential Map

3 Hazard & Risk Terms

3.1 Hazard Definition

The term hazard relates to a process or phenomena that negatively affects things that society values. Those things which are affected are called receptors (e.g., an example of valued receptors can be humans, infrastructure, landscape features like wetlands etc). The term hazard for this assessment relates to debris flows (a shallow, rapid form of landslide) and flooding (inundation by water) that pose a threat to community safety and infrastructure downslope of Place Glacier.

These hazards, or rather geohazards (i.e., hazards derived from earth processes), have a likelihood of occurrence on the landscape (e.g., probability of landslide occurrence per kilometer squared) and in time (e.g., probability of flooding per year, often expressed as a return period such as 1:200-yr etc.). Stantec used a combination of the available information sources, field observations and geohazard modeling to define these aspects of the hazard. The methods for determining hazard for debris flows and flooding are provided in each of the respective chapters in this report (Section 4: Debris Flows and Section 5: Debris Flood and Clearwater Flood).

3.2 Risk Definition

Risk is a measure of the likelihood and severity (consequence) that a particular hazard will negatively impact a receptor (Engineers & Geoscientists British Columbia 2025). In its most basic form, risk can be expressed as:

$$Risk = Hazard \times Consequence$$

Stantec considered risk to public safety along paved roads and within residential buildings. The methods for determining the consequence and hazard used to inform risk for debris flows and flooding are provided in each of the respective chapters in this report (Section 4: Debris Flows and Section 5: Debris Flood and Clearwater Flood).

4 Debris Flow

4.1 What Is a Debris Flow?

Debris flows are a form of landslide that are typically shallow (< 3 m deep), gravity driven, very rapid to extremely rapid (> 3 m/s) and that surge downslope as turbulent flows. Debris flows can travel long distances from their initiation source, entraining (mobilizing) material along the runout path, bulking into destructive slurries of soil, rocks, trees, and other entrained debris, impacting lives, infrastructure, and communities as a result. Debris flows are typically saturated upwards of a 60% with debris; this is a key distinction between the flood types discussed later in this assessment (e.g. debris flows can often transition to hydraulically driven debris floods as materials drop out of suspension as the mass transitions along gentle slopes along alluvial fans) (Hungr, Leroueil and Picarelli 2014).

Debris flows are often triggered by heavy rainfall on steep slopes (Guzzetti, et al. 2022), (Guthrie, Mitchell, et al. 2010). Other factors such as seismic events, rapid snow-melt, wildfire, or in this particular instance, glacial outbursts, can trigger, or exacerbate, the likelihood of debris flow occurrence.

4.2 Methods

4.2.1 Defining Debris Flow Hazard ($H_{T,S,R}$)

For the purpose of determining debris flow hazard ($H_{T,S,R}$) for the assessment, the term can be considered as a three-part function to attain a probability of occurrence[5], whereby:

$$H_{T,S,R} = H_T \times H_S \times H_R$$

H_T = the probability of the hazard initiation per unit of time (e.g., landslide probability/year);

H_S = the spatial probability of the hazard initiation per unit area (e.g. landslide probability/km^2); and

H_R = the likelihood that the hazard will reach any specific location in the landscape.

The methods for defining these terms are further explained in the subsequent sections.

[5] Guidelines provided by EGBC (2025) provide related but slightly different terms. We intentionally choose these terms to reduce confusion related to other key measurements in Geohazards studies, and to better clarify and discretize measurable components of hazard.

4.2.2 Determining the Likelihood of Debris Flow Initiation ($H_{T,S}$)

The dominant driver of debris flow hazard in the assessed catchment was identified to be the glacial outburst events, whereby the sudden outburst of water from the mouth of the glacial cirque entrains debris through the Place Creek channel along steep slope sections.

Based on the repeat events over the past two years, field observations and the ongoing research for the glacier being completed by NRCAN, the outburst events are inferred to occur on an annual basis, or rather, have a forecasted 1:1 annual return until the marginal ice lake progresses to a stage which outburst are no longer possible. Consequently, for runout scenarios related to the outburst, Stantec assumed an annual likelihood of one (1); rather an $H_{T,S}$ of 1 at the mouth of the glacial lake outlets.

Stantec reviewed the available Google Earth imagery history, spanning approximately thirteen years (2012-2025) to develop a landslide frequency for debris flow events not initiated by a glacial lake outburst. The inventory was limited. Consequently, Stantec used debris flow frequencies (landslides/per km^2/year) developed from a recent – and more exhaustive – landslide inventory assessment completed for the Geological Survey of Canada (Stantec Consulting Ltd. 2023); the return rates used were developed in the Highway 99 (Duffey) corridor, which is the neighboring valley to the east with comparable terrain conditions. A frequency of **0.23 landslides/km^2/year** was used in this assessment for debris flows occurring outside of outburst event.

4.2.3 Modeling Debris Flow Hazard

Stantec used DebrisFlow Predictor to model the Landslide Hazard Fingerprint for debris flows that may initiate within the Place Glacier catchment.

DebrisFlow Predictor is a probabilistic, agent based, runout simulation model for shallow landslides created by Dr. Richard Guthrie (Guthrie, Deadman, et al. 2008) and developed by Stantec (Guthrie and Befus 2021, Guthrie and Befus 2025).

DebrisFlow Predictor predicts sediment volume (erosion and deposition) along a landslide path by deploying '*agents*', or '*autonomous subroutines'* over a five-meter spatial resolution DEM. The DEM surface provides basic topographic information to each agent, in each time-step, that triggers the user adjustable rule set that comprises the subroutine (behaviors). In this manner, agents interact with the surface and with other agents. Each agent occupies a single pixel in each timestep.

The model utilizes probabilistic agent behaviors, allotting for the stochastic (random) nature of landslide runout (i.e., no two landslide simulations are the same). Running the model simulation multiple times yields variable (probabilistic) results and allows the user to identify areas most prone to hazard.

4.2.3.1 Model Surface Preparation

To prepare the debris flow model, Stantec used ESRI's ArcPro to process LiDAR Aerial Survey (LAS) point-cloud elevation data, sourced from the Hakai Institute – Airborne Coastal Observatory (Hakai Institute 2018), into a high-resolution bare-earth digital elevation model (DEM) with 1.0 m spatial resolution. This DEM was then resampled to 5-m spatial resolution to ensure adequate agent behaviour in the runout model (Guthrie and Befus 2021).

4.2.3.2 Scenario Development

Two scenarios were developed for modeling

1. The “Landslide Hazard Fingerprint” for the entire catchment area
2. An “Outburst Scenario” to simulate debris flows driven by glacial outbursts through the Place Creek channel

The first scenario was designed to develop the Landslide Hazard Fingerprint[6] for the catchment. This scenario informed the interpretation of debris flow hazard from potential source areas within the catchment, including through the Place Creek channel and from the other steep slope areas in the catchment. By using the Landslide Hazard Fingerprint method, a range of initiation and magnitude scenarios were completed. For the scenario, landslides were spawned from 356 unique locations within the susceptible ground (slopes >26°), with 100 m spacing between each location. The initiation areas were divided into 96 randomized group configurations (sub-scenarios) and each sub-scenario hosted between 1-9 discrete initiation locations. Sub-scenarios control the density of debris flows simulated in each model run, allowing the analyst to accurately characterize runout from any source, but preventing unrealistic interaction from too many landslides occurring at one time. Each sub-scenario was simulated 100 times to account for natural variability between runs and allow for probabilistic analysis in the runout zone.

The second scenario was designed specifically for the outburst event. Here a landslide was seeded (i.e., a 3x3 agent configuration in the model) from the mouth of the cirque outlet into Place Creek and run 100 times to develop a runout profile downslope.

4.2.3.3 Model Calibration

To calibrate the model, Stantec placed debris flow agents in areas assumed to be debris flow prone (terrain with slope gradients greater than 26°) and monitored their behaviour. Agent parameters were adjusted throughout iterative runs until accurate landslide runouts could be replicated, both in the context of scour/depositional depths and inundation footprint; this was largely informed by field observations and assessor’s experience, geomorphic interpretation and experience operating the model.

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[66] The Landslide Hazard Fingerprint is a method of modeling the unique landslide profile within a catchment. It involves simulating a specific density of landslides in the model space and processing the results in such a manner that allows the user to identify areas of landslide hazard on the landscape, agnostic of a discrete initiation source (Knibbs, Guthrie and Wasklewicz 2023).

Two agent calibrations settings were established. The first setting was used for the Landslide Hazard Fingerprint and was calibrated to simulate debris flows occurring both within the Place Creek channel (not during outburst driven event) and from steep slopes in the surrounding catchment. Notably, the deposition multiplier and fanning parameter were adjusted (increased) to accommodate a higher percentage of blocky, angular material (as informed by field observations).

The second set of agent settings were developed to simulate the outburst event, whereby the deposition multiplier and fanning parameter were adjusted to replicate a more fluid flow.

Final agent settings for the model are provided in Table 4-1.

Table 4-1. Calibrated agent parameters used for landslide modelling.

Debris Flow Predictor Model Parameters	Agent Settings: Landslide Hazard Fingerprint	Agent Settings: Outburst Scenario
Fan Maximum Slope	27°	24°
σ Steep Slopes	0.35	0.35
σ Low Slopes	3.35	3.35
Skew Fanning to Low Slopes	1	1
Max Spawns	100	100
Deposition Multiplier	0.6	0.4
Erosion Multiplier	1	1
Minimum Initiation Depth	0.5	0.5

4.2.3.4 Runout (H_R)

Landslide runout, the probability that any downslope terrain cell will be occupied by a landslide from an upslope source, is a combination of two probabilities:

- Scenario probability – the likelihood that any location will be reached at least once in one or more sub-scenarios, and
- Run Probability – the likelihood that any location will be reached within a particular sub-scenario or a group of sub-scenarios.

Scenario Probability is calculated by:

$$P_{Scenario} = \frac{number\ of\ sub\ scenarios\ reaching\ a\ pixel}{number\ of\ sub\ scenarios}$$

Run Probability is calculated by:

$$P_{Run} = \frac{\sum Event\ counts\ in\ all\ sub\ scenarios}{number\ of\ sub\ scenarios\ reaching\ a\ pixel\ \times number\ of\ runs}$$

Where "*Event counts*" is the number of times a pixel was reached in a single sub-scenario (labelled 'Events' in DebrisFlow Predictor).

And runout (H_R) is:

$$P_{Scenario} \times P_{Run}$$

4.2.3.5 Correcting for $H_{T,S,R}$

With H_R developed, the runout hazard still needs to be scaled to the *in-situ* (*observed* or *predicted*) hazard ($H_{T,S}$). By scaling the model to the *in-situ* hazard, the user can rely on the downslope results of often coalescing debris flows, to represent the actual probability of encountering a landslide at any location under the triggering scenario (**$H_{T,S,R}$**). This is done by multiplying a determined correction factor to the modeled runout, or H_R. To determine the correction factor:

$$P_{MD} \times C = P_{OD}$$

Where "P_{MD}" is the modelled density of landslides, "*C*" is the correction factor, and "P_{OD}" is the observed in-situ landslide density.

For the Landslide Hazard Fingerprint Scenarios, the runout results were corrected to the regional annualized debris flow occurrence (i.e., 0.23 landslides/km^2/year (P_{OD})) versus the model frequency of four (P_{MD}=4).

For the second scenario, Outburst Event Scenario, the runout was corrected to a 1:1 annual return ($H_{T,S}$) and used to facilitate the interpretation of debris flow hazard from the outburst events (i.e., P_{MD}=P_{OD})

4.2.4 Determining Debris Flow Risk

Risk for the assessment was determined where the intersection of debris flows occurred with a defined receptor, and determining the consequence under those conditions. Defined receptors for the assessment included only occupied residential dwellings, as identified via the available imagery, and paved roads from the BC Road Atlas.

4.3 Results

4.3.1 Modeled Debris Flow Hazard Results

Figure 4-1 shows the uncorrected runout results (H_R) for the Landslide Fingerprint. This figure provides the probability (from 0-1) of terrain cell in the DEM being reached by a landslide from an upslope event.

Figure 4-2 shows the corrected runout profile for the Landslide Hazard Fingerprint scenario. This shows the annual debris flow hazard, for non-outburst events, assuming an annual return frequency of 0.23 landslides/km^2/year. Figure 4-3 shows the hazard ($H_{T,S,R}$) results for a glacial outburst event with an inferred 1:1 annual return.

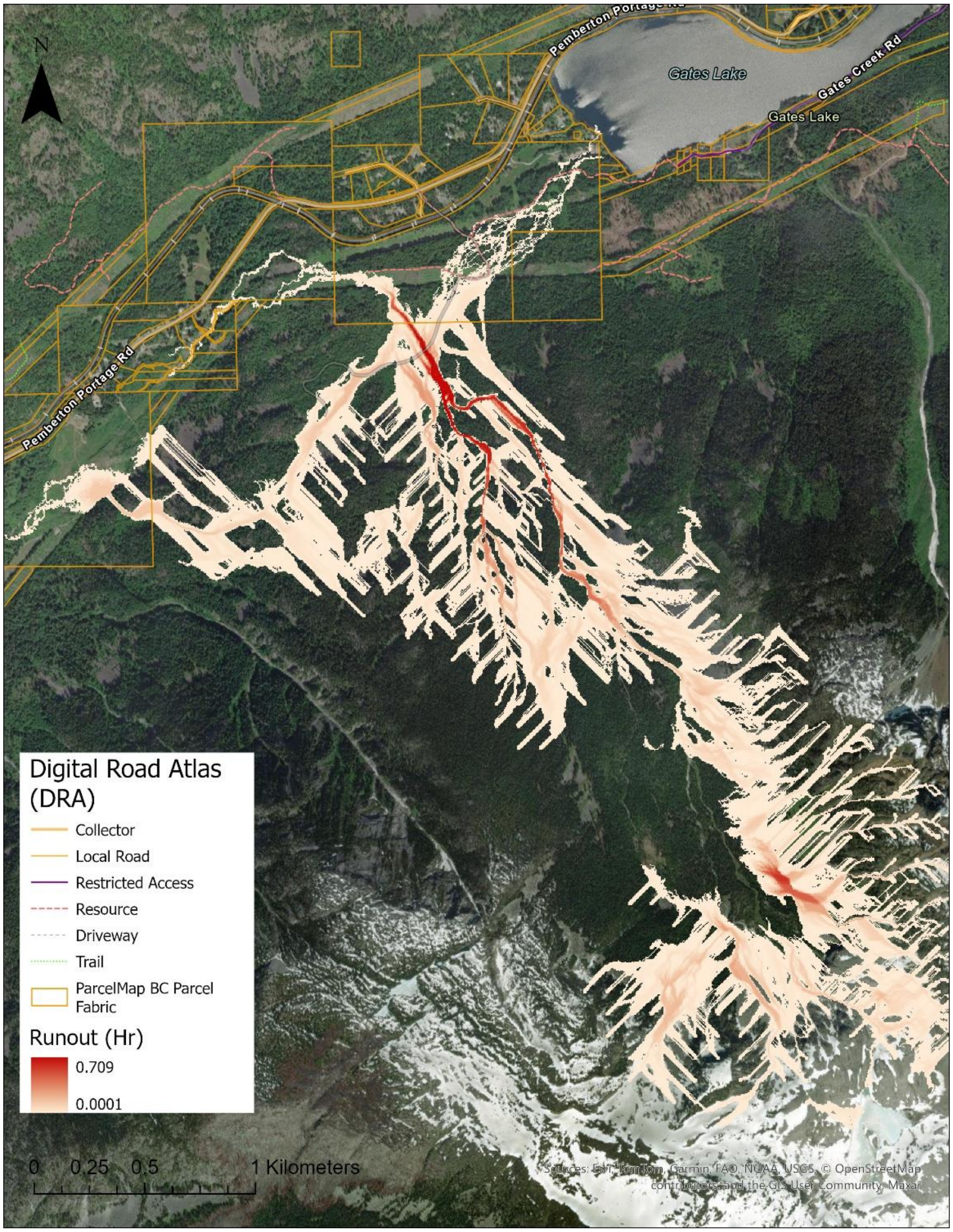

Figure 4-1. Runout profile (H_R) for the Landslide Hazard Fingerprint.

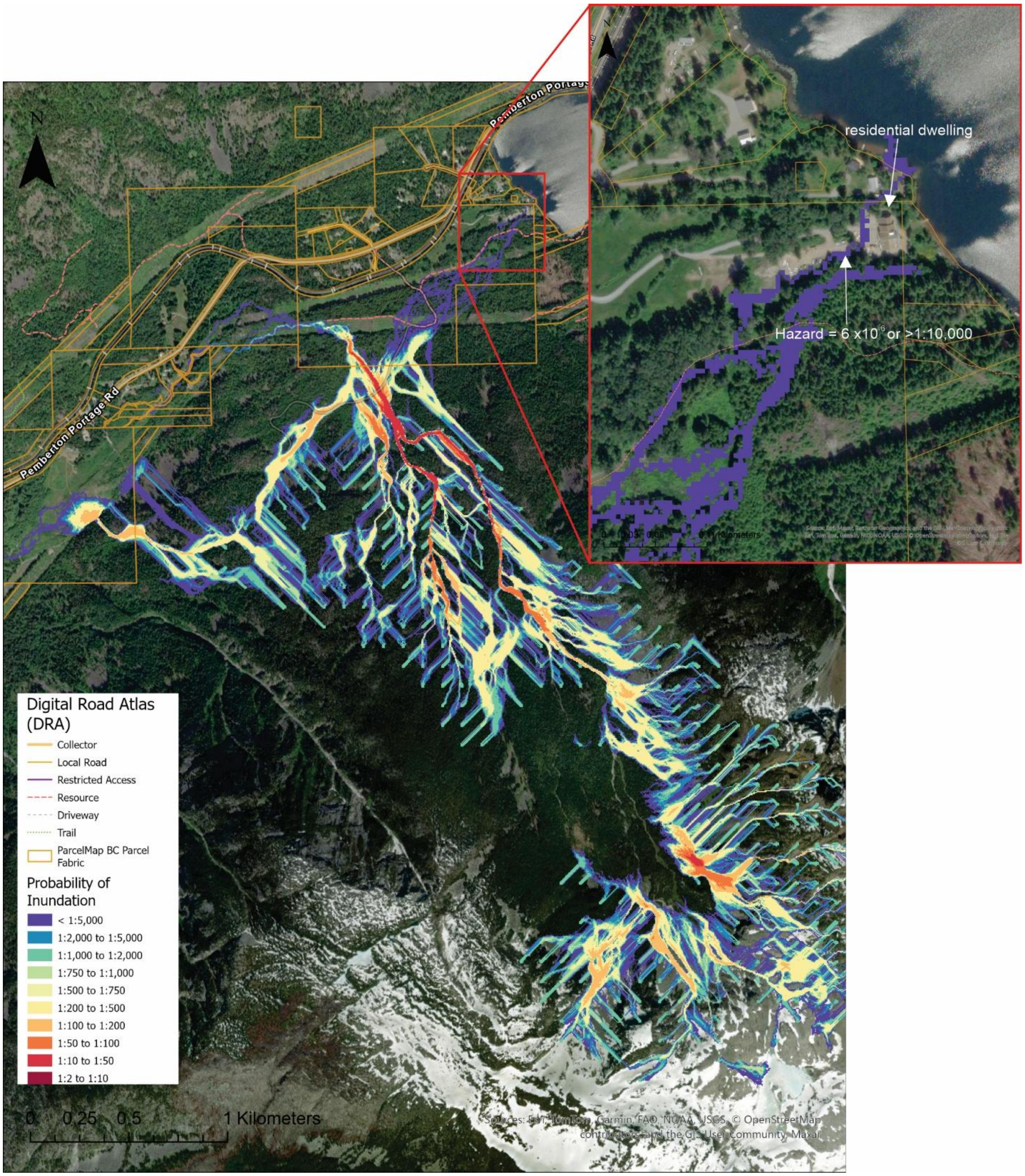

Figure 4-2. Landslide Hazard Fingerprint ($H_{T,S,R}$) scenario. This figure shows the annual debris flow hazard for events not derived from outburst event. Outbreak box shows the nearest residential dwelling related to the debris flow hazard profile – no intersection identified, and the nearest hazard is 6.0x10^{-6} per year (>1:10,000 return).

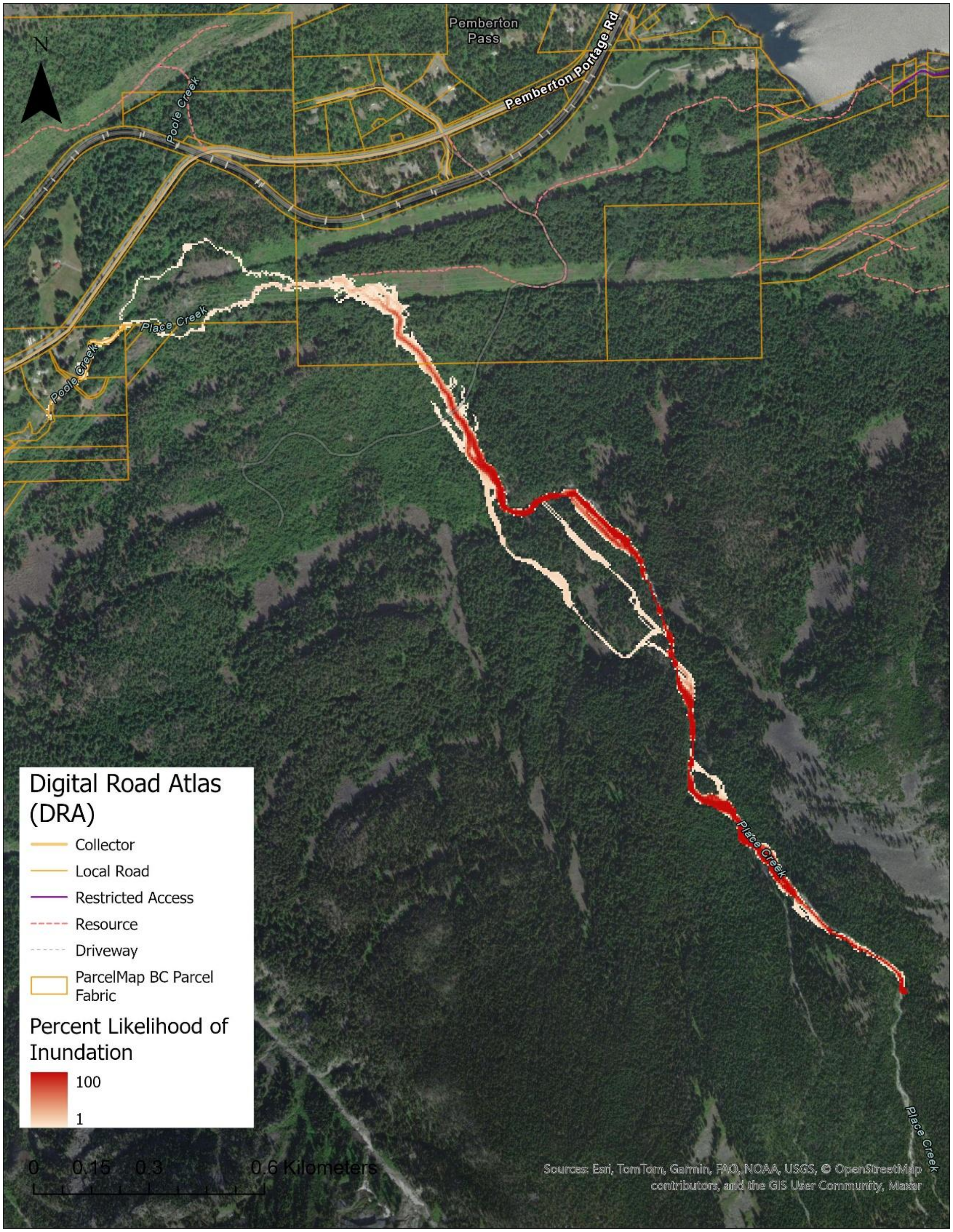

Figure 4-3. Likelihood of debris flow (landslide) inundation during a glacial outburst event.

Hazard in the lower slope position largely converged in defined channels including Place and Pool Creek and along the BC Hydro right-of-way on the alluvial fan.

4.3.2 Debris Flow Risk Results

Stantec identified a total of 11 land parcels from the BC Land Parcel Fabric that intersect with the Landslide Hazard Fingerprint (Table 4-2). No major roads or identified residential dwellings - other buildings for that matter – were intersected by modeled debris flows. Consequently, **it was determined that risk was null for the assessed receptors** (public safety on paved roads and within residential buildings) by this assessment.

Table 4-2. Land parcels that intersect the Landslide Hazard Fingerprint.

Parcel Number	Parcel Status	Parcel Class	Owner Type	Municipality	Regional District
007715498	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
007715528	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
031127827	Active	Bare Land Strata	Private	Rural	Squamish-Lillooet Regional District
013310283	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
027932061	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
006513409	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
027932087	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
026564017	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
013076965	Active	Subdivision	Crown Provincial	Rural	Squamish-Lillooet Regional District
013321706	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District
02653991	Active	Subdivision	Private	Rural	Squamish-Lillooet Regional District

4.4 Discussion and Recommendations

Debris flow hazards are evident within the Place Creek catchment and confirmed by this assessment. The most frequent threat occurs during glacial outbursts from the Place Creek Glacier. Outburst events have occurred annually in the last two years and are expected to continue until the glacial lakes no longer recharge. Assessment of glacial recession associated with climate change was not within the scope of this assessment.

No defined receptors (residential buildings and paved roads) were intersected by modeled debris flows; however, several private lands parcels are exposed to debris flow hazard. Property owners of these parcels (PID's listed in Table 4-2) should be informed of the results of this assessment as it may affect future development of their property and land user safety. Messaging should convey that debris flow hazard was identified on unoccupied portions of their property and that future debris flow events are expected. Currently these events are expected on an annual basis, as they relate to future glacial outburst events; however these events are likely to translate to debris flooding (see next section). Additional safety messaging for those with identified landslide hazard on their property could include safe tips such as:

- **Avoid building or living in hazard zones** – stay clear of steep gullies, alluvial fans, and historical/modelled debris flow paths. Geotechnical investigation may be warranted for future developments on the properties to ensure they are safe for the use intended.
- **Stay alert during intense rainfall** – debris flows often occur during or shortly after heavy storms. While the most frequent threat of landslide hazard in the area was determined to be from glacial outbursts, debris flows can occur during periods of sustained rainfall or rapid snowmelt.
- **Have an evacuation plan** – know the fastest route to higher ground and practice it.
- **Listen to warnings** – pay attention to local alerts from the SLRD, sirens, or weather bulletins.
- **Do not camp in areas of identified debris flow hazard** – avoid setting up tents in dry creek beds, ravines, or fan toes. Mapping provided in this report will support identification of hazardous areas on your property.
- **Watch for natural warning signs** – sudden rumbling, snapping trees, or increased sediment-laden water flow can signal an incoming debris flow. Know your evacuation plan.
- **Move to higher ground immediately** if you suspect a debris flow is coming — don't wait for confirmation.
- **Keep access routes clear** – don't block driveways or roads that emergency services might need.
- **Create defensible space** around properties – remove loose wood, debris, and objects that could be carried by flows.
- **Educate your family and neighbors** – ensure everyone knows the hazards and what to do in an emergency.

The defined receptors were not intersected by the model in this assessment; however, other receptors of interest – that were not within the scope of this assessment - may be at risk of debris flows. The information provided by this assessment could be utilized to facilitate future studies, such as fish impact studies to salmon populations in the Birkenhead River (etc.).

Stantec did not quantify glacial recession associated with climate change for this assessment. Rather a 1:1 return frequency was utilized for the Outburst Scenario event. As conditions change with the glacier, it may be necessary to re-evaluate the used frequency.

4.5 Debris Flow Assessment and Model Limitations

DebrisFlow Predictor incorporates peer-reviewed techniques to predict dynamic behavior in the physical world. Representation of that behavior assumes complete and accurate information about the environments for which the models are developed. There are practical limitations to meeting this standard, and the user must note that those limitations can affect the results.

There may be elements that are not known or not available that can affect predictions including local physical conditions that are not resolvable at the model scale, or inputs and interactions that arise dynamically through behavior that are not included in model dynamics. To reduce or address these limitations and uncertainties we obtain representative environmental data, using mapping techniques, reference published literature, and review previous studies.

Probabilistic models do not mean that any particular outcome will occur in any real-world event, nor do they mean that unpredicted outcomes will not occur. The predicted outcomes are the analyst's best effort to identify the locations and magnitudes of the most credible events. Interpretation of these predictions require an understanding of these uncertainties, high level of subject matter expertise, and good professional judgment. Assumptions that apply specifically to the use of DebrisFlow Predictor:

- Local topography smaller than the DEM resolution or not captured by the DEM (due to DEM quality or the difference between ground conditions when the DEM was captured and existing ground conditions) may affect the path selection or landslide behavior in a manner not resolvable by DebrisFlow Predictor.
- Topographic changes, including but not limited to mitigation ditches and roads, which postdate the LiDAR acquisition will not be represented in the DEM and thus were not represented in the model.
- Landslide behavior including inundation, runout, scour, deposition, spread, and path selection, may vary from modeled behavior for several reasons including stochastic variability in the landslide process (natural or modeled), controlling factors that defy parameterization within the model, generalizations used to make the model practical and applicable across large areas.

DebrisFlow Predictor simplifies extremely complex behavior to provide reasonable predictions of outcomes. Should there be a perceived difference between modeled results, and on-the-ground evidence, ground-based evidence should take priority. DebrisFlow Predictor does not relieve professionals from using their experience, training, and education to make good judgments when assessing actual ground conditions, but provides additional understanding of processes, and credible outcomes.

The list of receptors, and possible facets of risk (i.e., economic costs, cultural losses etc.) for the debris flow assessment were not exhaustive. The receptors assessed were those scoped into the project through discussion, and approval, by the SLRD. First Nation engagement and consultation was not within the scope of this assessment; however Stantec understands that the SLRD has, and continues to, engage and consult with First Nations according to protocols outside the scope of this report.

5 Debris Flood and Clearwater Flood

5.1 What is a Debris Flood and Clearwater Flood?

Debris floods are hydraulicly driven, very rapid to extremely rapid flows of water, heavily charged with debris (up to 40% by volume) in which the stream bed is entirely mobilized for at least a few minutes (Church and Jakob 2020, Hungr, Leroueil and Picarelli 2014). Debris floods can be caused by the dilution of debris flows in channels and form a continuum of processes. Watersheds susceptible to debris flows and debris floods can often be distinguished through stream length, total area, and relief. Debris floods can be considered transitional between debris flows and clearwater floods.

Clearwater flooding refers to flooding where the water carries low volumes of sediment and debris (typically less than 40% by volume). This type of flood is characterized by relatively clean water compared to other types of floods, such as debris floods, debris flows or mudslides, which contain substantial amounts of sediment and debris. Compared to debris floods, clearwater floods typically occur in watersheds with lower topographic relief.

A debris flood is defined as a flood involving high rates of coarse bedload transport in steep channels (gradient of 5% to 27%). Debris floods commonly occur in confined channels or alluvial fans with gradients of more than 5% and are considered transitional between clearwater floods and debris flows (NRCAN, 2024).

To perform a hazard assessment and determine whether remedial actions are required to mitigate immediate debris flood hazards associated with a 200-year return period fall flow events or an outburst event equivalent to the 2025 Outburst Event, Stantec complete the following:

- conducted a visual assessment (detailed in Section 2.4)
- developed a terrain differential map using LiDAR from post-2024 emergency response works and the post-2025 Outburst Event
- developed a 2D hydraulic model using the U.S. Army Corps of Engineers Hydraulic Engineering Center’s River Analysis System (HEC-RAS version 6.4.1) software to model flood hazards

5.2 Methods

5.2.1 Defining Clearwater and Debris Flood Hazard

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 et al. 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 et al. 2014).

Combining the aforementioned elements, flood hazard curves can be produced that relate the vulnerability of a community with floodwater (Figure 5-1). Table 5-1 details which stability thresholds from individual flood hazard curves defined the limit for each flood hazard class and Table 5-2 summarizes the corresponding limiting parameter values. A flood hazard vulnerability classification map can be determined using HEC-RAS and is further discussed in Section 5.6.3.

Table 5-1. Flood Hazard Classification Defining Limits

Hazard Vulnerability Classification	Depth	Velocity
H1	Vehicle Stability – Small Car	Building Stability - Light Building
H2	People Stability – Children 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 5-2. 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

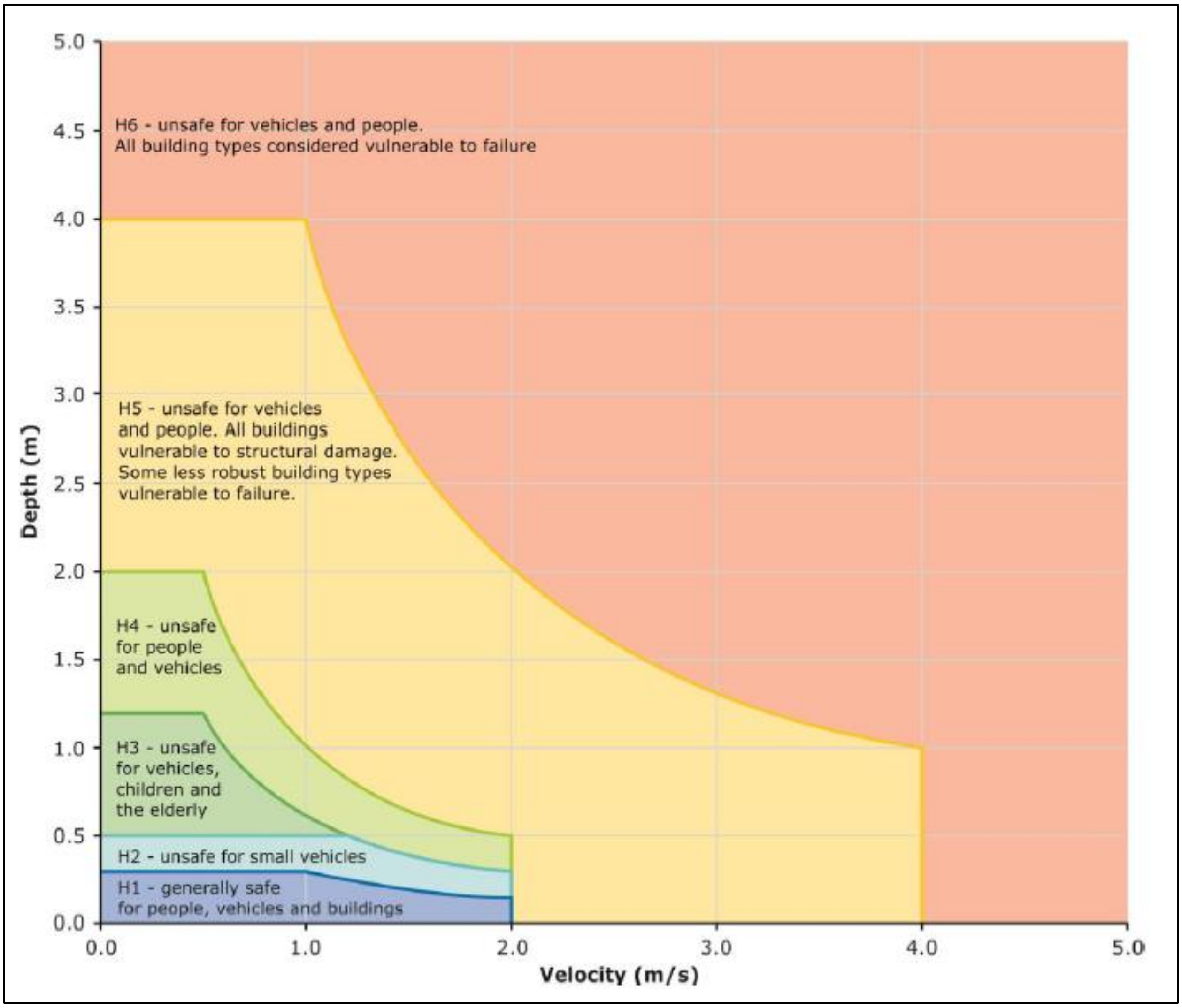

Figure 5-1. Flood Vulnerability Classification Based on Flood Depth and Velocity (Smith et al. 2014).

5.3 Hydrological Assessment

A hydrological assessment consisting of a watershed delineation, area-based scaling flood frequency analysis (FFA) and regional flood frequency analysis (RFFA) was conducted for the following temporal periods and locations:

- Fall months (Sept to November) at the outlet of Place Creek
- Fall months (Sept to November) for Poole Creek at the confluence with Place Creek
- Month of June for Poole Creek at the confluence with Place Creek

These periods align with the scope of the Project, i.e. assessment of hazards posed by the current conditions of the channel in response to extreme fall clearwater and debris flood flows. As the 2025 Outburst Event occurred in June an average June Poole Creek flow was required for modelling purposes.

The catchment area for Poole and Place Creek at the above noted locations are 10.86 km^2 and 13.59 km^2, respectively (Figure 5-2). An area-based scaling FFA and RFFA were completed to estimate stream flows for a range of defined return periods using three nearby WSC gauges (Table 5-3). WSC gauges were selected based on the following criteria:

- Adequate available data (>20 years);
- Close proximity to the Watershed (<50 km);
- Located within the same hydrologic zone;
- No substantial basin regulation (dams, diversions, etc.); and
- Watershed size (similar size is preferred for area-based scaling and a range of sizes selected for the RFFA).

Figure 5-2. Catchment Areas for Place (Blue) and Poole (Orange) Creek

Table 5-3. WSC Stations

WSC Station Number	WSC Station Name	Watershed Area (km^2)	Hydrologic Zone	Distance from Site (km)	Years Active
08MG019	Place Creek Near Birken	7.25	27	4.8	21 (1968 to 1989)
08ME027	Hurley River Below Lone Goat Creek	312	27	44.8	22 (1996 to 2017)
08MG026	Fitzsimmons Creek Below Blackcomb Creek	89.7	27	35.5	23 (1993 to 2016)

Historical stream flow datasets were downloaded from the WSC website and used to generate a mean monthly discharge (MMD) dataset for June and maximum daily flow dataset for the fall months (i.e., September, October, and November). The June dataset was created by taking the average of daily flow values for the entire month, for each year of continuous record and then taking the average of the recorded years to determine the corresponding flow at each WSC station.

The fall months datasets were created by extracting the peak maximum daily flow from each month for each year of continuous record. Each fall dataset was used to inform the FFAs. The average value of each of the fall datasets represents the mean monthly flow (MMF) for the WSC and month of interest.

For return period estimates, these datasets were imported into HYFRAN-PLUS© software (HYFRAN), which was used to evaluate data quality and derive the discharge for the 2.5-, 5-, 10- and 200-year return periods, which are equivalent of the annual exceedance probability of 40%, 20%, 10%, and 0.5%, respectively. Each dataset was checked for independence (Wald-Wolfowitz test), stationarity (Kendall test), and homogeneity (Wilcoxon test) at the 5% significance level.

Datasets were tested with multiple probability distribution functions to determine the best-fit (determined using HYFRANs comparison and criterion functions), which was used to calculate discharges for the selected return periods and the June MMD. Following the completion of the HYFRAN analysis, area-based scaling and an RFFA were applied to the HYFRAN outputs to generate multiple datasets for comparison when selecting the design flows. Each approach is described in subsections below.

5.3.1 Area-Based Scaling

An area-based scaling technique was used to create one of the two datasets for comparison of the resulting design flows. This technique uses the following equation:

$$Q_{ungauged} = Q_{gauged}\left(\frac{DA_{ungauged}}{DA_{gauged}}\right)^{n} \qquad \text{(Equation 1)}$$

Where Q = discharge (m^3/s)

DA = watershed area (km^2)

n = scaling exponent

Poole and Place Creek and the selected proxy station, Place Creek Near Birken (08MG019; Table 5-3), are both located within eco-province 14.3 which corresponds to a scaling exponent of 0.98 (NHC, 2021). The Place Creek gauge (08MG019) was selected because it has a watershed area closest to the size of Poole and Place Creek, is within close proximity, has similar physiographic characteristics, is within the same eco-zone/eco-province, and has an acceptable length of continuous data. The results of the area-based scaling based on the Place Creek proxy station are presented in Table 5-4.

Table 5-4. Flow Results Using Area-Based Scaling (m^3/s)

Return Period (Years)	Sept	Oct	Nov	Sept-Nov	June
Place Creek					
MMF	4.03	2.67	1.03	4.31	-
2.5	3.68	2.11	0.61	4.02	-
5	5.78	3.18	1.18	6.39	-
10	7.87	4.28	1.98	8.74	-
200	16.90	9.77	9.57	18.88	-
Poole Creek					
MMD	-	-	-	-	1.48
MMF	3.23	2.15	0.83	3.46	-
2.5	2.96	1.69	0.49	3.22	-
5	4.64	2.56	0.95	5.13	-
10	6.31	3.43	1.59	7.01	-
200	13.57	7.85	7.68	15.16	-

5.3.2 Regional Flood Frequency Analysis

The HYFRAN outputs discussed in Section 5.3 were used to complete an RFFA using stream flow data from the three WSC stations in Table 5-3. A graph for each of the MMF, 2.5-, 5-, 10- and 200-year return periods was created for each period of interest, with discharge for each return period plotted against its watershed size. A best-fit power function between drainage area (DA) and discharge (Q) was created for each return period and used to estimate the Place Creek and Poole Creek flows. Results are summarized in Table 5-5.

Table 5-5. Flow Results Using Regional Flood Frequency Analysis (m^3/s)

Return Period (Years)	Sept	Oct	Nov	Sept-Nov	June
Place Creek					
MMF	2.94	2.20	1.10	3.53	-
2.5	2.78	1.82	0.71	3.31	-
5	4.12	2.72	1.32	5.10	-
10	5.42	3.64	2.15	6.90	-
200	10.86	8.54	8.22	6.90	-
Poole Creek					
MMD	-	-	-	-	1.39
MMF	2.54	1.84	0.88	2.98	-
2.5	2.41	1.53	0.56	2.80	-
5	3.60	2.27	1.05	4.34	-
10	4.74	3.02	1.72	5.87	-
200	9.32	6.92	6.75	5.87	-

5.3.3 Hydrological Assessment Results

The estimated June and fall flows that are used for the clearwater flood assessment included in this Project are presented in Table 5-6. The estimated stream flows are the average of the results from the area-based scaling presented in Table 5-3 and the RFFA in Table 5-4. While the area-based scaling method alone can provide reliable results with a very similar reference watershed and a defensible scaling exponent, results can suffer from biases associated with potential for errors and noises within a single dataset. The RFFA can suffer from input from less relevant stations; however, it has the benefit of cancelling the noises and errors from single stations. Due to the area-based scaling and RFFA yielded different results, an average of the two values is the recommended approach for estimating the June and fall flows.

Table 5-6. Estimated Clearwater Flows used for the Project (m^3/s)

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

5.4 Debris Flood Bulking Factor

Discharges for the 200-year return period debris floods were estimated by applying a bulking factor to the estimated clearwater discharge associated with the corresponding return period. A bulking factor is used to account for the increased volume of flow due to entrained sediment and debris in floodwaters.

Appropriate values for debris flood bulking factors have been researched and suggested to range from 1.05 to 2.0 or more (Church and Jakob 2020, Wilford, et al. 2004, O'Brien and Julien 1988, Julien and Leon S n.d.). A watershed's susceptibility to floods, debris floods, and debris flows can be estimated based on the channel length and the "Melton Ratio" which is a dimensionless quotient of drainage relief and watershed area, i.e. a measure of the steepness of a watershed (Church & Jakob, 2020). The steep mountainous section of Place Creek that extends upstream from the 2024 emergency response works has a Melton Ratio of 0.58 indicating it is susceptible to mixed debris floods and debris flows. The planform of Place Creek shifts from steep mountainous terrain to a meandering, multi-threaded channel downstream of the 2024 emergency works, along the Pemberton Pass to the confluence with Poole Creek. Based on visual assessments following the 2024 and 2025 outburst events and results from the debris flow modelling, larger sediments entrained within the flow deposit within the Place Creek channel at the transition from mountainous terrain to the Pemberton Pass while finer sediment is transported further downstream depositing along the Pemberton Pass reach of Place Creek and Poole Creek. Previous studies (Gusman, 2009) indicate that for this type of channel, bulking factors vary from 1.25 to 1.67, or channels that are on the threshold of debris flood to channels on the threshold of debris flows. As the magnitude of the flow bulking will vary along Place Creek, evidenced by visual observations and the debris flow modelling indicating that debris flows tail out at the transition from the steep mountainous reach to the flatter Pemberton Pass reach, an average of the bulking factor range has been used for determinig the debris flood flow: 1.4.

This value was applied to the clearwater discharges for the 200-year return period fall flows for both Place Creek and Poole Creek (Section 5.3.3) to derive the debris flood discharges utilized in the assessments (discussed in Section 5.5.1). A bulking factor was not applied to the 2025 Outburst Event as the model results based on the hydrograph provided by NRCAN aligned with visual observations of water levels along Place and Poole Creek collected by SLRD during the event (discussed further in Section 5.6).

Table 5-7. Estimated Debris Flood Flows (m^3/s)

Return Period (Years)	Sept	Oct	Nov	Sept-Nov
Place Creek				
200	19.43	12.82	12.46	18.05
Poole Creek				
200	16.02	10.33	10.11	14.71

5.5 Clearwater and Debris Flood Assessments

5.5.1 2D Hydraulic Model

To create the 2D hydraulic model, Stantec used River Analysis System (HEC-RAS version 6.4.1) developed by the Hydrologic Engineering Center (HEC) with the U.S. Army Corps of Engineers (USACE). HEC-RAS can perform 2D unsteady flow simulations using either Shallow Water (SWE) or Diffusion Wave (DWE) equations (USACE 2024). HEC recommends using the SWE computation equations when the flow conditions have the following characteristics:

- Highly dynamic flood waves,
- Abrupt contractions and expansions,
- Flat sloping river systems,
- Tidally influenced conditions,
- General wave propagation modelling,
- Super elevation around bends,
- Detailed velocities and water surface elevations at structures, and
- Mixed flow regimes.

The reaches of Poole and Place Creek exhibited most of the flow conditions where SWE simulations are recommended above DWE. SWE was selected as the computation equations for the 2D hydraulic model simulations

The model simulated three scenarios using the hydrologic inputs determined in Section 5.3, the outburst event hydrograph provided by NRCAN and described in Section 5.5.1.3, and the bulked debris flood flows in Section 5.4 as the inflow boundaries:

1. 2025 Outburst Event – Using the hydrograph provided by NRCAN[7] and Poole Creek June flows
2. Post-2025 Outburst Event 200-year Fall Clearwater Flow – Using the clearwater 1 in 200-year return period Poole and Place Creek September flow (Table 5-6)
3. Post-2025 Outburst Event 200-year Fall Debris Flood Flow – Using the debris flood 1 in 200-year return period Poole and Place Creek September flow (Table 5-7)

5.5.1.1 Model Terrain and Surface Roughness

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 2024). The terrain was developed based on post 2024 emergency response works LiDAR and 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.

[7] The hydrograph provided by NRCAN is data recorded from the bottom of Place Glacier, upstream of Cirque Lake. There is no bathymetry for Cirque Lake thus the attenuation will be modeled using the water level captured in the 2025 LiDAR. Therefore, the water level from the LiDAR might not reflect the water level of the lake at the time of the outburst event.

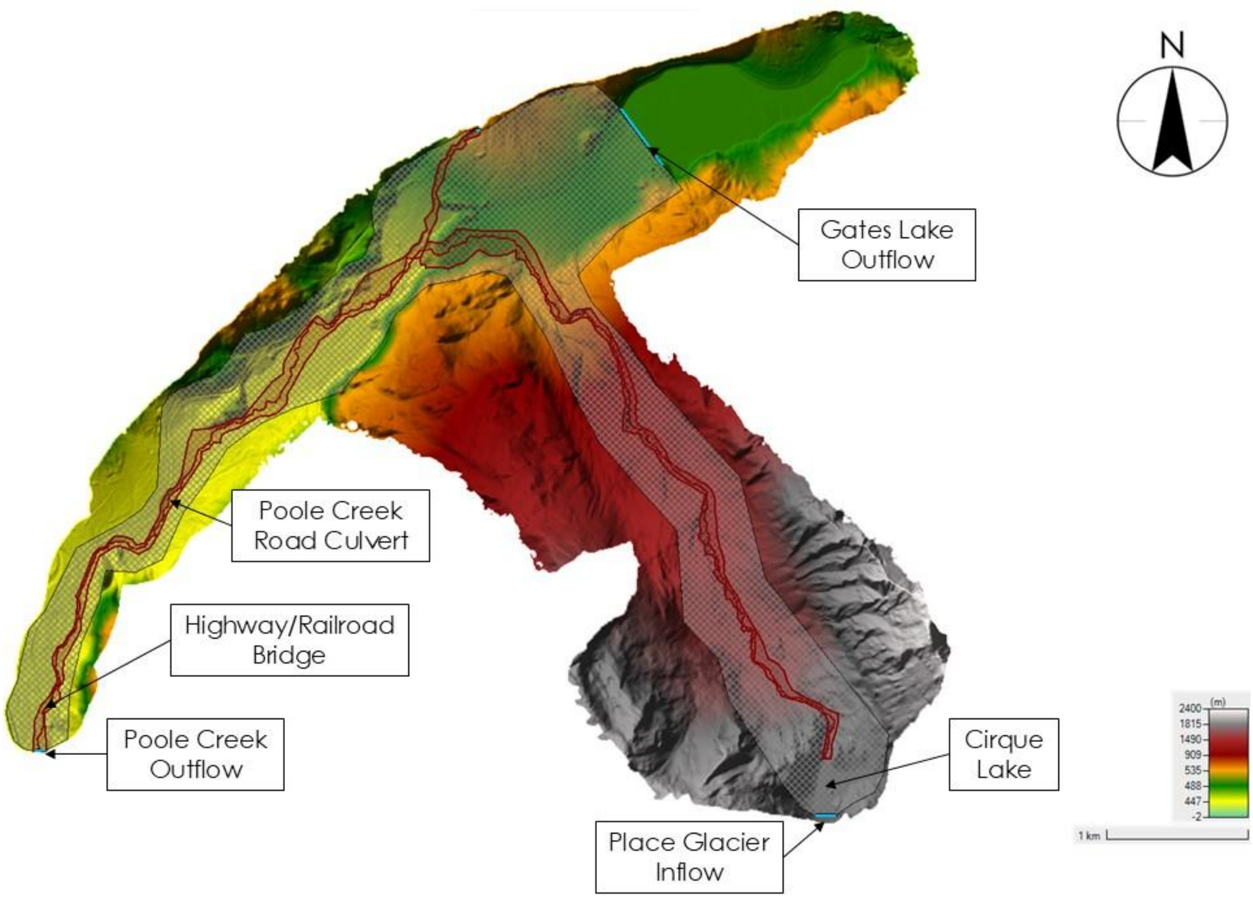

Figure 5-3. HEC-RAS Model Set-Up

Manning's n values within the creek channels were based on Chow (1959). Surrounding land cover conditions were defined for the terrain based on the North American Environmental Atlas – Land Cover 2020 map (Commission for Environmental Cooperation 2020). For surrounding land cover, Manning's n values were determined based on National Land Cover Database (NLCD) land cover type. The HEC-RAS 2D manual provides estimates of Manning's n values for each NLCD land cover type (USACE 2024). Refer to Table 5-8 for the corresponding Manning's n values for each defined land cover condition.

Table 5-8. Manning's N for Model Land Cover Conditions

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

As detailed channel bathymetry was not available/incorporated into the model mesh nor hydrometric data available along any of the Place Creek or Poole Creek reaches, model calibration was not possible. Some model validation was provided by comparing the results from the 2025 outburst event model to visual observations collected by SLRD during the event and field observations of high water marks collected by Stantec during the visual assessment.

5.5.1.2 Model Meshing

HEC-RAS is able to create a flexible model mesh that can include breaklines and refinement regions to increase or decrease mesh size. The mesh for the model was set to 10 m and refinement regions were delineated to increase the mesh resolution to 3 m within the channel banks of Place Creek and Poole Creek. Breaklines were also added to the model for the Place Creek and Poole Creek alignments to increase accuracy along the alignment. The breaklines were defined to have the same spacing as the refinement region. A typical cell arrangement is shown in Figure 5-4.

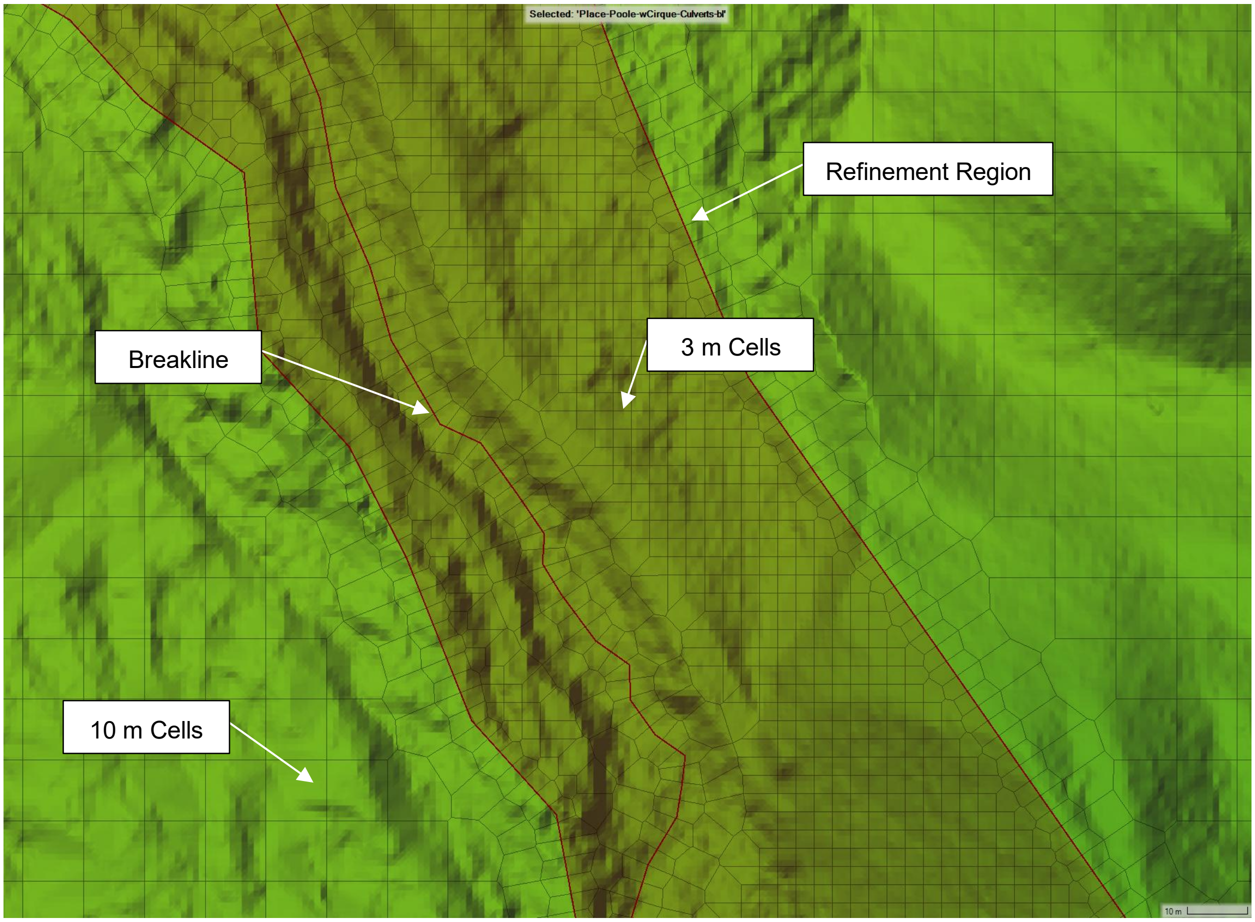

Figure 5-4. Typical Cell Sizing Near Refinement Regions

5.5.1.3 Boundary Conditions

The inflow boundary conditions for the hydraulic model were set at the upstream ends of Place Creek and Poole Creek. The inflow hydrographs were set to model the three scenarios. Two downstream boundary conditions were included into the hydraulic model. The primary outflow was inserted approximately 5 km downstream of the confluence between Place Creek and Poole Creek, an additional outflow was included for overtopping flows that discharge into Gates Lake.

Figure 5-5 presents the measured flow hydrograph used for the inflow boundary condition for the 2025 Outburst Event. The gauge stopped operating at the peak flow of 17.67 m^3/s therefore post-peak data of the event was unable to be recorded.

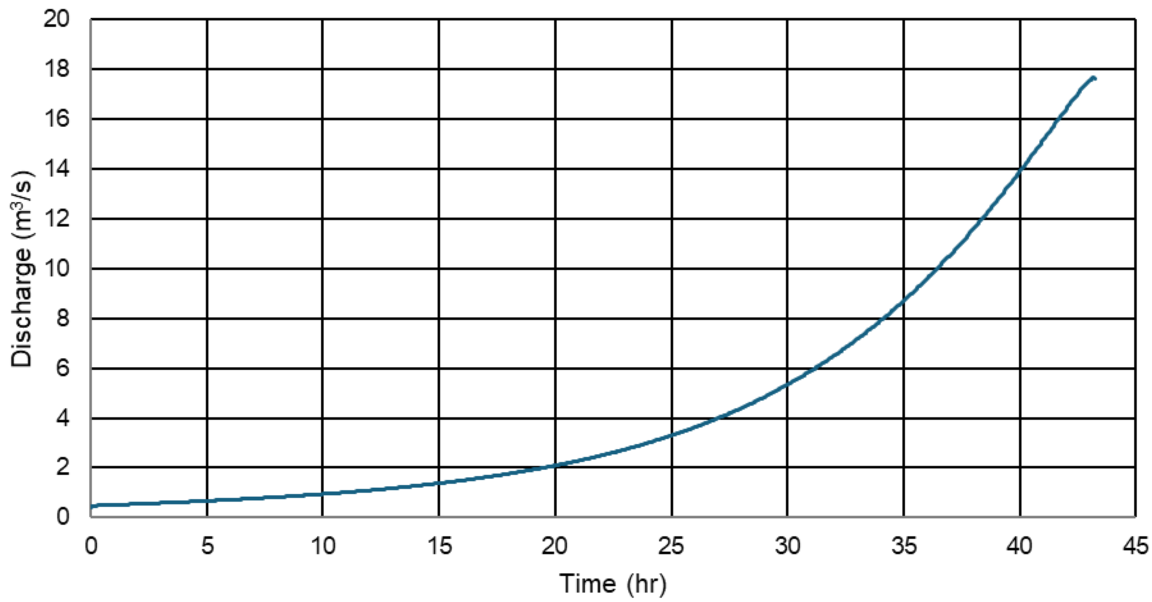

Figure 5-5. 2025 Outburst Event Hydrograph

5.5.2 Poole Creek Road Culvert Model

To analyze the hydraulics and potentially overtopping of the MOTT culvert crossing at Poole Creek Road, a discrete model using HY-8 culvert analysis software (developed by the U.S. Federal Highway Administration (FHWA)) was used to assess local hydraulics specific to the culvert. As a ground survey was not within the scope of the Project nor publicly available the geodetic location and elevation of the culvert inverts are unknown – Stantec used field observations collected as part of the visual assessment (Stantec, 2025) to develop the HY-8 culvert model.

5.6 Results

5.6.1 2D Hydraulic Model Results

Water depths and velocities associated with the three scenarios introduced in Section 5.5.1 are used to develop the hazard maps detailed in Section 5.6.3. The 2025 Outburst Event results align with observations collected by SLRD during the event and by Stantec during the visual assessment, specifically:

- No overtopping of Poole Creek Road at the MOTT culvert crossing
- Flow remained within the 2024 emergency works reach of Place Creek and overtopped the right bank at the transition from the steep mountainous reach to the Pemberton Pass

- Flow did not encroach upon the BC Hydro ROW except for a short section at the furthest downstream portion of the Pemberton Pass.

Results indicated that during all three of the scenarios the Pool Creek Road culvert crossing causes backwatering of flow upstream with flows encroaching upon several buildings – indicative of an undersized culvert. The Post-2025 Outburst Event 200-year Fall Clearwater Flow and Debris Flood Flow scenarios showed flow overtopping Pool Creek Road at the culvert crossing.

Results for all scenarios indicated that flood flow may encroach upon several structures and inundate large portions of private lands – the hazard this poses is discussed in Section 5.6.3.

The results from the 2025 Outburst Event were similar to those of the Post-2025 Outburst Event 200-year Fall Clearwater and Debris Flood Flows; however, the fall flow scenarios have larger flood extents along Poole Creek while the 2025 Outburst Event flood extents are larger along Place Creek. Due to the limitations of the models (see Section 5.9) figures and specific hydraulic values have not been included within this report.

5.6.2 Poole Creek Road Culvert Model Results

Hydraulics at the Poole Creek Road culvert associated with all three model flow scenarios were analysed using HY-8 software. The HY-8 results aligned with the 2D HEC-RAS model results, i.e. surcharging of the culverts and backwatering upstream but no overtopping of Poole Creek Road during the 2025 Outburst Event and overtopping during the Post-2025 Outburst Event 200-year Fall Clearwater and Debris Flood flows. Profiles presenting water surface elevation through the culvert for each scenario are presented in Figure 5-6, Figure 5-7, and Figure 5-8.

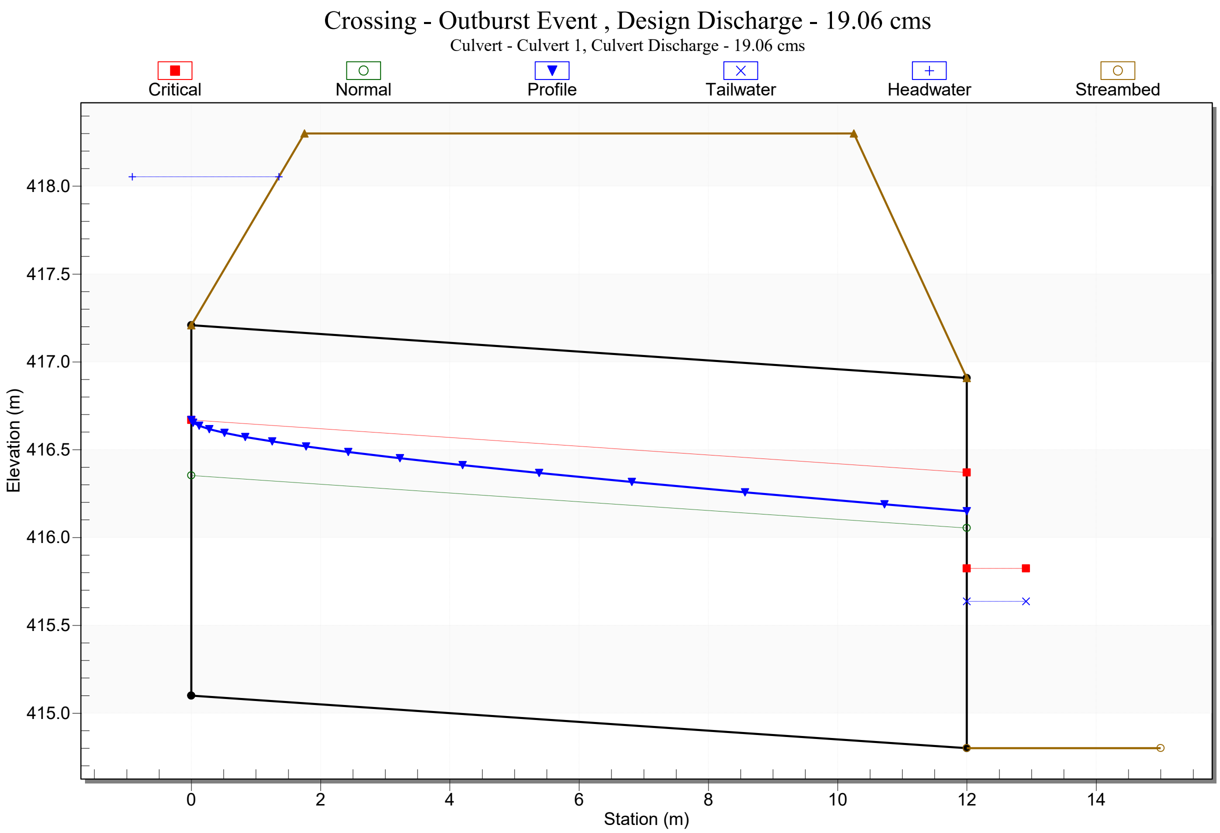

Figure 5-6. HY-8 Results for the 2025 Outburst Event

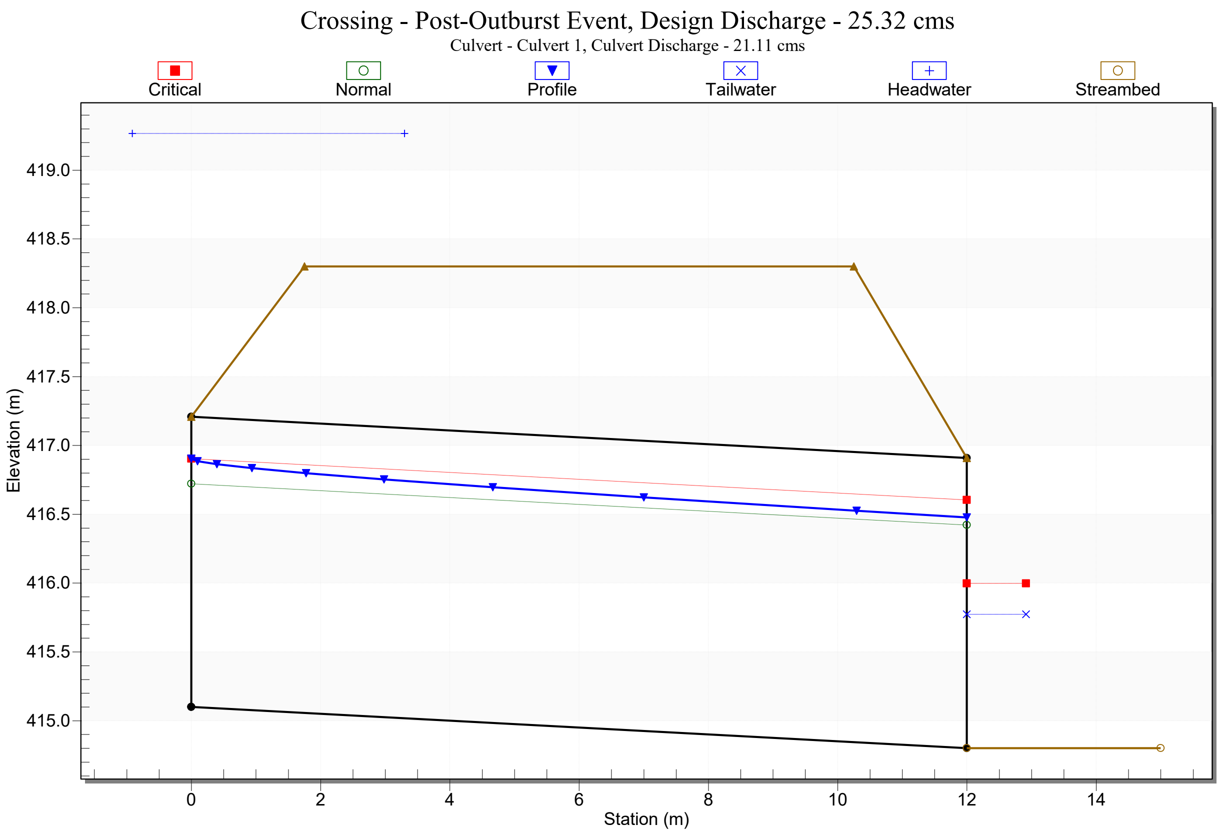

Figure 5-7. HY-8 Results for the Post-2025 Outburst Event 200-year Fall Clearwater Flow

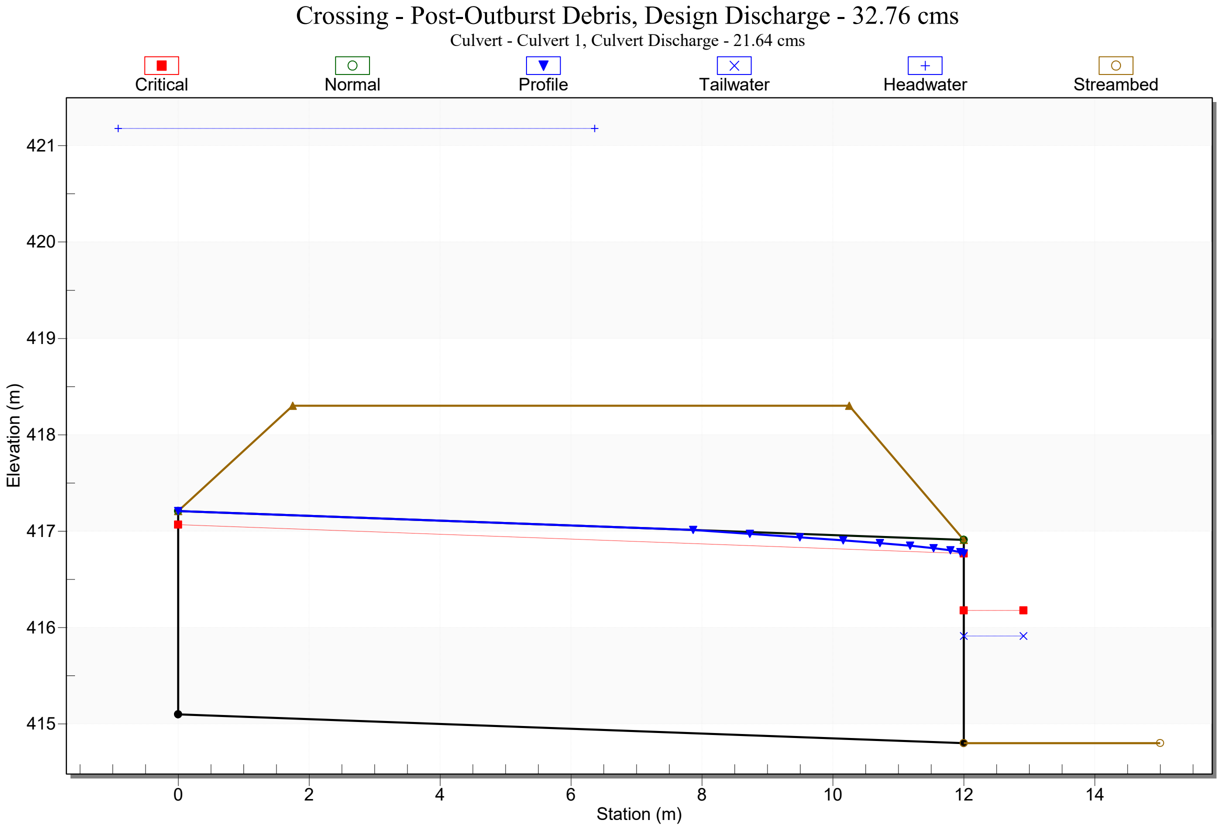

Figure 5-8. HY-8 Results for the Post-2025 Outburst Event 200-year Fall Debris Flood Flow

5.6.3 Flood Risk to Human Life & Property

Appendix B presents the 2025 Outburst Event hazard maps that were created based on the flood hazard curves defined in Section 5.2 and model results detailed in Section 5.6.1. The results indicate the potential for flood hazards from a glacial outburst event are posed to private lands between Gramsons and Birken that are adjacent to Poole Creek; however, higher-level hazards areas are contained within the creek banks and floodplains are characterized as “generally safe for people, vehicles and buildings,” equating to an H1 hazard classification. However, the community upstream of the culvert crossing at Poole Creek Road shows a large area as “unsafe for people and vehicles” and immediately upstream of the culvert as “vulnerable to structural damage,” equating to H3 and H5, respectively.

Appendix C displays the Post-2025 Outburst Event 200-year Fall Clearwater Flow while Appendix D displays the Post-2025 Outburst Event 200-year Fall Debris Flood event hazard maps based on the same aforementioned hazard classification. Similar to the 2025 outburst event, higher-level hazard areas are contained within the creek banks and the floodplains fall under the H1 class. Further, the area upstream of the culvert crossing at Poole Creek Road is again at a higher hazard level. In comparison to the 2025 Outburst Event results, the area upstream of the Poole Creek Road culvert crossing has a wider H2 classification extent.

5.7 Avulsion Hazard

The re-established embankment constructed following the 2024 Outburst event (further details in Section 2.2) was eroded and damaged due to the 2025 Outburst Event (further details in Sections 2.4). If the erosion site is left unprotected, further bank retreat at this location could results in an avulsion and routing of flow potentially back along the 2024 Outburst Event avulsion alignment towards Gates Lake. To determine whether remedial actions are required to mitigate the potential for an avulsion to occur in response to peak fall flows, terrain modifications were made to the 2D HEC-RAS model to account for potential further bank retreat towards the 2024 avulsion channel (Figure 5-9). The results show that if the bank is left unprotected and eroded further back there is low probability of an avulsion occurring in 2025 during the Post-2025 Outburst Event 200-year Fall Clearwater or Debris Flood Flow events (Figure 5-10 & Figure 5-11). The 2025 Outburst Event flow was also run through the modified terrain model which showed that there was a higher potential for an avulsion to occur at this location routing flow back through the 2024 avulsion channel towards Gates Lake (Figure 5-12).

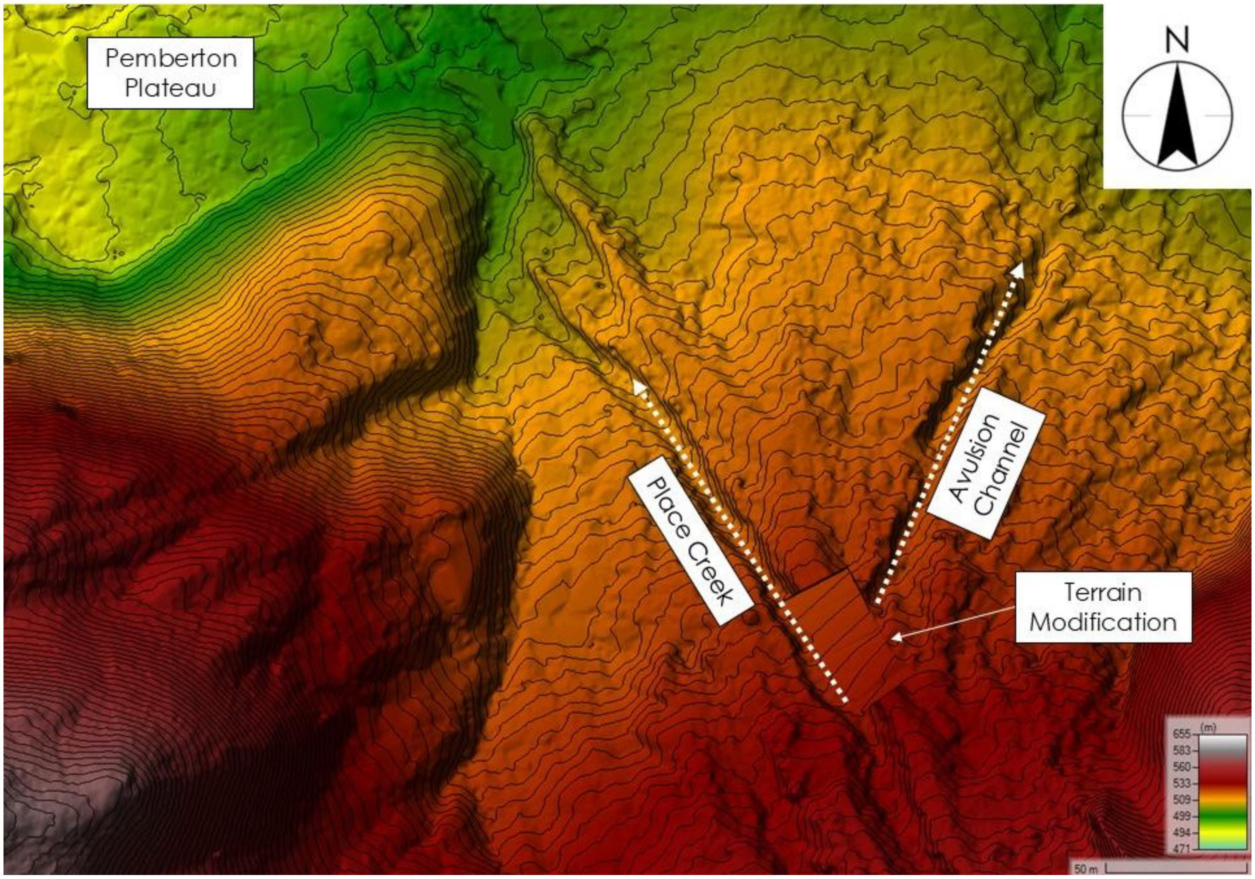

Figure 5-9. Terrain Modification For Full Erosion of Bank at 2024 Avulsion Point

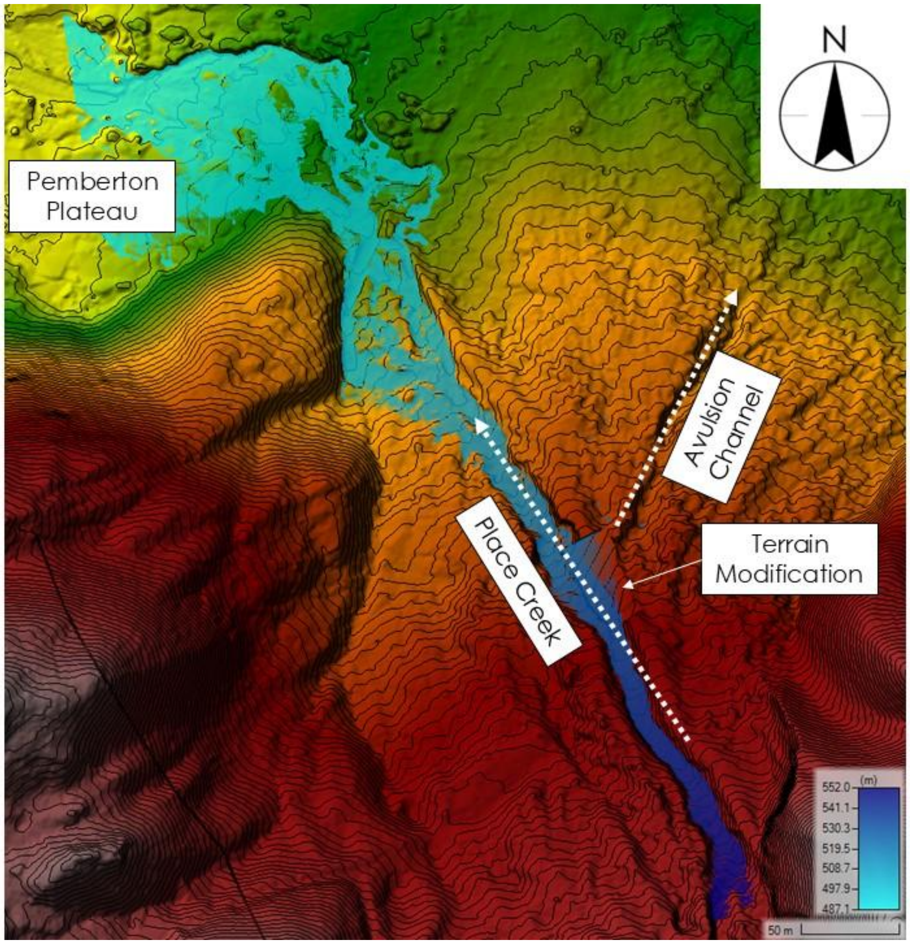

Figure 5-10. Result of Post-2025 Outburst Event 200-year Fall Clearwater Flow on a Fully Eroded Bank

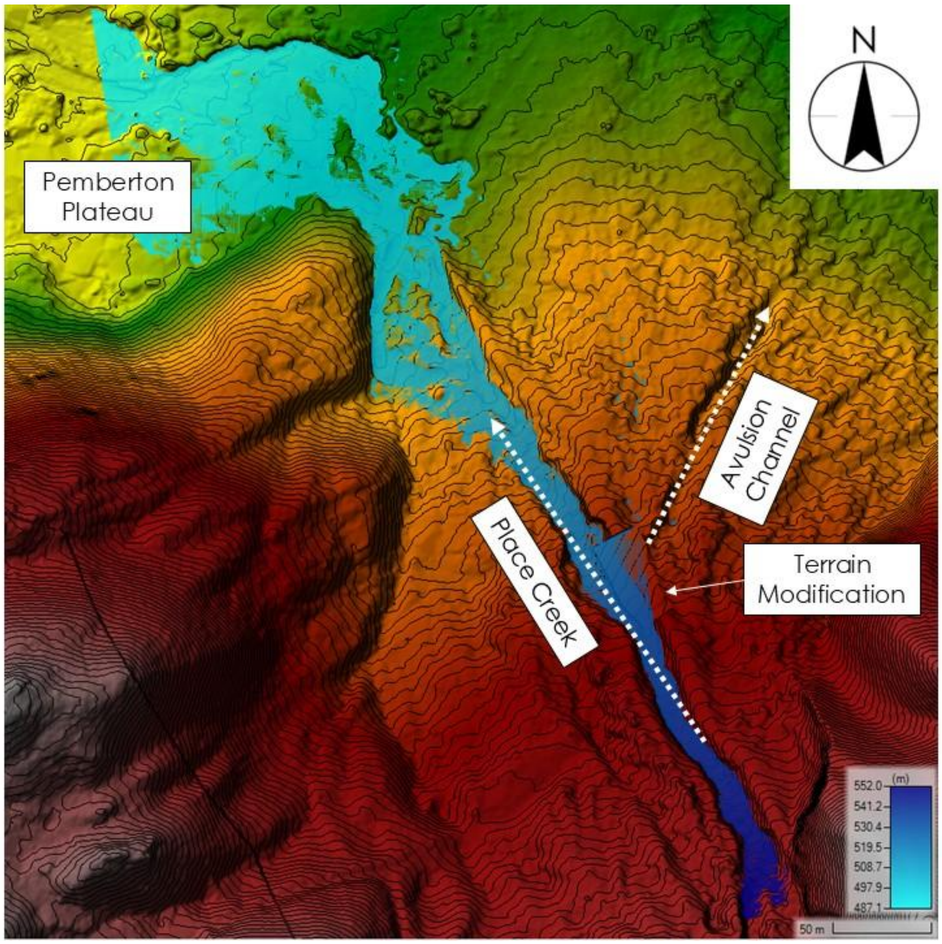

Figure 5-11. Result of Post-2025 Outburst Event 200-year Fall Debris Flood on a Fully Eroded Bank

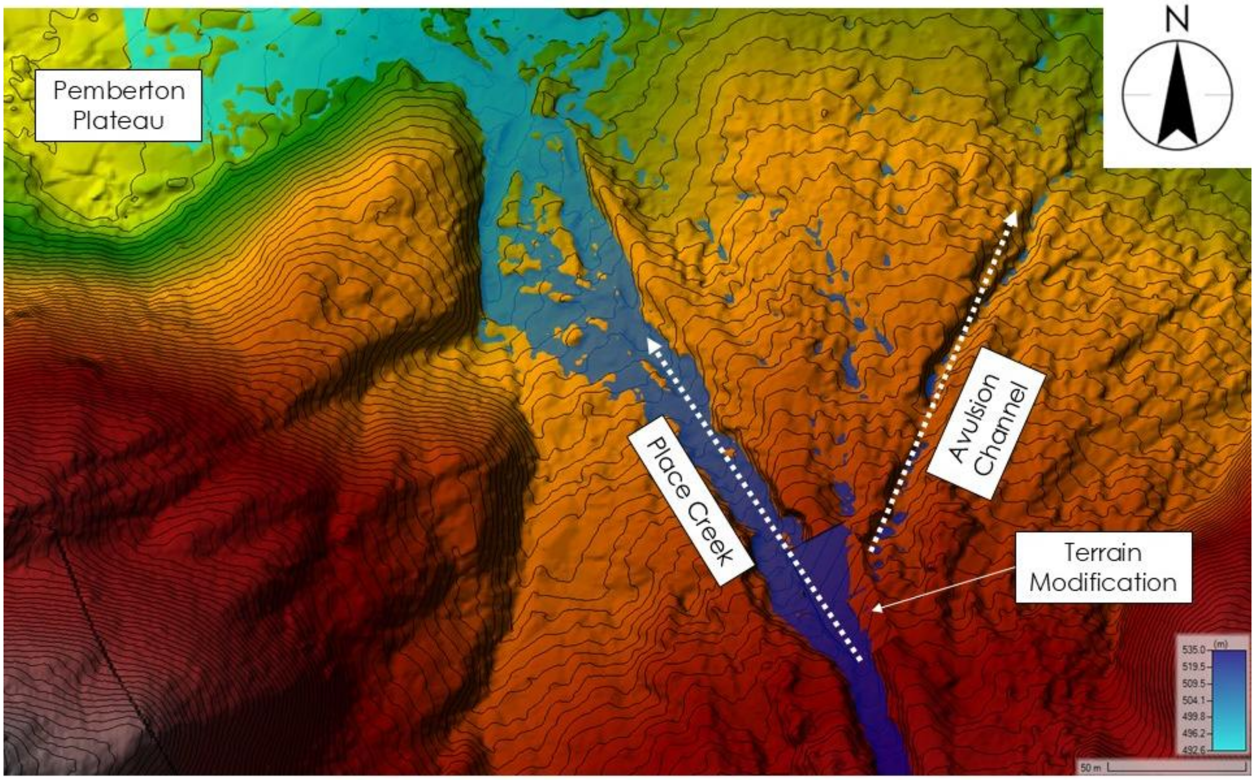

Figure 5-12. Result of 2025 Outburst Event Flow on a Fully Eroded Bank

5.8 Summary

Comparing hydraulics and hazard ratings from the 200-year return period fall clearwater and debris flood flows to the 2025 Outburst Event flows, demonstrate that the flood extents and hazard magnitudes are similar between all three scenarios; however, the extents are slightly larger within Poole Creek for the fall flow scenarios and slightly larger within Place Creek for the 2025 Outburst Event scenario. In all scenarios the Poole Creek Road culvert crossing was found to surcharge and backwater upstream flooding large areas of private lands – hazard ratings within these flooded areas were also high with some areas “unsafe for people and vehicles” or “vulnerable to structure damage”. Overall higher hazard level areas are contained within the channels with floodplains characterized as “generally safe for people, vehicles and buildings” with flow encroaching upon several structures. A critical conclusion that can be taken away from this Project is that hydraulics, flood extents, and hazard ratings associated with the 2025 Outburst Event are equivalent to the 200-year return period fall clearwater and debris flood flows. The 200-year return period can also be described as a 0.5% probability of occurring in any given year while an outburst event has now occurred in 2024 and 2025 and is anticipated to continue to occur yearly until Place Glacier has receded far enough to eliminate the depression where the ice-marginal lake forms. In summary, the communities adjacent to Place Creek and Poole Creek may be subject to flood hazards associated with a 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. The riprap bank protection has failed and the embankment has eroded and retreated back at the 2024 avulsion location. Though the bank crest width has been reduced to 2-3 m at this location, there is low potential for a peak 2025 fall flow event to result in an avulsion; however, there is higher potential for an ice-marginal lake outburst event to result in an avulsion at this location without remedial works being implemented. The emergency works constructed in 2024 were intended to reduce the potential for another avulsion event to occur in the immediate future, they were not intended to be a long-term structural mitigation subject to multiple ice-marginal lake outburst events. Repairing the 2024 emergency works would provide temporary mitigation of an avulsion to occur in response to high flow events; however, it is unknown whether it could provide avulsion mitigation from a larger outburst event then the one experienced in 2025. Section 6 details a conceptual option to remediate the 2024 emergency works; however, as ice-marginal lake outburst events are anticipated to occur on an annual basis it is recommended that a more robust, longer term option be considered. If a longer term option cannot be implemented prior to the anticipated 2026 ice-marginal lake outburst (historically between June and July) it is recommended that the concept detailed in Section 6 be implemented by no later than May 2026.

5.9 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.).
- The 2025 Outburst Event hydrograph provided by NRCAN terminates at the peak flow as the equipment was damaged in response to the sudden drop in ice-marginal lake level. Therefore post-peak data of the event was unable to be modeled.

- Model calibration and accurate validation of the model was not possible due to the above 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 debris flood and clearwater flood assessment included in this study is not intended to align with EGBC guidelines for flood hazard assessments or flood mapping and is not 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 for various clearwater and debris flood events. 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.

6 Conceptual Design Layout

Due to the risk of erosion and avulsion at the upstream and downstream erosion sites along Place Creek (defined in Section 2.4), a conceptual design has been prepared to repair the damaged 2024 Emergency Works along Place Creek in response to the 2025 Outburst Event. The proposed remedial actions consist of re-establishing the embankment 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 sites. Conceptual drawings can be found in Appendix E.

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.

It is anticipated that while annual ice-marginal outbursts are occurring the re-established bank and other segments of the 2024 emergency response works will sustain damage and require yearly maintenance until the Place Glacier recedes far enough to eliminate the ice-marginal lake. It is unknown how the re-established bank and other segments of the 2024 emergency response works will perform during an outburst event of greater magnitude than the 2025 Outburst Event.

6.1 Conceptual Design Resource Estimates

Due to the field fit nature of the design, sourcing of material from the local debris flood deposits, and need to adapt to conditions at time of construction the opinion of probable cost has been developed based on contractor equipment and personnel hours rather than material quantities (as was done for the 2024 emergency response works). Approximate hour estimates required to construct the conceptual design is listed in Table 6-1.

Table 6-1. Approximate hour estimates for conceptual design

Item	Description	Hours
General & Site Closure	Excavator for establishing access route and site closure	30
Class 500-kg Riprap	Excavate, source, & place 500 kg Riprap (riprap sourced from debris flood deposits adjacent to site, cost includes 1 x 210, 1 x 300 Excavator)	105
Fill Material	Excavate, source, & place Fill (fill sourced from debris flood deposits adjacent to site, cost includes 1 x 210, 1 x 300 Excavator)	35
Labourer	Operator for 1 x 210, 1 x 300 Excavator	160
Construction Supervision	Engineering construction supervision during construction	170
Environmental Monitor	Environmental monitoring during construction	170

6.2 Opinion of Probable Cost

A Class D opinion of probable costs (OPC) was developed for the recommended remedial actions. A Class D OPC has an uncertainty of -30% to +50% (ACEC, 2022). The cost basis and assumptions used to derive this opinion of probable cost 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 environmental monitoring and construction review services during construction. A Summary of the OPC is presented in Table 6-2, a detailed breakdown is provided in Appendix F.

Table 6-2. Summary of OPC

Costing Element	Probable Cost
Construction	$176,300
Engineering and Environmental	$23,500
Contingency (+50%)	$99,900
Total Cost	**$299,700**

6.2.1 Project Engineering, Environmental, and Contingency Costs

Project costs include fees associated with project management, planning, engineering, and environmental design and constriction 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.

In addition, this OPC is completed 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.

6.2.2 Unit Costs

Unit costs used in the OPC (Table 6-3) were the same as used for the 2024 emergency response works (Stantec, 2024a). A detailed breakdown of the OPC can be found in Appendix F.

Table 6-3. Summary of Unit Costs

Cost Item	Description of Item	Unit Rate
General & Site Closure	Excavator for establishing access route and site closure	$565 / hr
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
Labourer	Price per hour of service	$75 / hr
Construction Supervision	Price per hour of service	$195 / hr
Environmental Monitor	Price per hour of service	$195 / hr

7 Limitations and Liabilities

The conclusions in the Report titled Place Glacier Hazard Assessment Report Memo 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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Appendices

Appendix A 2024 Place Creek Qualitative Hazard Assessment Report

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

July 24, 2025

Project/File: 111700836

Squamish-Lillooet Regional District
Mike Fusca
1350 Aster Street,
Pemberton, BC, V0N 2L1

Dear Mike Fusca,

Reference: Place Creek Visual Hazard Assessment

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 (supraglacial lake) outburst event from the Place Glacier. From June 18th to the 20th, 2025 the same lake situated on Place Glacier experienced a rapid emptying – though not a sudden outburst like experienced in 2024, this emptying appears to have caused a debris flood event within Place Creek (2025 outburst event). Based on photos provided by the Pemberton Valley Dyking District (PVDD) portions of the re-established channel banks have been damaged and sediment has deposited within the lower reaches of the channel minimizing freeboard and increasing the potential for an avulsion and re-direction of flow away from the Poole Creek catchment to the Gates Lake catchment (as happened in 2024).

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 supraglacial 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 supraglacial lake, the supraglacial lake will continue to pose a potential risk to the downstream communities from outburst events.

Stantec was retained by SLRD to complete the following tasks:

1. Conduct a visual assessment of the Place Creek channel extending from the 2024 avulsion site downstream to the confluence with Poole Creek to assess current hydrotechnical conditions (i.e. channel formation and morphology, bank erosion, channel scouring, bed material, debris jams, overland flood areas) and potential geohazards and determine whether they pose immediate hazards to the local population.
2. Conduct geohazard and debris flood risk assessments and determine whether actions are required to mitigate risks posed by current channel and supraglacial lake conditions.

This document summarizes the visual assessments conducted by Stantec as part of Task 1 above and provides recommendations to assist the SLRD with immediate emergency response planning.

2 Background

2.1 Pre-Event 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 year old), Hurley Formation, and Cretaceous-aged (70 million year 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 (Baumenn 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 Creek). A historical map from 1914 (City of Vancouver, 1914) indicates that a portion of Place Creek (referred to as Summit Creek) flowed northeast and outletted 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 outletting 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 existing in living memory and was the basis for developments along Poole Creek, Gates Lake, and Gates River.

2.2 2024 Event and Emergency Response Works

On July 22nd, 2024, a sudden and large volume of water flowed from Place Glacier into Place Creek. Based on information provided by Natural Resources Canada (NRCAN, 2025) this sudden release of water was associated with a supraglacial 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 10-12 hours and conveyed $1.2x10^6$ 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). This 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, 2024).

Stantec directed the implementation of emergency 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 results of extreme rainfall events, and the absence of quantitative hazard analyses immediate mitigative actions be taken (Stantec, 2024). For further details on the assessment please see the preliminary hazard assessment prepared by Stantec (2024).

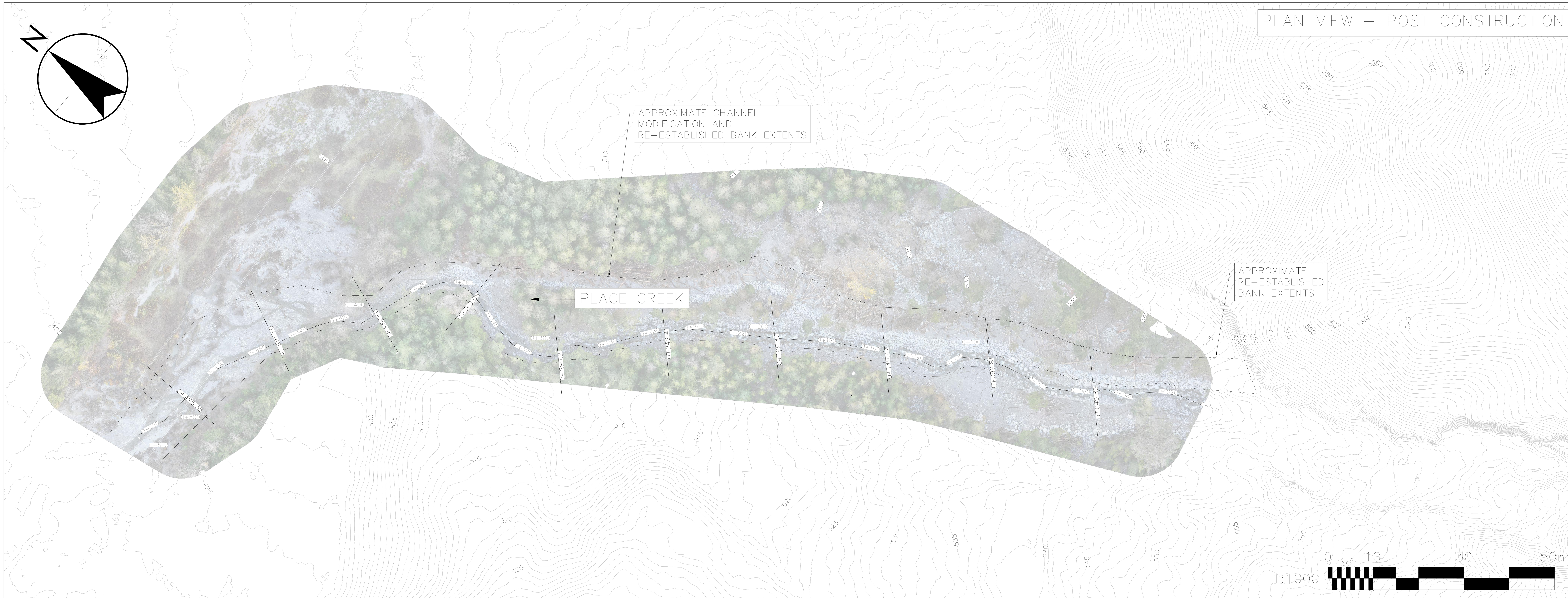
To mitigate the immediate hazard, SLRD further retained Stantec to develop an accelerated, field-based channel modification based on rudimentary hydrologic and channel capacity analyses to re-direct Place Creek back to the previous alignment and provide engineer of record services during construction.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

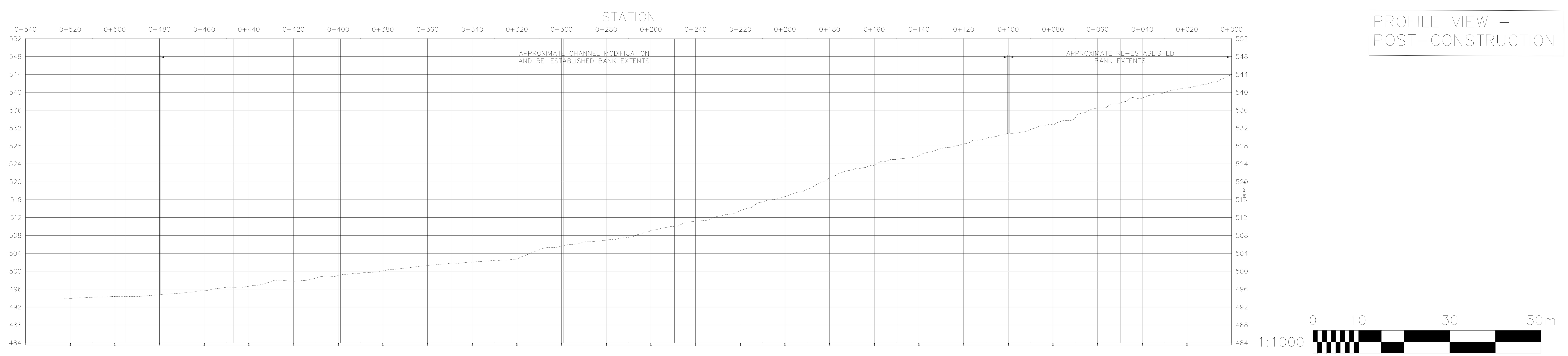
- Channel modifications are to alleviate the immediate debris flood and flood hazards posed to the properties around Gates Lake and portion of Gates River immediately downstream of Gates Lake prior to the imminent extreme rainfall events generally experienced in the fall. The channel modifications are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

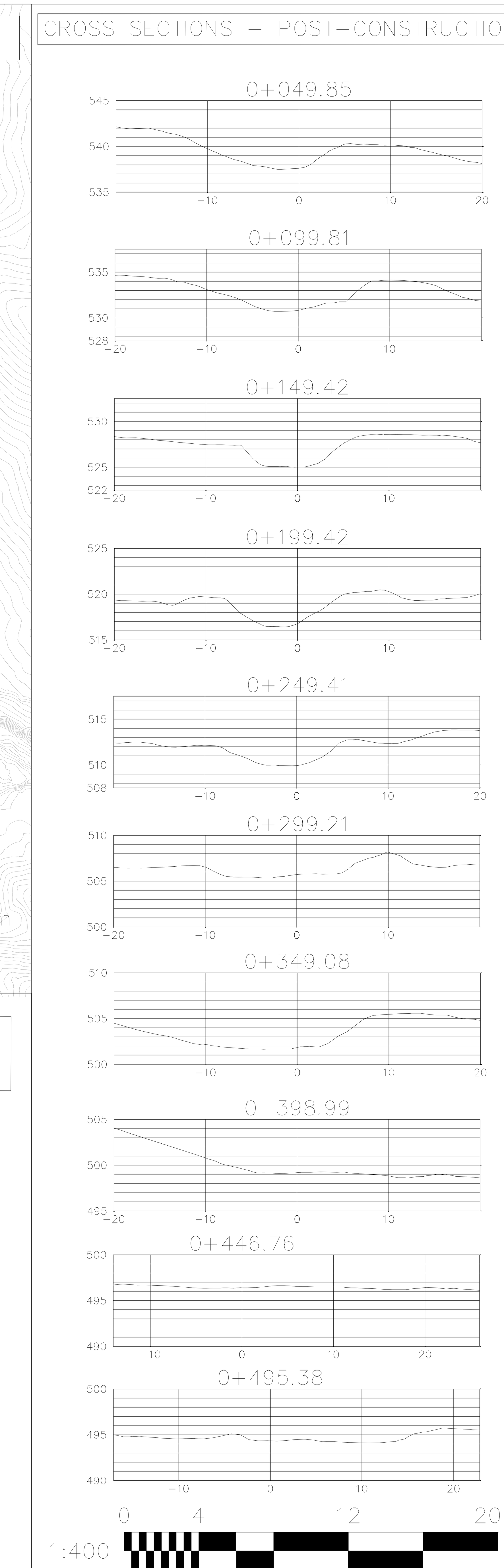
Based on these criteria Stantec developed a mitigative action concept that involved removing large woody debris jams within the previous Place Creek channel alignment, excavating a channel and re-establishing the previous Place Creek east embankment. Large boulders were sourced from the debris and placed along the east embankment to provide some form of erosion protection from high flow events. The channel

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

works were completed on September 26, 2024, Figure 2-1 presents the record drawings of the constructed mitigative works.







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Notes

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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.
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4. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS IF NOT OTHERWISE INDICATED. HORIZONTAL DATUM IS NAD83 (CSRS) Zone 10N, VERTICAL DATUM IS CGVD2013 (CGG2013a).

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PLACE CREEK CHANNEL REALIGNMENT

Project No.
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Revision	Date
0	NOV/8/2024
SCALE	**Figure No.**
SEE DRAWING	1

2.3 2025 Event

NRCAN installed a real-time monitoring equipment in the depression that the 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 supraglacial lake began to form sometime on or before May 27, 2025. On June 11, 2025, the lake depth was estimated to be 24m and contained about 40% of the water that was impounded immediately prior to the 2024 outburst event (Figure 2-2) – NRCAN indicated that an outburst event should be anticipated when the lake deepened by another 4 m (i.e. reached about 50% of the 2024 lake volume) (NRCAN, 2025).

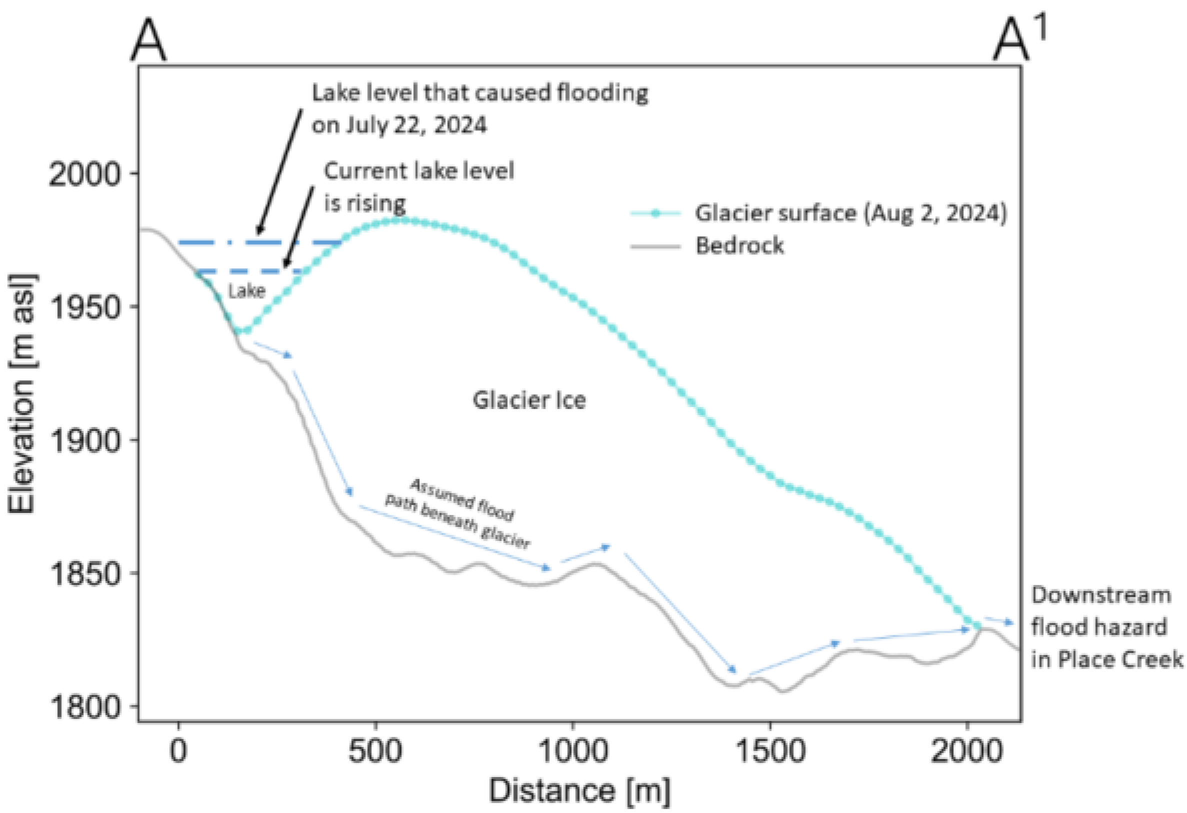

Figure 2-2 Cross section of ice surface and bed elevation of Place Glacier showing June 11, 2025, supraglacial lake level (NRCAN, 2025)

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 outburst event (SLRD, 2025).

From June 18 to the 20th, 2025, an outburst event occurred from the supraglacial lake on the Place Glacier resulting in a debris flood event within Place Creek (2025 outburst event). As Stantec understands, NRCAN is processing data from the monitoring equipment and that this data will be available to support the quantitative hazard assessments that are ongoing.

3 Visual Hazard Assessments

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 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 supraglacial 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.

This section summarizes the visual observation assessments – extents of the assessments are presented in Figure 3-1.

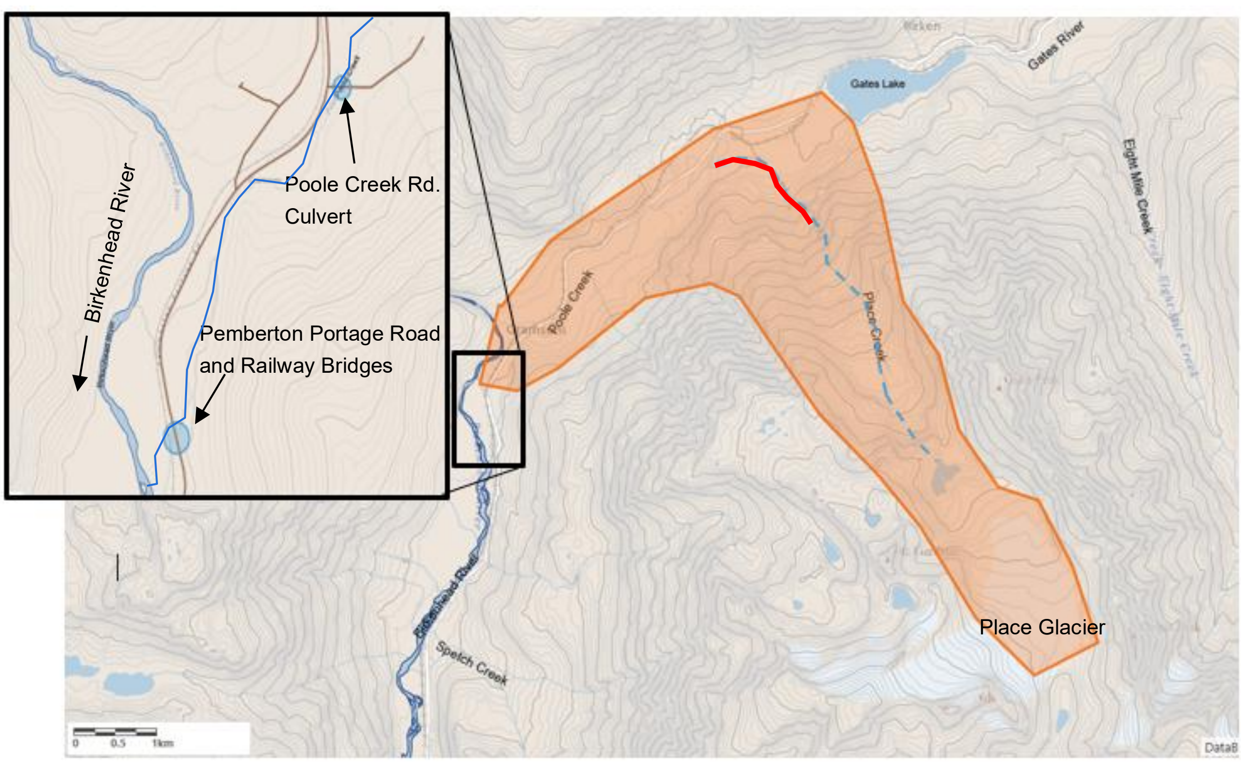

Figure 3-1 Extents of aerial (orange area) and ground based (red line and solid blue circles) visual assessments.

3.1 Debris Flow Visual Hazard Assessment

On July 4, 2025, Mr. Graham Knibbs (P.Geo.), of Stantec, conducted an aerial survey, via helicopter, of the Place Glacier and downslope area between Gates Lake and the confluence of the Birkenhead River and Poole Creek. On route to the site, representatives of the Geological Survey of Canada (GSC), who were conducting a separate assessment on the glacier, were dropped off at the lower cirque lakes prior to Stantec's completing the aerial assessment. Weather conditions were favorable during the flight with clear skies and ultimately unhindered atmospheric visibility. Through the course of the assessment, Mr. Knibbs collected video and GPS referenced photos at varying elevations (Figure 3-2).

The intent of the aerial assessment was to identify steep slope hazards that may pose an imminent threat to public safety. The secondary goal of the aerial assessment was to collect visual observations of the event and current site conditions that would inform the subsequent modelling and risk assessment planned for the area (e.g., geomorphology, current glacier conditions etc.). Inferences stated herein for this subsection are largely based on observations made Stantec during the aerial survey; notably Mr. Knibbs also conducted the 2024 aerial assessment following the last glacial lake outburst event, which provided additional context to his observations during the assessment.

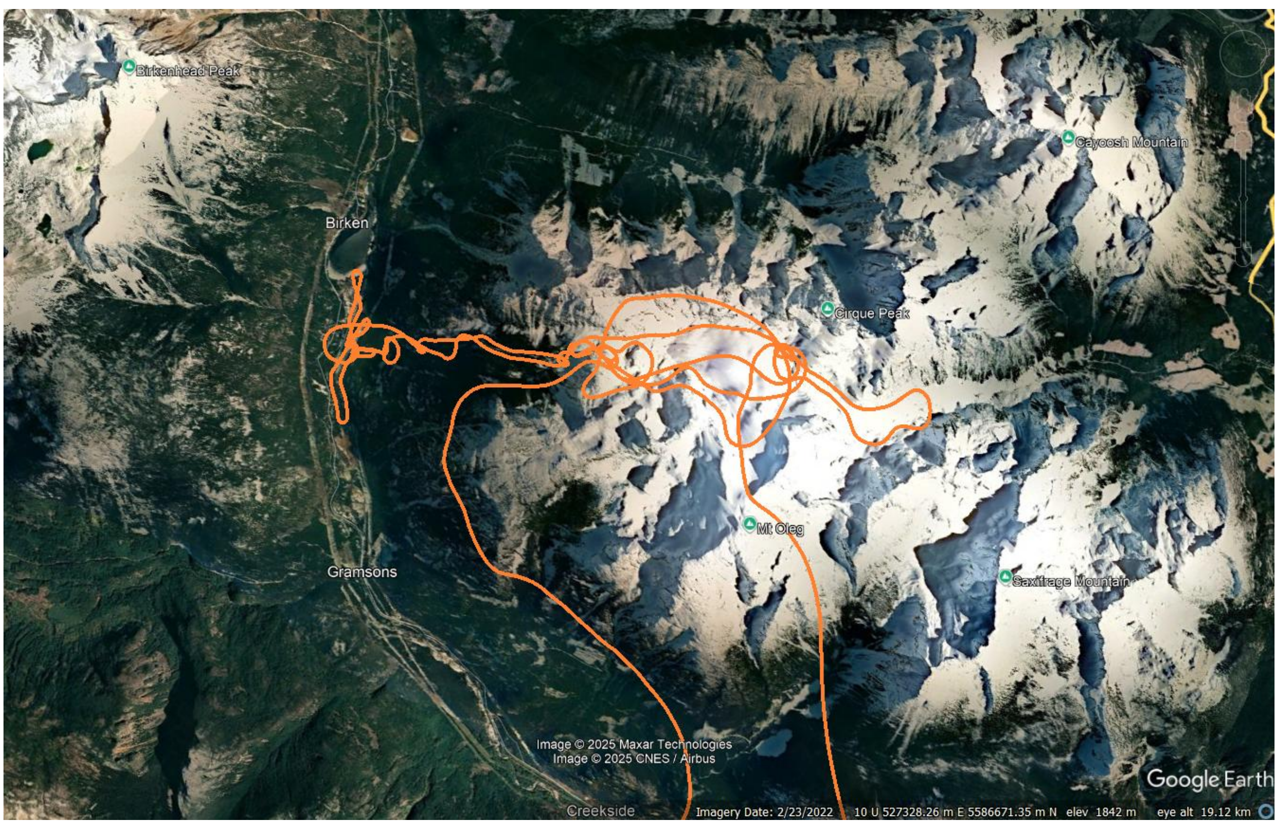

Figure 3-2. Flight path taken during aerial survey on July 4, 2025.

During the aerial assessment, Stantec first flew the supraglacial lake in the higher elevations to observe the source waters of the outburst event. Stantec observed some ponding water in the lakebed; however the amount was much lower than the inferred maximum levels of the lake prior to the event occurrence, as evident from the ice floats laying on the glacier ice denoting the relative lake levels prior to the flood (Figure 3-3). No evidence of overland flow along the ice surface to, or from, the upper lake was observed. Based on these observations, and through conversation with the GSC, who were monitoring the lake with pressure transducers at the time of the event, it was inferred by Stantec that the initiation mechanism for this event closely mimicked processes of the outburst event of 2024 (i.e., melt waters filled the upper lake until the hydrostatic head was sufficient to elevate the glacial ice and drain impounded waters along the basal surface to the lower cirque lakes, resulting in the outburst).

Based on the observed condition of Place Glacier (i.e., the extent and inferred volume of ice remaining), it is anticipated the upper lake area will continue to impound water again over time and pose a similar threat in the future. The rate of this is unknown at this time and was not ascertained during this assessment.

Figure 3-3. (Left) Viewing north at the upper cirque lake (supraglacial lake). (Right) Viewing east at the same lake for varied perspective. Some standing water was observed in the lakebed.

At the distal limb of the glacier, above the lower cirque lakes, the ice appeared structurally competent and no evidence that may indicate imminent glacial calving was observed (e.g., large fractures in the ice). The lip (outflow) of the glacial lake, where a weir was constructed and now remains destroyed, is rock (i.e., not a morainal dam, that could be more susceptible to failure).

Deposits of mass wasting along the steep slopes of the cirque, including rock fall and rock slides, were observed upslope of the lower cirque lakes (Figure 3-4). Most of the observed deposits were inferred to be low volume spalling events that deposited on well-established talus slopes – no large colluvial blocks were observed in the area.

Some localized faults and areas of poor bedrock quality were identified in the steep bedrock slopes and buttresses in the upper cirque. Slope stability along the upper elevation bedrock slopes was inferred to be variable with most areas being deemed susceptible to continued mass wasting. No evidence that would indicate an imminent threat to public safety was observed (e.g., a landslide event that may enter the lower cirque lakes and initiate an outburst flood).

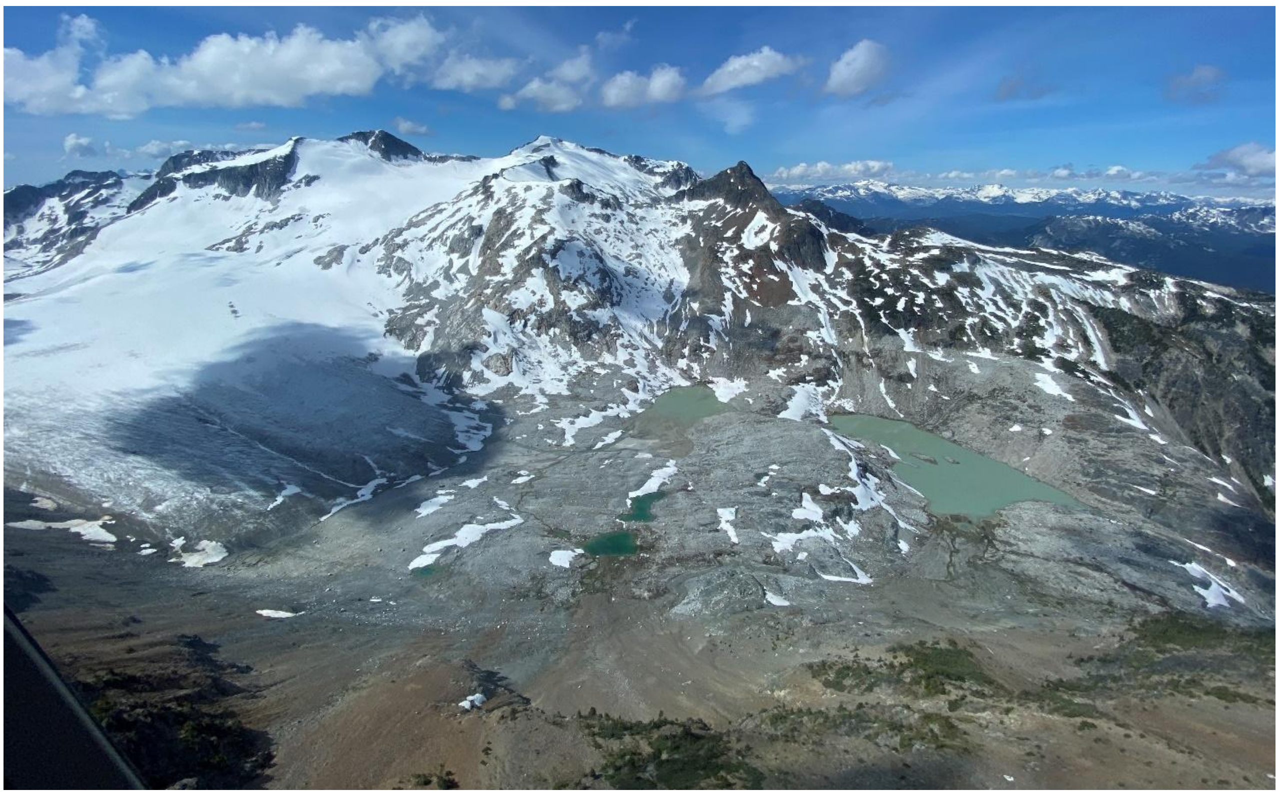

Figure 3-4. Viewing south-southwest at distal limb of the glacier and steep slopes above the lower cirque lakes. (Note: the supraglacial lake (source of the outburst event) is just out of frame to the photo left).

Evidence of debris flows along the aproning slopes below the outlet of the cirque were identified. These slopes comprise deep deposits of reworked till, colluvium and fluvial sediments (Figure 3-5). Stream flow through Place Creek along the outflow of the cirque was observed to be actively under cutting the unconsolidated banks of the stream here. Consequently, raveling and channel erosion and expected to occur frequently until the stream returns to a stable flow – this time frame is unknown. This reach of the stream can provide an ultimately *unlimited* sediment supply, that is anticipated to be entrained and reworked by stream flow during high flow events, such as sustained melting or rainfall events, or another outburst event. This will contribute to stream bulking and consequently elevates debris flood and landslide (debris flow) hazard down gradient.

Figure 3-5. View of the outlet of cirque lakes. Evidence of debris flows were identified here.

In the mid to lower reaches of the stream, large woody debris and evidence of bank erosion were identified. No woody debris jams or stream occlusions were observed; tree canopy did obscure some areas of the gully channel.

At the time of the assessment, flow from Place Creek was directed south to Poole Creek; however, evidence of recent stream flow and flooding – both overland flows and channelized flows - were observed along the BC Hydro right-of-way towards Gates Lake. The flow along these areas of the right-of-way appeared ephemeral, and where water was observed, it appeared stagnant at the time of the assessment.

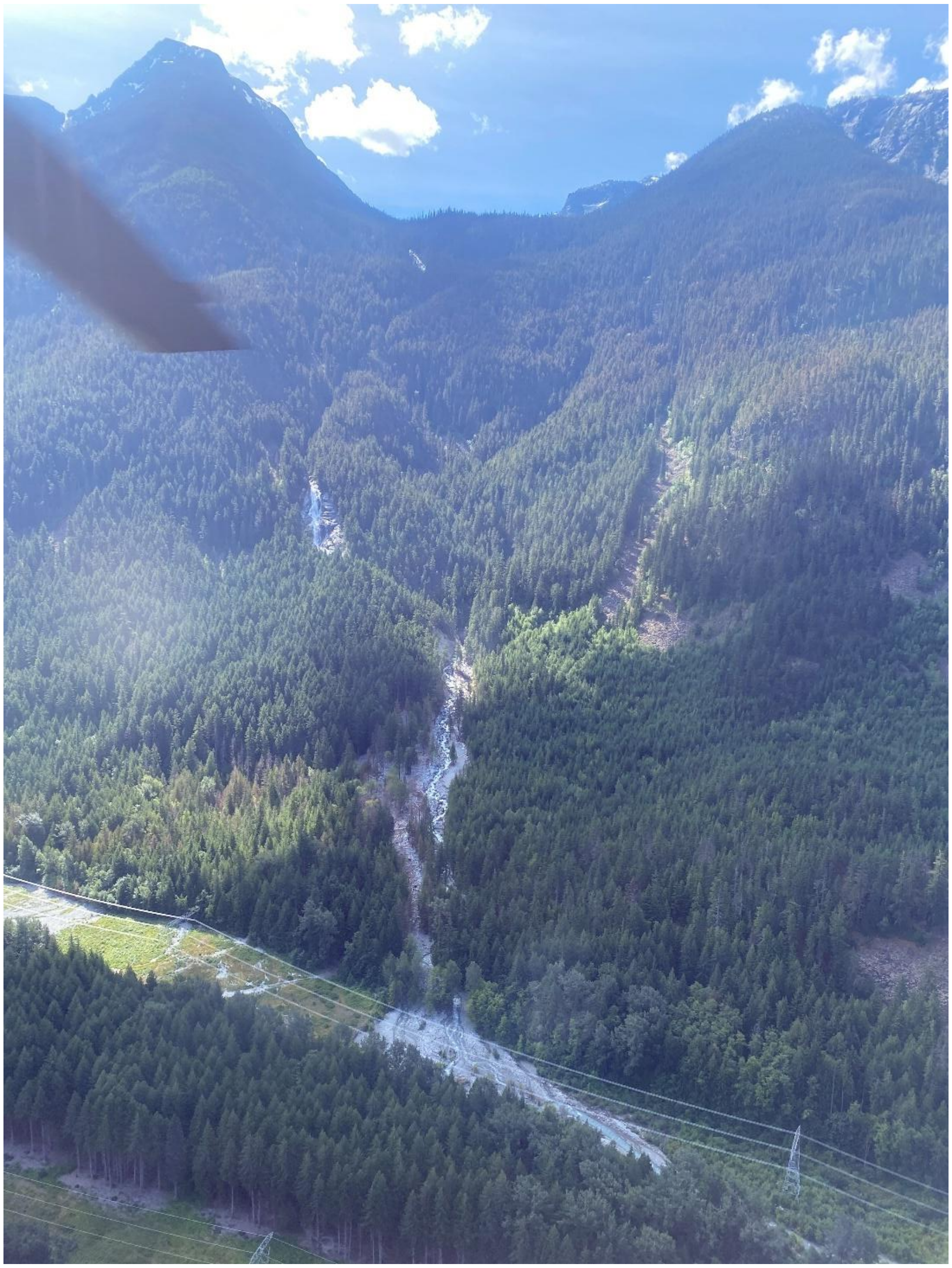

Figure 3-6. Overview of flood deposits in lower reach of Place Creek. Flow can be observed flowing south (image right) towards Poole Creek.

Based on observations of the aerial assessment, slopes susceptible to debris flows were identified downslope of the glacial cirque, along Place Creek. However, low gradient depositional slopes, up-gradient of private property in the area were identified (depositional slopes along the BC Hydro right-of-way shown in Figure 3-6). Debris deposits are anticipated to be remobilized through fluvial processes.

Beyond an anticipated outburst flood to occur in the future as the supraglacial lake refills, no imminent hazard that would pose a threat to the public safety was observed during the course of the assessment.

Based on the timings of outburst events of 2024 and in 2025, it is anticipated that another flood event may occur in 2026; however, increased melt conditions (e.g., heat waves, rain on snow events etc.) may exacerbate the rate of filling in the supraglacial lake and accelerate the timing of the anticipated hazard.

3.2 Debris Flood Visual Hazard Assessment

The following section discusses observations collected by Stantec during the 2025 visual debris flood hazard assessment and compares them to photos collected immediately following the completion of the 2024 emergency response works. Observations are broken down into four linear reaches of Place Creek and Poole Creek:

1. Place Creek Mountainous Reach – extending from the upstream extent of the 2024 emergency response works down to the transition with the Pemberton Plateau (red reach in Figure 3-7)

2. Place Creek Plateau Reach – continuing from the downstream extent of the Place Creek Mountainous Reach to the confluence with Poole Creek (green reach in Figure 3.-7)

3. Poole Creek Road Culvert Crossing of Poole Creek – portion of channel extending 50 m upstream and downstream from the Poole Creek Road Culvert (Figure 3-1)

4. Pemberton Portage Road and Railway Crossing of Poole Creek – bridge crossings immediately upstream from Poole Creek confluence with Birkenhead River (Figure 3-1)

Figure 3-8 overlays observations and comparison photos over the 2024 emergency response works record drawings. All photos are taken on July 8, 2025 by Stantec unless otherwise specified.

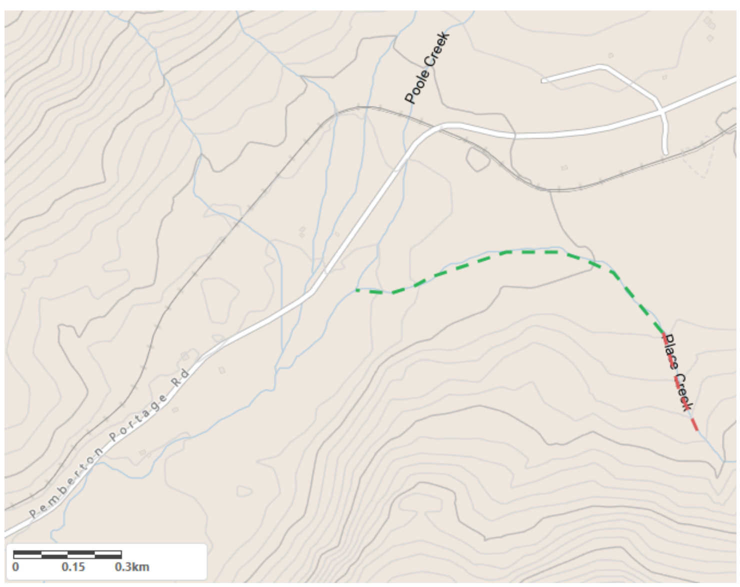

Figure 3-7 Extents of ground based visual assessment along Place Creek. Red line is the Mountainous Reach and green line is the Plateau Reach

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Notes

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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

3.2.1 Place Creek Mountainous Reach

At the furthest upstream extent of the 2024 emergency response works the channel had scoured and incised down into the sediments deposited during the 2024 outburst event which had resulted in undermining of the right bank riprap toe in localised areas. In these areas the riprap was perched above the channel bed and unstable (Figure 3-10); however, the majority of the riprap was in good condition with tightly interlocked stones, minimal voids and little evidence of slumping or displacement – a comparison of 2025 to 2024 conditions is provided in Figure 3-9. The unprotected left bank of the channel experienced erosion and retreat resulting in near vertical 2 to 5 m high bank slopes (Figure 3-11).

Figure 3-9 Looking upstream at upstream extent of 2024 emergency recovery works. Left image is 2025 and right image is 2024.

Figure 3-10 Localised areas where scour and incising of channel has undermined right bank riprap

Figure 3-11 Looking downstream at scoured and incised channel and eroded left bank from upstream extent of 2024 emergency response works.

These channel conditions continued downstream for approximately 80 m. At this location approximately 20 m of the right bank riprap failed and the bank eroded back resulting in a vertical 4 to 5 m high wall (Figure 3-12). Following the 2024 emergency works the crest of the right embankment at this location was approximately 5 m wide before dropping down to the 2024 outburst avulsion channel. The crest width is now 2 to 3 m wide and lacking erosion protection. Further bank retreat at this location could result in an avulsion and routing of flow potentially back along the 2024 outburst event avulsion alignment towards Gates Lake.

Figure 3-12 Looking downstream towards failed riprap and vertical face of eroded embankment

The right bank riprap extending approximately 30 to 40 m downstream from this location was in good condition with tight interlocking of stones and no scouring or undermining of the toe observed. At this location the channel had incised down into the 2024 outburst sediment and exposed a stand of trees. Flow appears to have been deflected by this stand of trees and concentrated along the right bank resulting in failure of the riprap along a 20 m long section of channel (Figure 3-13). At this location the crest width following the 2024 emergency recovery works was approximately 10 m wide before gradually tapering down into the forested mountain terrain. The bank erosion has reduced the crest width to approximately 7 m wide at this location – an avulsion of the channel due to further bank retreat at this location is not anticipated.

Figure 3-13 Looking downstream towards failed riprap

The channel continues downstream from this location a further 40 m with the right bank riprap in good condition and channel incised down into the 2024 outburst sediment. At this location the gradient flattens out and 2025 outburst sediment appears to have deposited, filling the 2024 emergency response channel (Figure 3-14). Flow is now being conveyed through multiple channels incised into the 2025 outburst sediment extending from the left valley wall to the 2024 emergency response east embankment (Figure 3-15).

Figure 3-14 Looking upstream where channel gradient flattens and 2025 outburst sediment has filled the 2024 emergency response channel (left image 2025, right image 2024)

Figure 3-15 Looking downstream at deposited 2025 outburst sediment and multi-channel flow.

At the downstream extent of the mountainous reach the flow transitions back to a single channel along the 2024 emergency response alignment; however, deposited sediment, large woody debris, and channelization within the deposited sediment along the right riprap embankment indicate that flow during the 2025 outburst event had encroached upon the right embankment (Figure 3-16).

Figure 3-16 Looking upstream at re-channelized flow along the 2024 emergency response channel alignment and deposited sediment and large woody debris along the right riprap embankment

At the downstream terminus of the right embankment riprap flow overtopped the right embankment, evidenced by woody debris and fine sediment deposited along the crest of the embankment and through the adjacent forest, resulting in failure of the riprap and the placed embankment fill (Figure 3-17 and 3-18). At the time of the assessment this area was dry; however, based on deposited fine sediment and woody debris flow appears to have been conveyed 40 m past this failed section of embankment east through the forest towards the Pemberton Plateau but then routed back west and rejoined Place Creek.

Figure 3-17 Looking downstream at terminus of right embankment riprap (left image 2025, right image 2024

Figure 3-18 Failed portion of right embankment and riprap

3.2.2 Place Creek Plateau Reach

Within the reach of Place Creek that extends downstream along the Pemberton Plateau to the confluence with Poole Creek flow following the 2025 outburst event appears to be conveyed through the 2024 emergency recovery channel alignment. There is evidence of sediment deposition along the flood plains of the channel; however, it is difficult to determine whether this was deposited due to the 2024 or 2025 outburst events (Figure 3-19). Some large woody debris may have been deposited at the two large woody debris sites that were cleared from the channel as part of the 2024 emergency recovery works but based on photo comparison it does not appear that conveyance through the channel has been impacted (Figure 3-20 and 3-21).

There was no evidence of sediment deposition or bank erosion along the Poole Creek immediately downstream of the confluence with Place Creek (Figure 3-22).

Figure 3-19 Looking downstream at Place Creek through the Pemberton Plateau


Figure 3-20 Place Creek flow through 2024 large woody debris jam site (left image 2025, right image 2024)


Figure 3-21 Place Creek flow through 2024 large woody debris jam site (left image 2025, right image 2024)

Figure 3-22 Looking downstream at Poole Creek at confluence with Place Creek

3.2.3 Poole Creek Road Culvert Crossing of Poole Creek

The Poole Creek Road culvert is comprised of a 2160 mm rise, 3500mm span corrugated multi-plate steel pipe arch that is approximately 12 m long with a slope of approximately 2-3%. The head slope of the culvert and adjacent embankment slopes are armoured with approximately 500kg to 1000kg Ministry of Transport and Transit (MOTT) class riprap (Figure 3-23).

Figure 3-23 Looking downstream to inlet of Poole Creek Road culvert

The channel upstream of the culvert has a channel gradient of approximately 2-3% (Figure 3-24) with a densely vegetated right bank with mature timber that extends approximately 2 to 3 m up from the channel bed (Figure 3-25) and a poorly defined left bank that extends approximately 0.5 m up from the channel bed and transitions to a wide shallow, densely vegetated floodplain with mature timber (Figure 3-26).

Figure 3-24 Looking upstream to channel upstream of Poole Creek Road culvert inlet

Figure 3-25 Right bank upstream of Poole Creek Road culvert

Figure 3-26 Left bank upstream of Poole Creek Road culvert

Fine sediments and both large and small woody debris are placed along the left floodplain extending more than 10 m from the poorly defined bankline, It is difficult to determine the extents of the 2025 outburst sediment deposition compared to the 2024 outburst sediment deposition; however, sediments near the left bank were loose, saturated and free from established vegetation which would indicate a recent high flow event inundated the area. Sediment and small woody debris were present along the right crest of bank and the adjacent floodplain; however, the material was compact with young vegetation established indicative that this was likely deposited during the 2024 outburst event.

The outlet of the culvert is perched approximately 0.5 m above the channel bed and a scour hole of unknown depth or length has formed immediately downstream of the outlet. 500kg to 1000kg MOTT class riprap is placed along the end slope and adjacent embankment slopes; however, the toe of the riprap has been undermined by scour and the riprap is slumping down into the channel (Figure 3-27).

Figure 3-27 Looking upstream at Poole Creek Road culvert outlet

Both channel banks immediately adjacent to the culvert outlet are eroding and near vertical approximately 1 to 2 m high with densely vegetated floodplains extending away from the channel (Figure 3-28). There was no evidence of recent overtopping of the banks downstream of the culvert outlet; however, there is large amounts of large woody debris collecting within the channel approximately 20 m downstream of the culvert outlet (Figure 3-29).

Figure 3-28 Looking towards left bank downstream of Poole Creek Road culvert outlet

Figure 3-29 Looking towards large woody debris collected within channel approximately 20 m downstream from Poole Creek Road culvert outlet

SLRD indicated that during the 2025 outburst event flow came within 0.3 m of the culvert obvert (i.e. not overtopping the culvert or Poole Creek Road) while during the 2024 outburst event the flow overtopped Poole Creek Road.

These observed conditions are indicative of an undersized culvert; however, to confirm this a quantitative assessment would need to be conducted.

3.2.4 Pemberton Portage Road and Railway Crossing of Poole Creek

The Pemberton Portage Road bridge crossing of Poole Creek is located approximately 130 m upstream from the Poole Creek confluence with the Birkenhead River. The bridge (girder type unknown) has a span of 11.7 m and a distance from the low chord to the channel bed of 2.7 to 3 m (Figure 3-30).

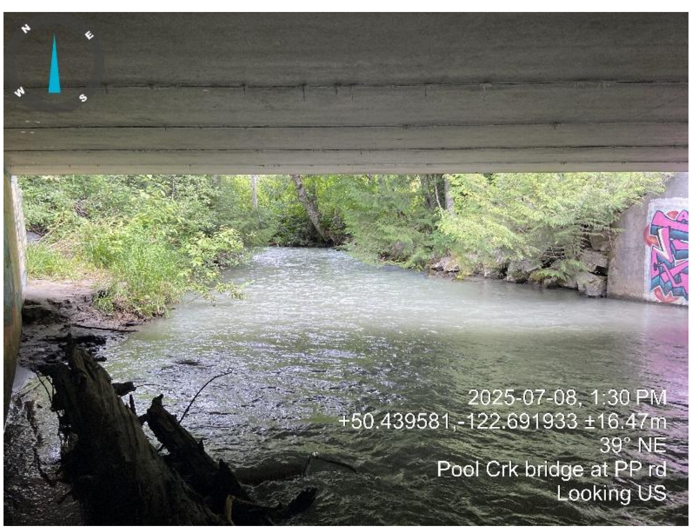


Figure 3-30 Looking upstream at channel from below Pemberton Portage Road Bridge

The abutments are comprised of vertical concrete walls (unknown whether spread footing or piles) with concrete wing wall extending approximately 2 m both upstream and downstream from the abutments (Figure 3-31). Estimated 250-kg MOTT class riprap ties into the backside of the wing walls and extend an unknown distance upstream and downstream along the banks. No scour holes were observed along the faces of the abutments, wingwalls, or riprap and the riprap appeared to be oversteepened (approximately 1H:1V slope) but stable with tight interlocking and free from displacement or slumping (Figure 3-32). One piece of large woody debris was observed along the face of the right wingwall but otherwise the bridge opening was free from debris (Figure 3-33).

Figure 3-31 Looking downstream from upstream face of Pemberton Portage Road Bridge

Figure 3-32 Estimated 250-kg MOTT class riprap along upstream left bank of wingwall

Approximately 0.2 to 0.3 m of sediment deposition was observed along the upstream right bank; however, grassy vegetation had established through it indicating this was likely deposited during the 2024 outburst event (Figure 3-33). SLRD indicated that during the 2025 outburst event there was approximately 1.5 m of clearance from the water surface to the low chord at the downstream face of the bridge.

Figure 3-33 Evidence of sediment deposition along upstream right bank of Pemberton Portage Road Bridge

The Railway Bridge crossing of Poole Creek is located approximately 30 m downstream from the Pemberton Portage Road Bridge. It has a span of 11.7 m span and a distance from the low chord to the channel bed of 2.7 to 3 m (approximately the same as the Pemberton Portage Road Bridge – Figure 3-34).

Figure 3-34 Looking upstream towards downstream face of Railway Bridge

The abutments are comprised of vertical concrete walls founded on what is assumed to be a concrete spread footing (Figure 3-34). Estimated 250-kg MOTT class riprap extends upstream and downstream from both abutments an unknown distance along the banks. No scour holes were observed along the faces of the abutments or riprap and the riprap appeared to be oversteepened (approximately 1H:1V slope) but stable with tight interlocking and free from displacement or slumping. The bridge opening was free from debris or sedimentation.

4 Summary and Recommendations

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 supraglacial lake has gone through an outburst event, 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 outburst event there was observed to be low hazard of another debris flow event occurring in the immediate future (i.e. summer months). Stantec is completing a detailed desktop assessment of debris flow runout utilizing DebrisFlow predictor software and will further assess whether a hazard is posed to the downstream population as a result of higher intensity autumn rains.

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 works, sections of the embankment riprap had failed and the embankment had retreated back 2 to 3 meters. At the location where the channel avulsed in 2024 only 2 to 3 m of crest width remain. 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 Plateau 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 inundated the portion of forest adjacent to the channel during the outburst event; however, this area was dry at the time of the assessment.

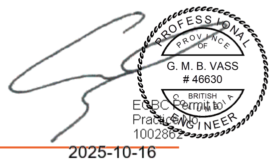
Flow within the flatter Pemberton Plateau section is largely within a single channel but secondary flood channels branch of from the main channel in places and convey small portion of flow or pooled water. Along this segment there was evidence of finer sediment being deposited and the channel incising 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, large log jams blocking the entire channel similar to what was observed and removed in 2024 was not observed.

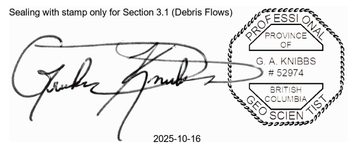
The culverts and bridges investigated were free from debris but there was evidence of resent backwatering upstream of the Poole Creek Road culvert crossing and site conditions indicated the culvert is undersized.

Based on these observations there appears to be low debris flow and debris flood hazards immediately posed to the downstream communities (i.e. during the summer months prior to more extreme rainfall that historically occurs during the fall and winter). At this time, it is unknown whether the damaged sections of the 2024 emergency recovery works pose a hazard to the downstream communities in the short term future (i.e. during the fall and winter when more extreme rainfall historically occurs). Stantec is currently completing quantitative risk assessments and hydraulic modelling of Place Creek and Poole Creek to determine whether remedial actions to repair the 2024 emergency response works is required to mitigate associated risks.

Best regards,

Stantec Consulting Ltd.





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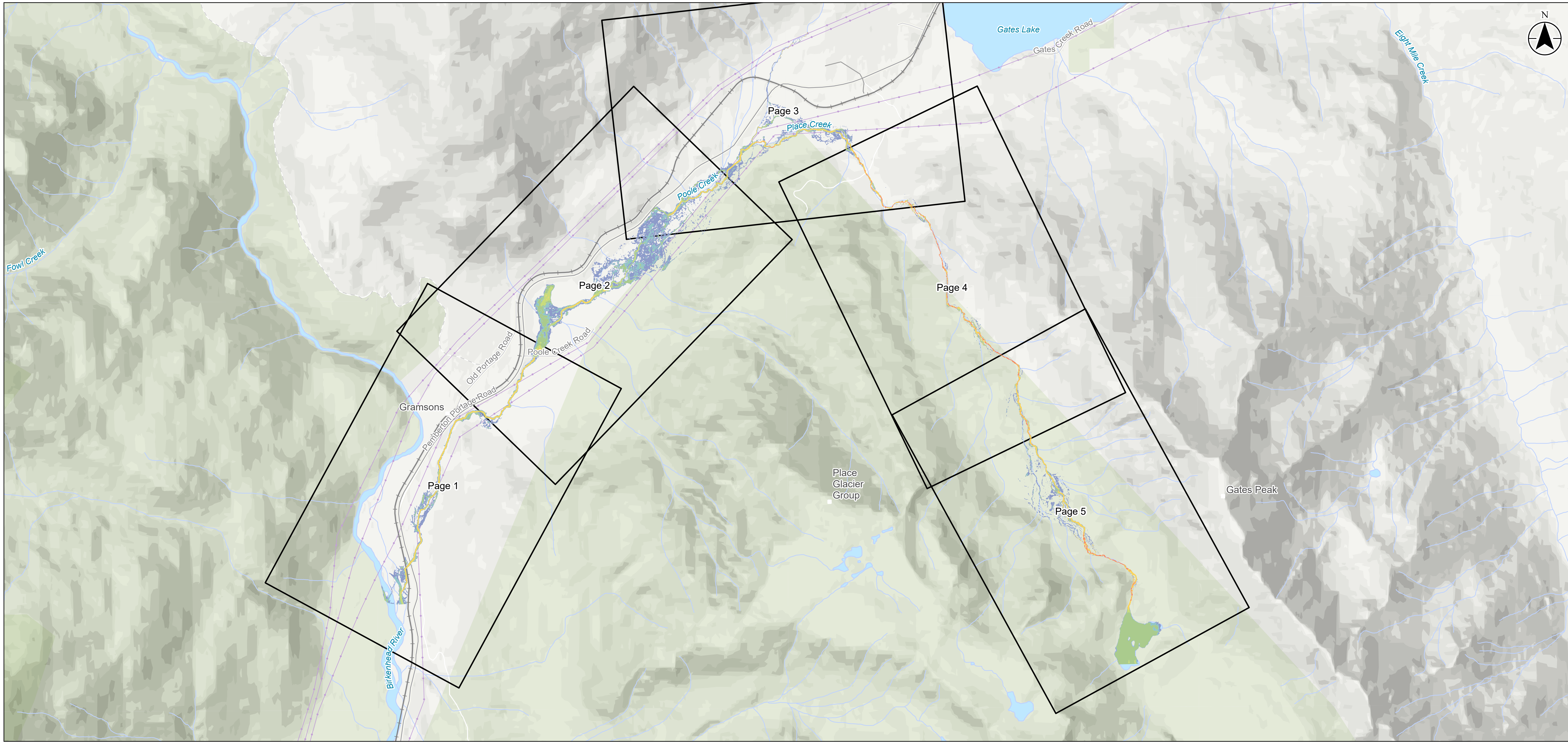
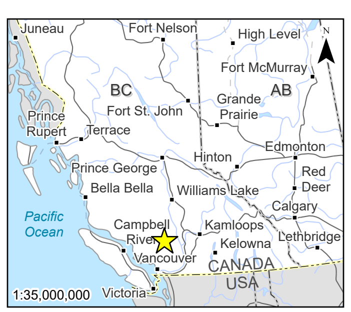
Appendix B 2025 Outburst Event Hazard Map Book





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- 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.

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2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix B

Title
2025 Outburst Event Flow Overview

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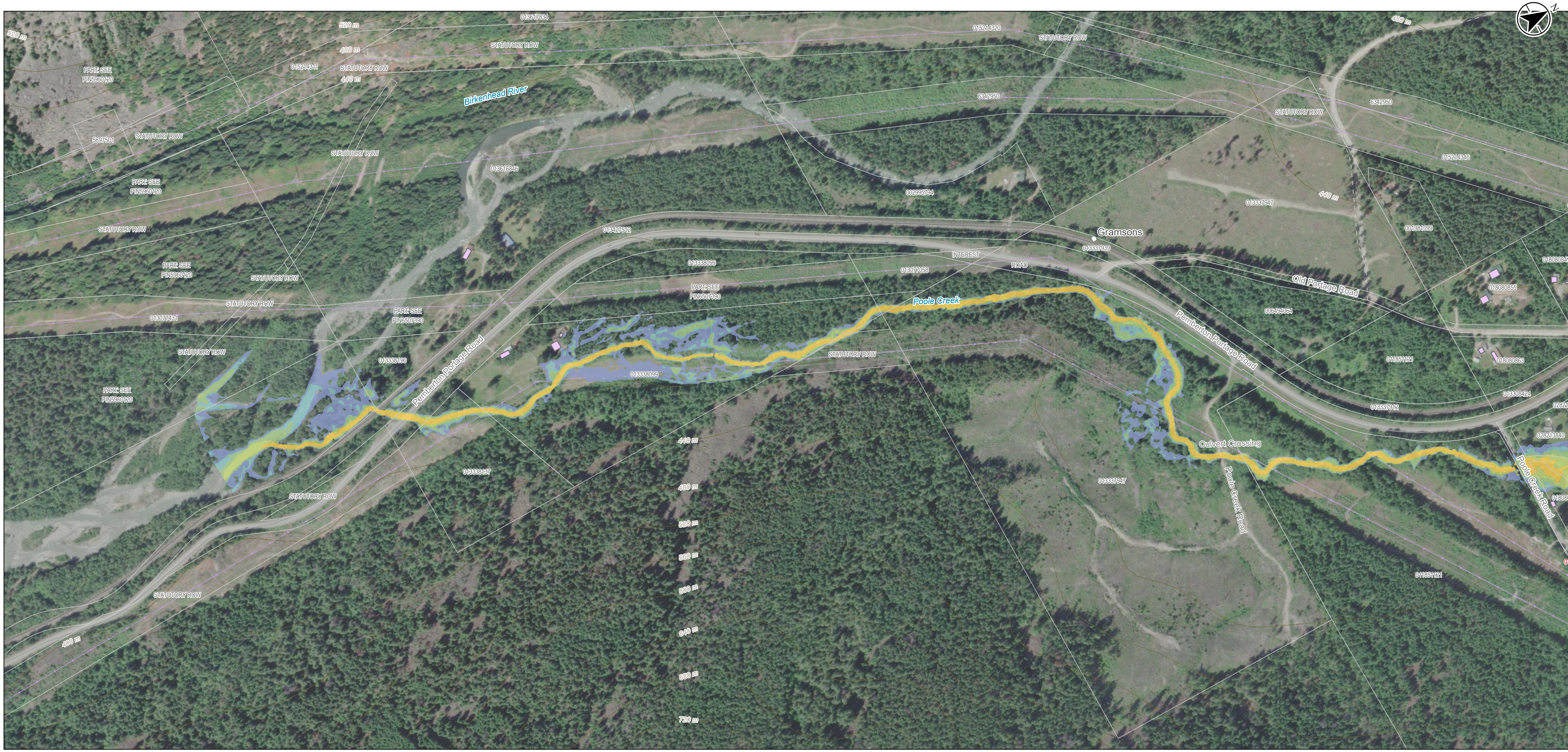

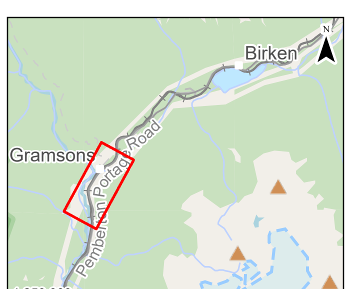

Road
Local Street
Resource Road
Railway
Transmission Line
Topographic Contour
Building or Structure

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2025 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix B**
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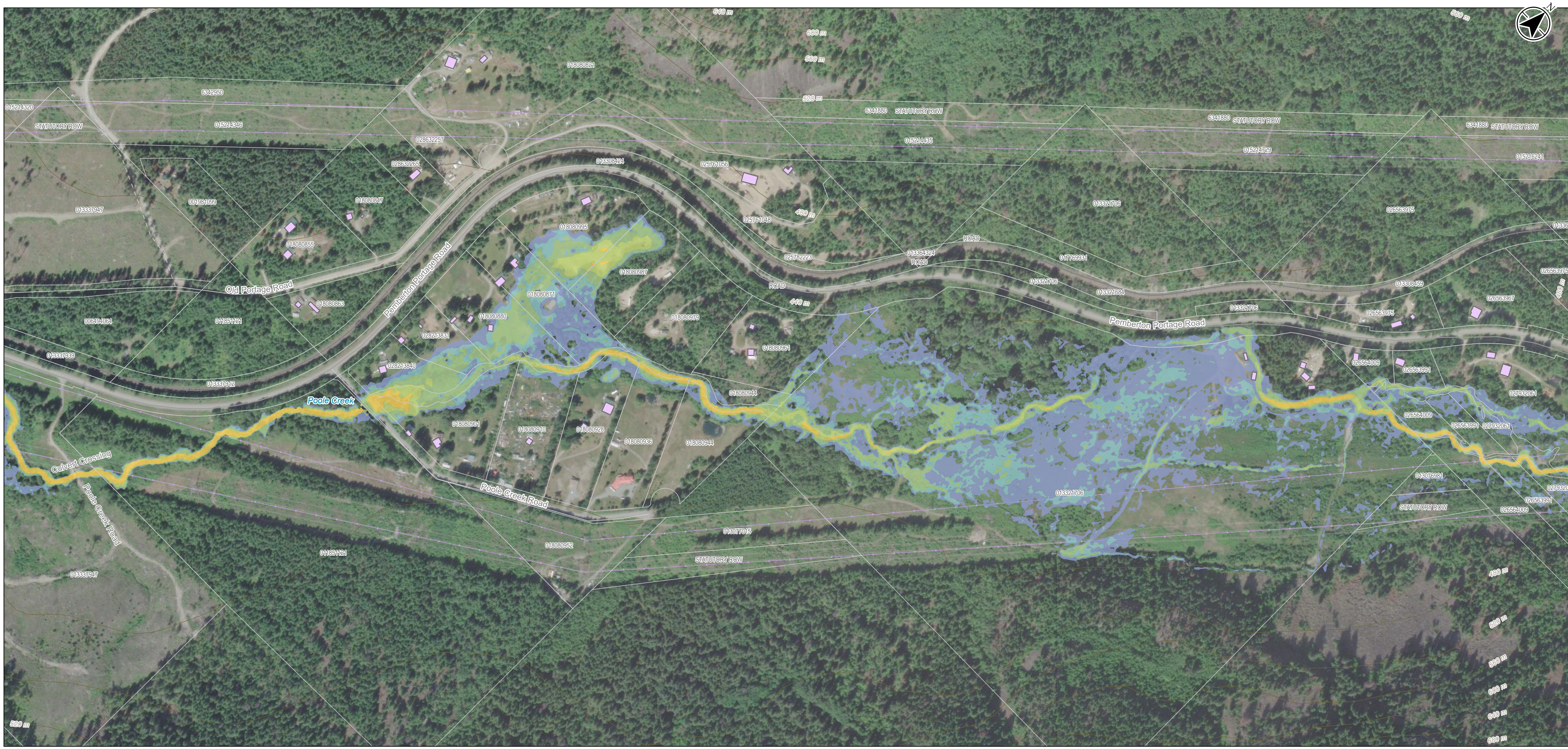
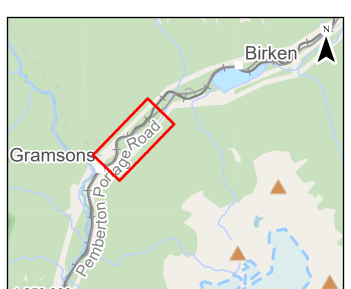
Title
2025 Outburst Event Flow





- Road
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Title
2025 Outburst Event Flow

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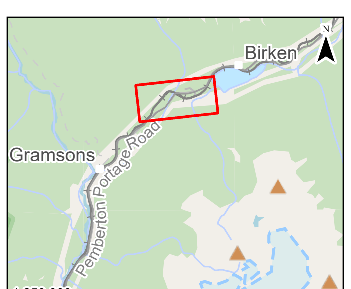

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2025 Place Creek Emergency Response – Hazard Assessment

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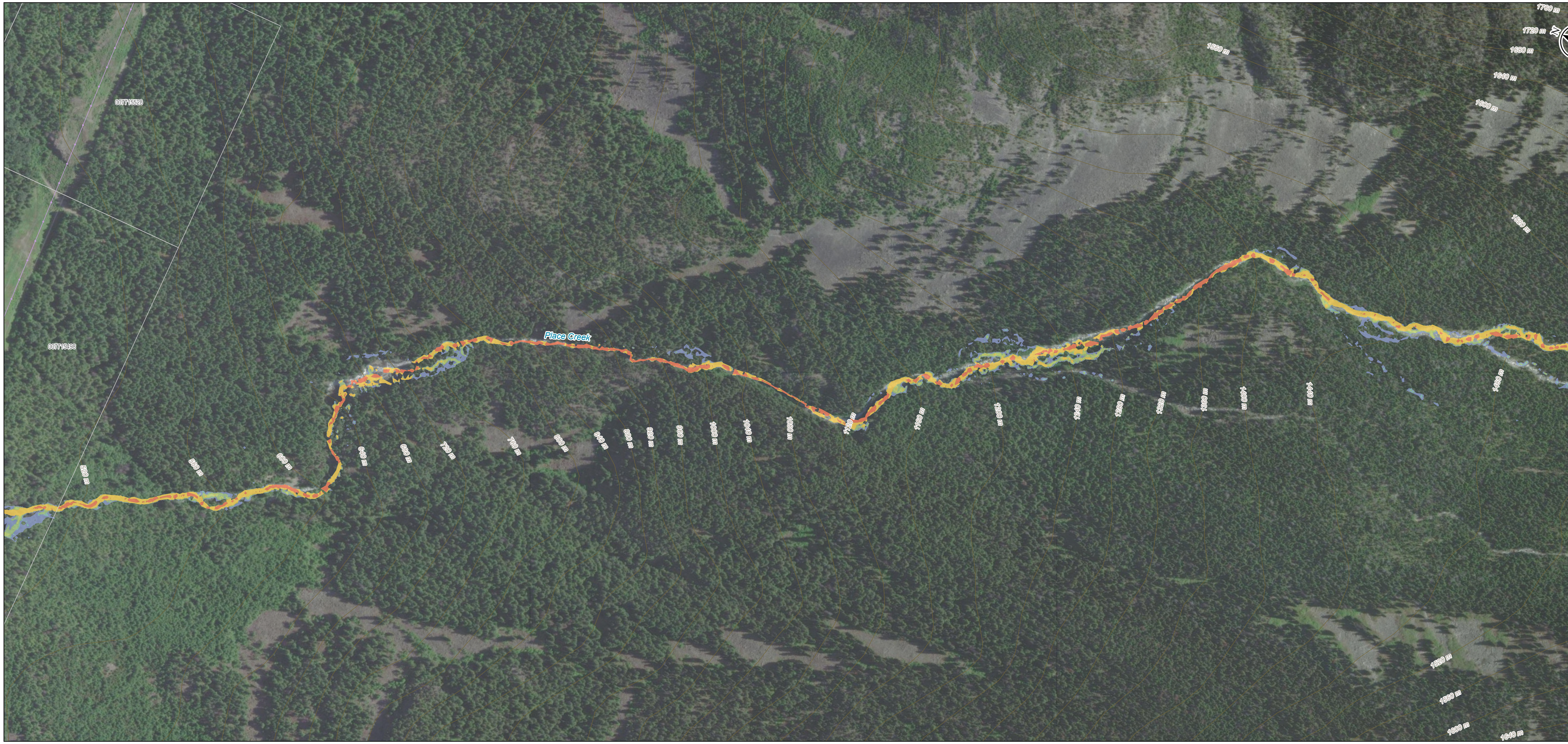
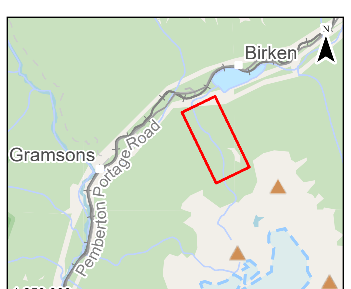
Title
2025 Outburst Event Flow





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Transmission Line
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Building or Structure

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2025 Place Creek Emergency Response – Hazard Assessment

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2025 Outburst Event Flow

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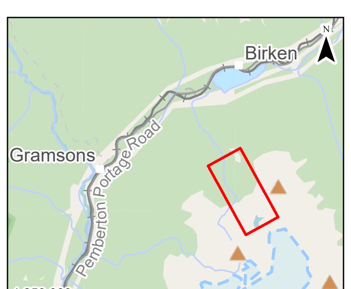

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Title
2025 Outburst Event Flow

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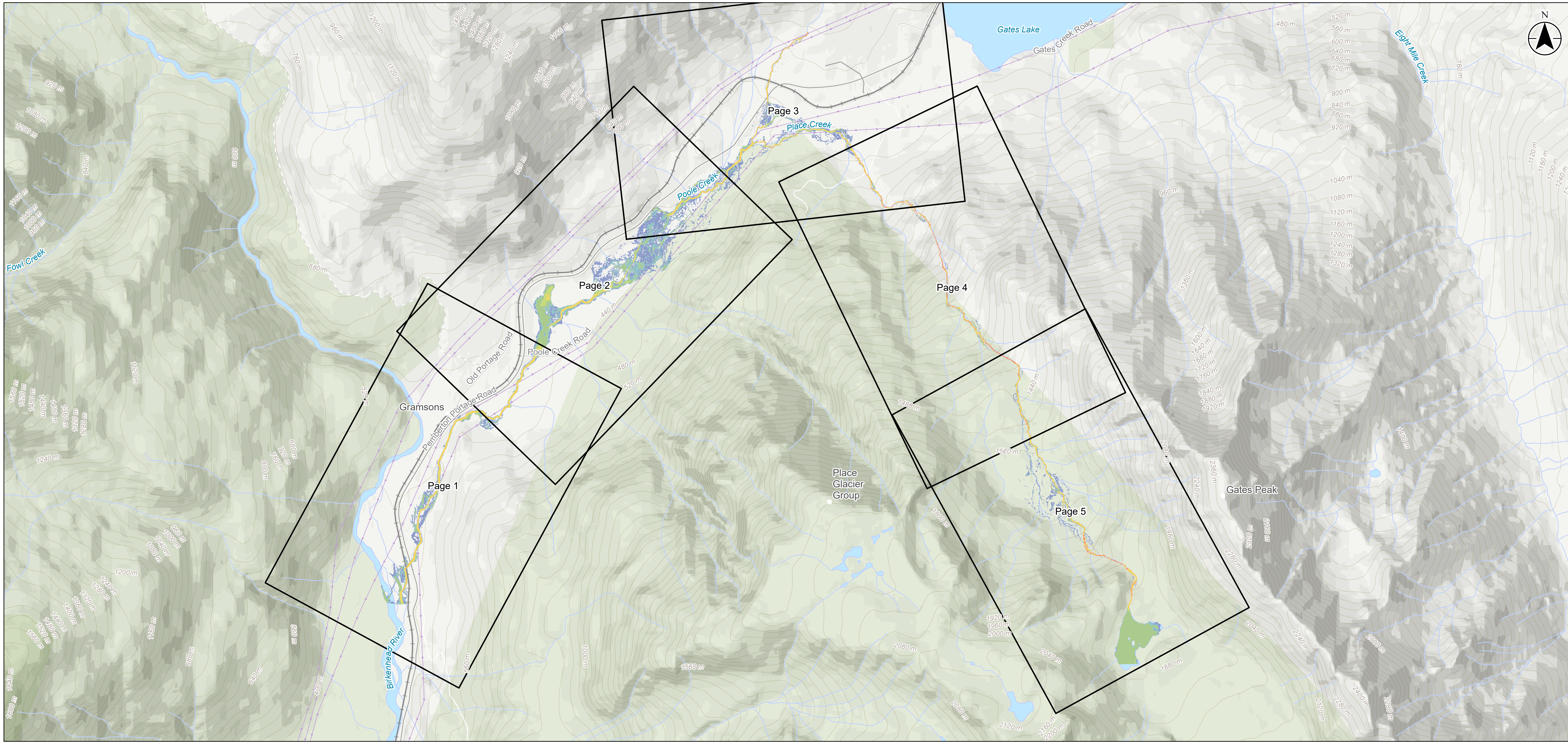
Appendix C Post-2025 Outburst Event 200-year Fall Clearwater Flow Hazard Map Book



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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
- 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
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- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure.
- Mapbook Sheet

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0 0.5 1 km
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Stantec

Project Location:
Birken, BC

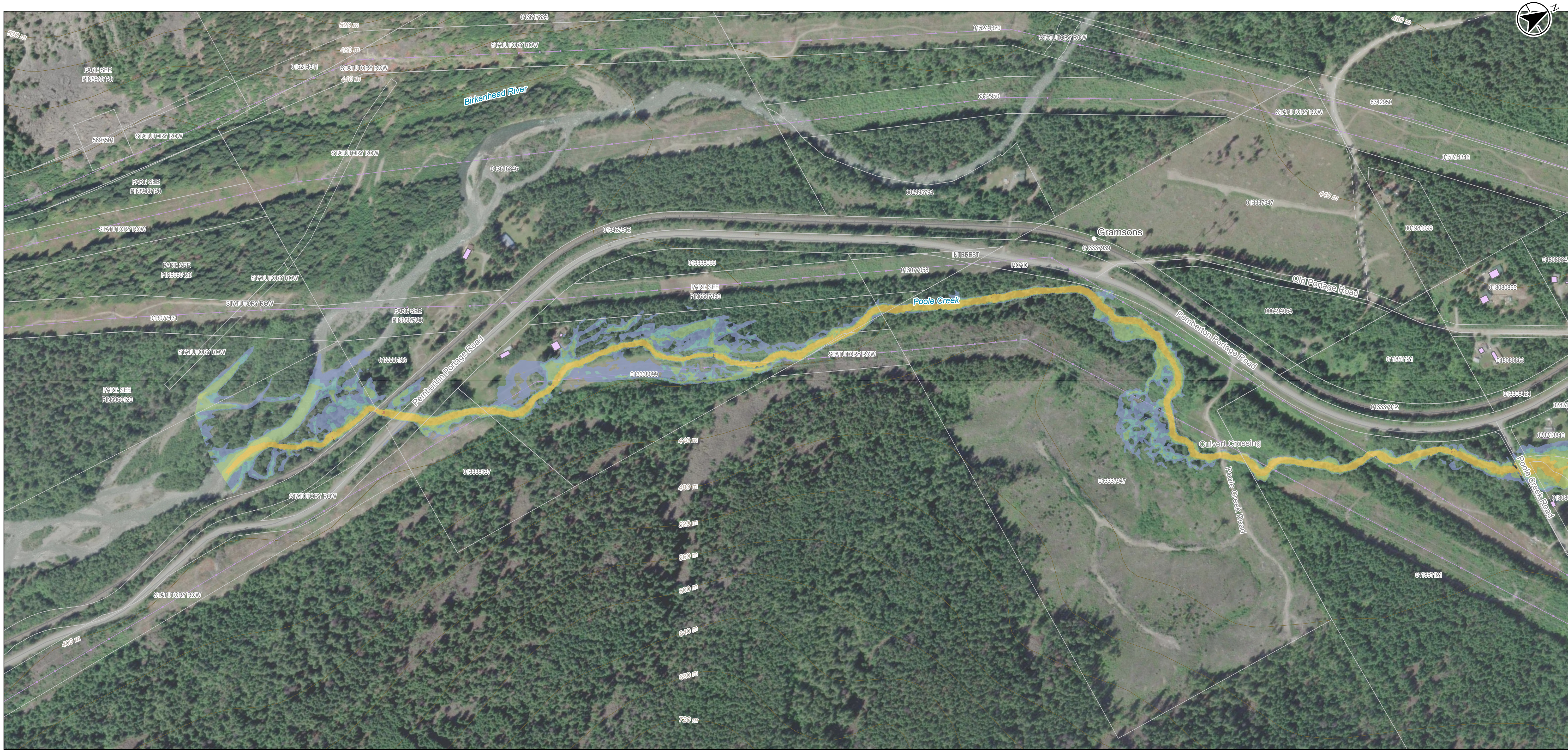
Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

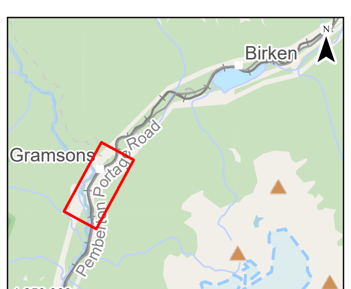
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix C

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek) Overview

\\CA0183-PBAGF01\Workgroup\1232\projects\111700836\figures\reports\place_creek_hazard_maps\fig_111700836_place_creek_hazard_maps.aprx Layout: fig_111700836_place_creek_200_yr_clearwater_flow_overview Map: Main Revised: 2025-09-16 By: jpoucher





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

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

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Stantec

Project Location:
Birken, BC

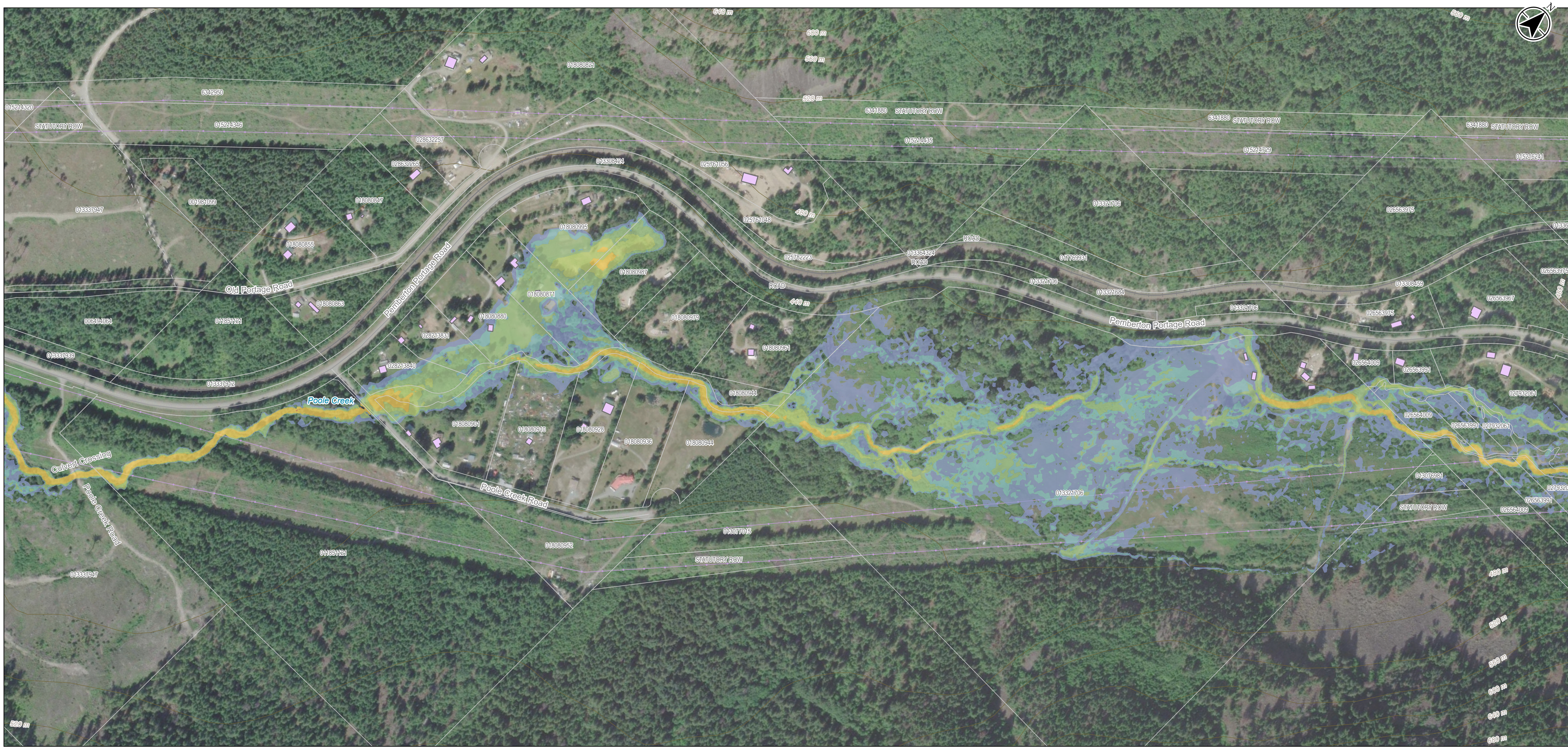
Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

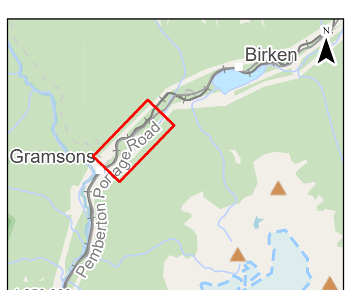
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix C

Page No.
1 of 5

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek)





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World_Imagery: Maxar

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

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0 50 100 150 200 250 m
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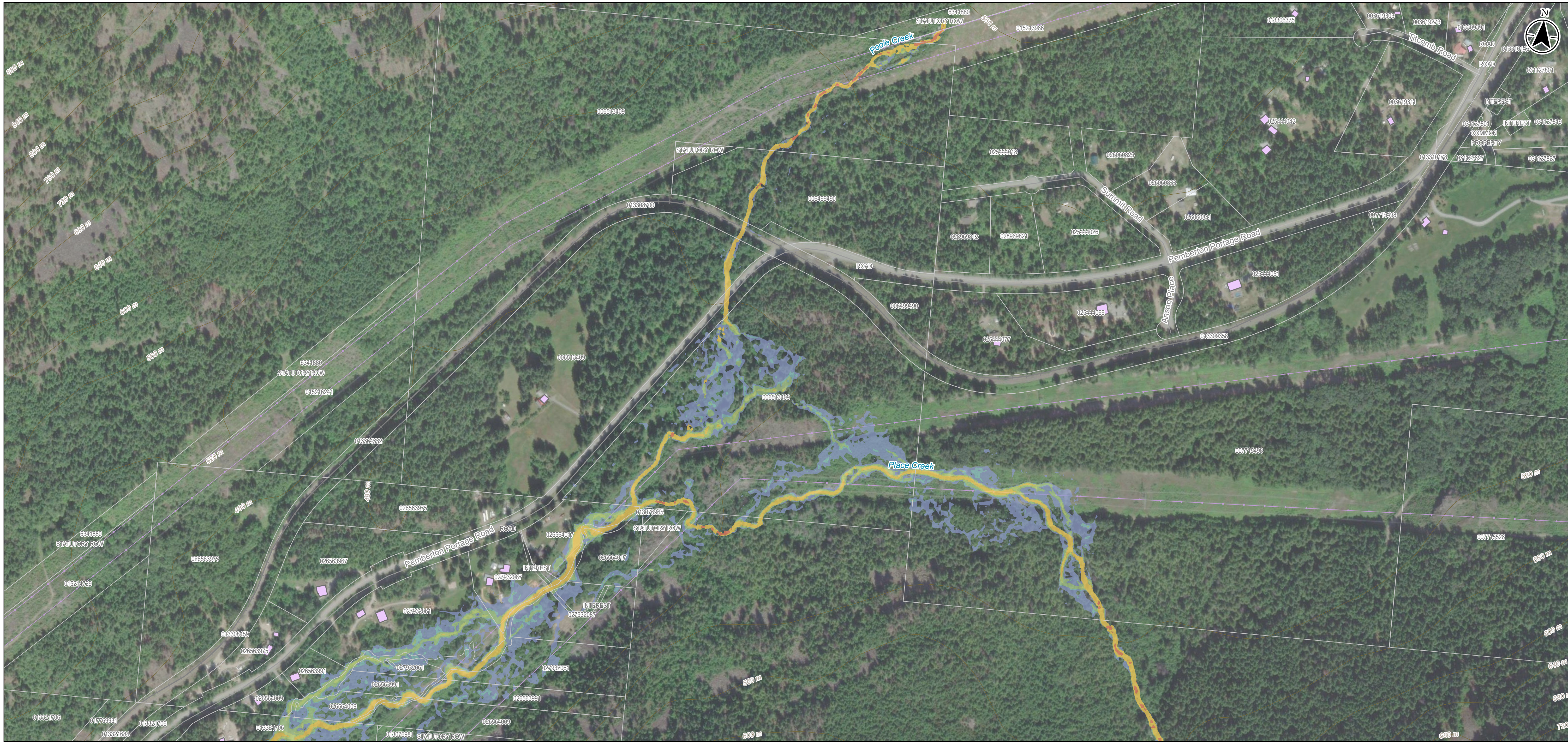
Project Location: Birken, BC
Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

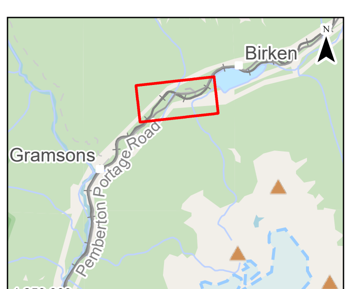
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix C**
Page No. **2 of 5**

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek)

\\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_200_yr_clearwater_flow_mapbook Map: Main Revised: 2025-09-16 By: jpoucher





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

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0 50 100 150 200 250 m

1:6,500 (at original document size of 11"x17")

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World_Imagery: Maxar

Stantec

Project Location: Birken, BC

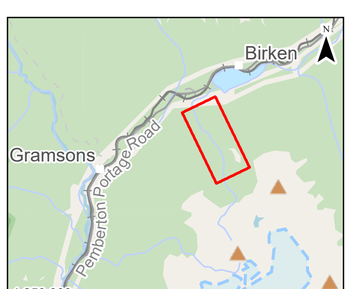
Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

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

Figure No. **Appendix C**

Page No. **3 of 5**

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek)



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Transmission Line
Topographic Contour
Building or Structure

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Project Location:
Birken, BC

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

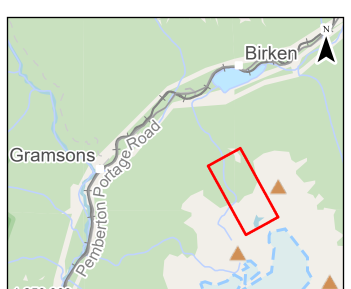
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix C

Page No.
4 of 5

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek)

\\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_200_yr_clearwater_flow_mapbook Map: Main Revised: 2025-09-16 By: jpoucher



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Topographic Contour
Building or Structure

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0 50 100 150 200 250 m
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Stantec

Project Location:
Birken, BC

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

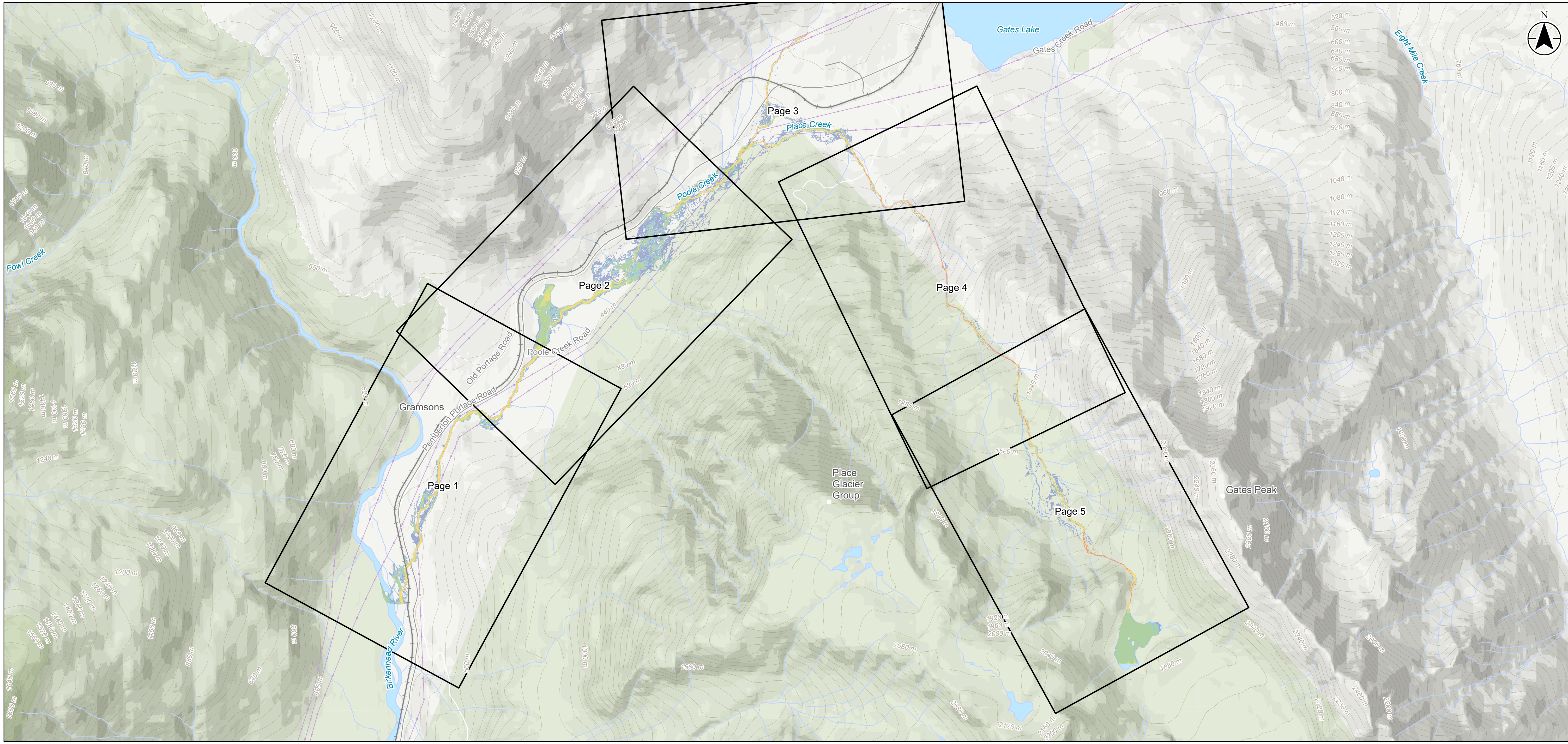
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix C

Page No.
5 of 5

Title
Post-2025 Outburst Event Flow 200-year Fall Clearwater Flow (Place and Poole Creek)

Appendix D Post-2025 Outburst Event 200-year Fall Debris Flood Flow Hazard Map Book



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- Watercourse
- Waterbody

- Mapbook Sheet

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

Project Location:
Birken, BC

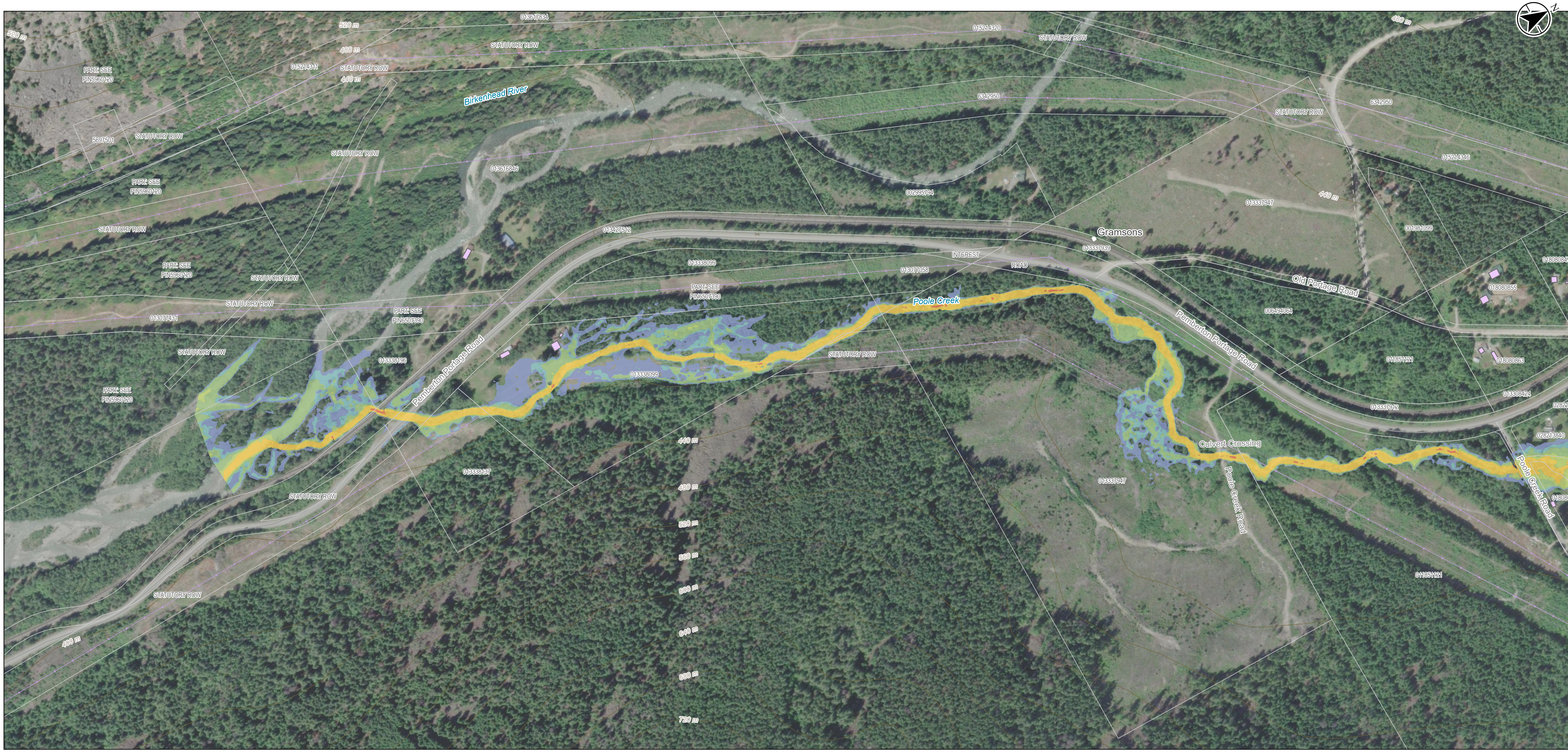
Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 20250911

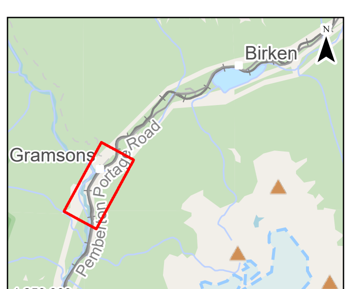
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No.
Appendix D

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek) Overview

\\CA0183-PPFSS01\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_200_yr_debris_flood_flow_overview Map: Main Revised: 2025-09-16 Bypoucher





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

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0 50 100 150 200 250 m

1:6,500 (at original document size of 11"x17")

Stantec

Project Location: Birken, BC

Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 2025

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

Figure No. **Appendix D**

Page No. **1 of 5**

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek)

Notes:
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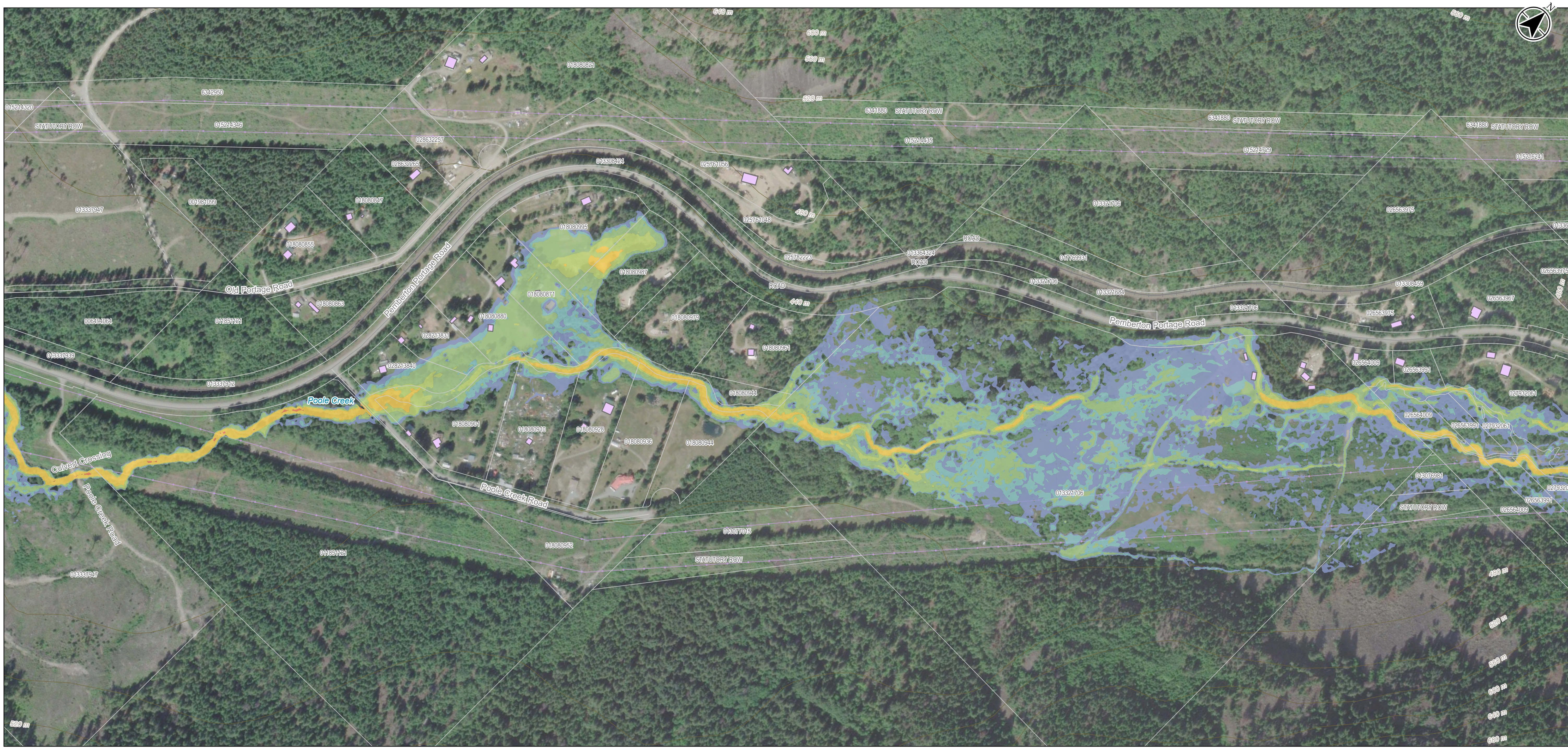

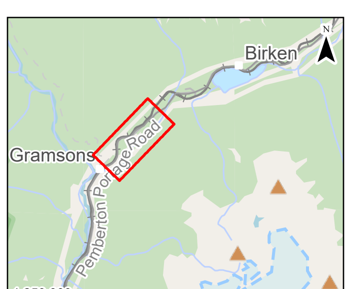

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Project Location: Birken, BC

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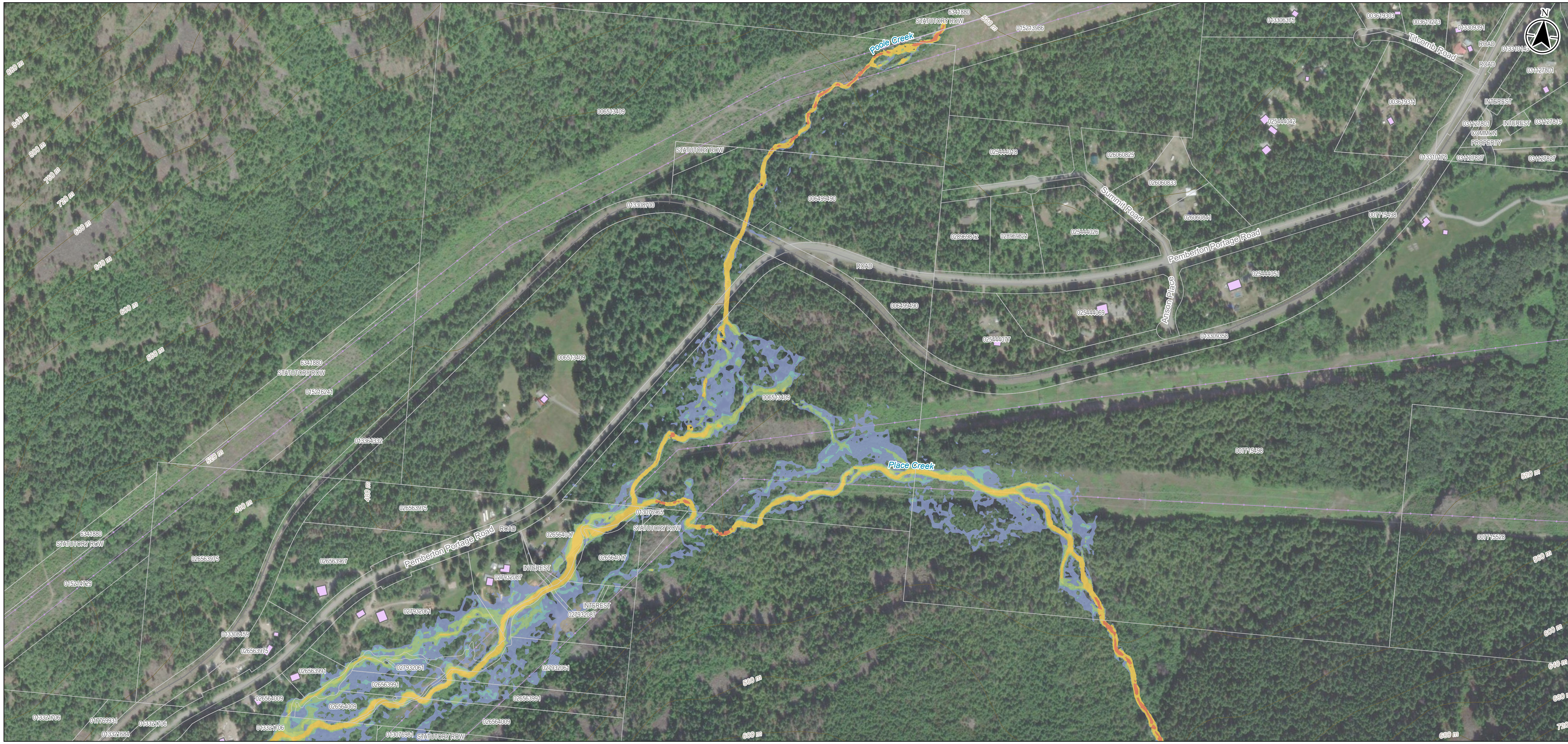
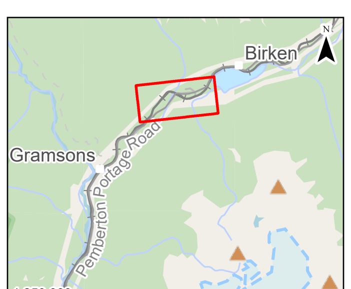
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

Figure No. **Appendix D**

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek)





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Project Location: Birken, BC
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Requested by MLEE 20250905
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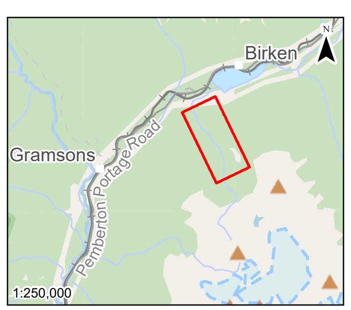
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

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

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek)

\\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_200_yr_debris_flood_flow_mapbook Map: Main Revised: 2025-09-16 Bypoucher



Transmission Line
Topographic Contour
Building or Structure

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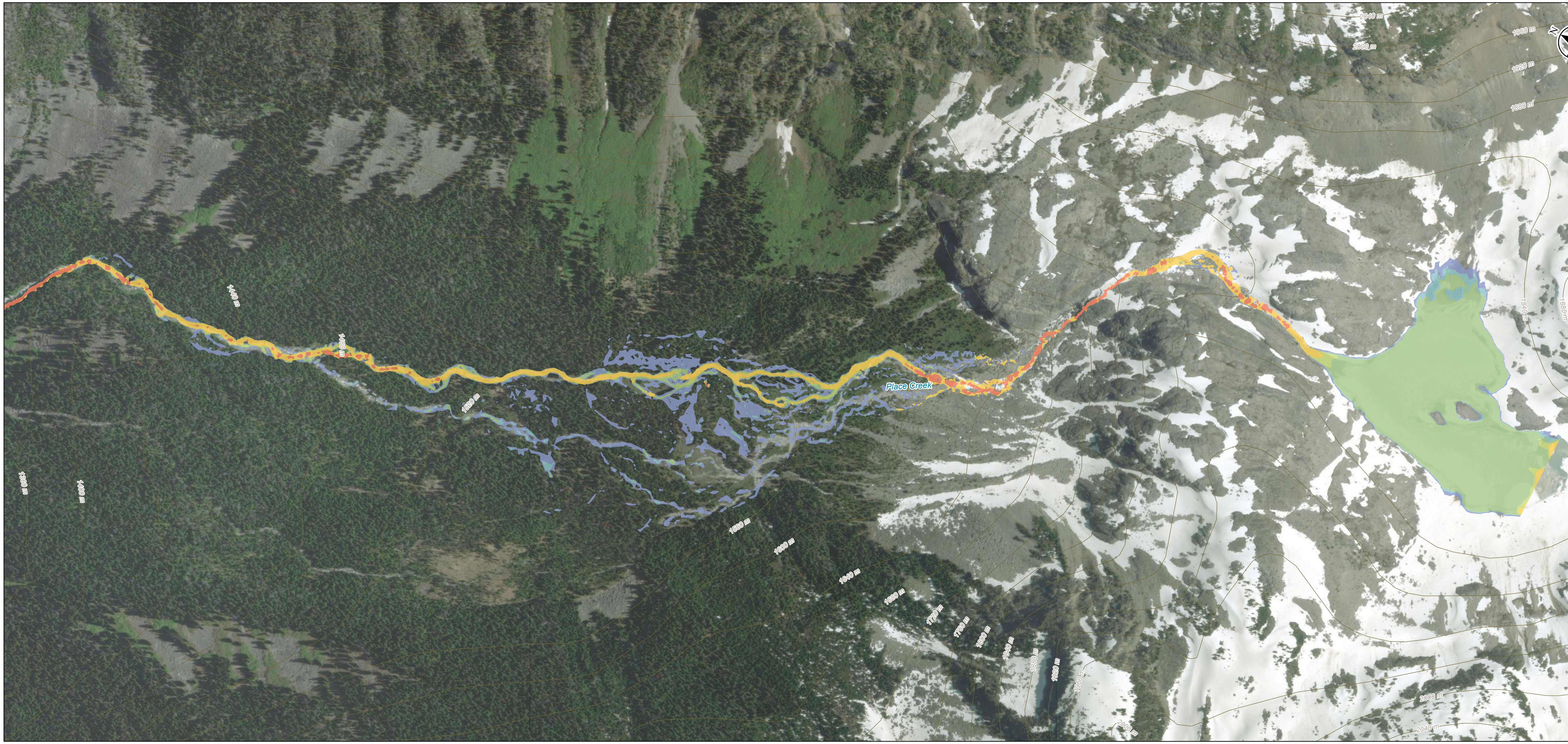
Client/Project/Report
Squamish Lillooet Regional District
2025 Place Creek Emergency Response – Hazard Assessment

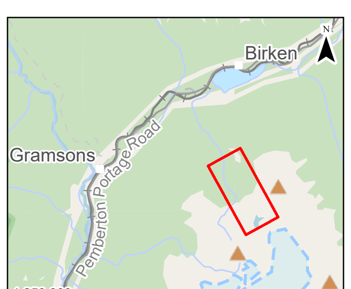
Figure No.
Appendix D

Page No.
4 of 5

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek)

\\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_200_yr_debris_flood_flow_mapbook Map: Main Revised: 2025-09-16 By:jpoucher





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Project Location:
Birken, BC

Project Number: 111700836
Requested by MLEE 20250905
Prepared by JPOUCHER 20250909
Checked by GVASS 2025

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

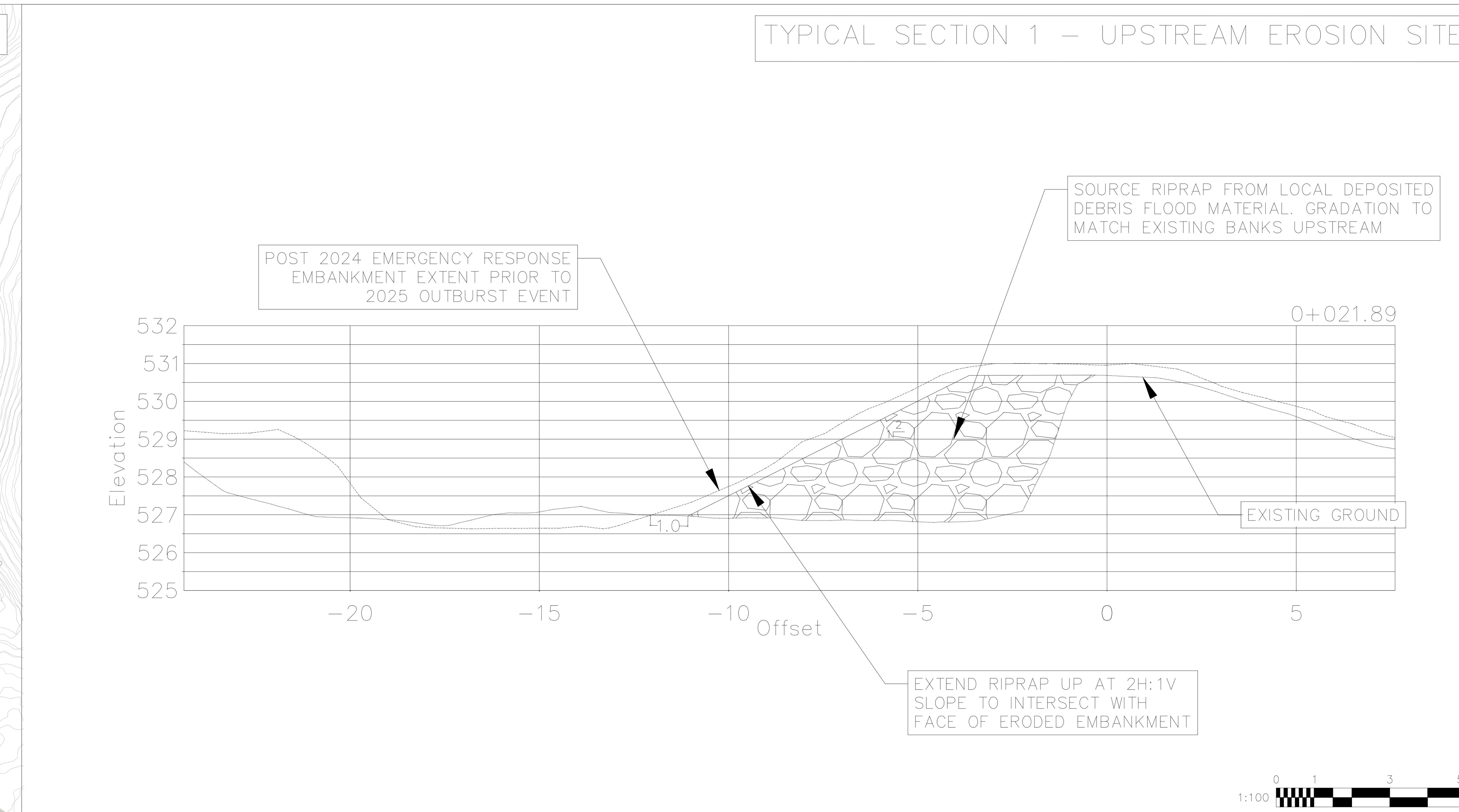
Figure No.
Appendix D

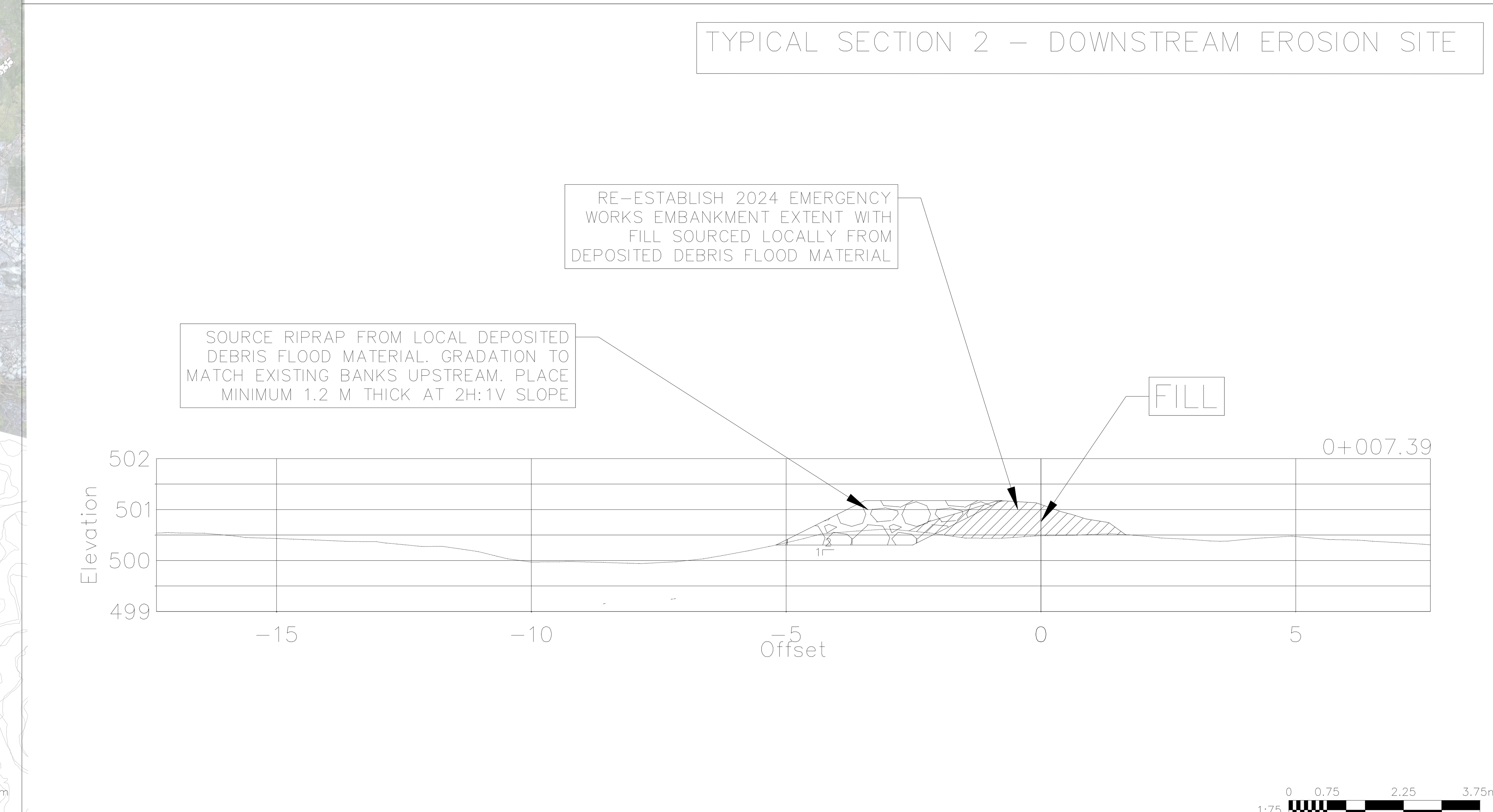
Page No.
5 of 5

Title
Post-2025 Outburst Event Flow 200-year Fall Debris Flood Flow (Place and Poole Creek)

\\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_200_yr_debris_flood_flow_mapbook Map: Main Revised: 2025-09-16 Byjpoucher

Appendix E Conceptual Design Figure





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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

Appendix F Class D Opinion of Probable Cost Breakdown

Opinion of Probable Cost Breakdown

SLRD - Place Glacier Risk Assessment - Conceptual Remediation

Class D Opinion of Probable Cost

Schedule of Approximate Quantities and Unit Prices

Project No: 111700836

Project Name: SLRD - Place Glacier Risk Assessment - Conceptual Remediation

TOTAL CONSTRUCTION AND ENGINEERING AND ENVIRONMENTAL SUPERVISION COST ESTIMATES

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
0	**PART A - CONSTRUCTION COST ESTIMATE**				
01	**SECTION 1 - GENERAL**				
01.01	Mobilization	L.S.	1	$1,200	$1,200
01.02	Establish Access Route - 1 x 210, 1 x 300 Excavator	Hour(s)	10	$565	$5,650
01.03	Labourer	Hour(s)	10	$75	$750
01.04	Engineering Construction Supervision	Hour(s)	10	$195	$1,950
01.05	Environmental Monitor	Hour(s)	10	$195	$1,950
				SubTotal	**$11,500**
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)	70	$565	$39,550
02.02	Labourer	Hour(s)	70	$75	$5,250
02.03	Engineering Construction Supervision	Hour(s)	70	$195	$13,650
02.04	Environmental Monitor	Hour(s)	70	$195	$13,650
				SubTotal	**$72,100**
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)	35	$565	$19,775
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)	35	$565	$19,775
03.03	Labourer	Hour(s)	70	$75	$5,250
03.04	Engineering Construction Supervision	Hour(s)	70	$195	$13,650
03.05	Environmental Monitor	Hour(s)	70	$195	$13,650
				SubTotal	**$72,100**
05	**SECTION 6 - SITE CLOSURE**				
05.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	20	$565	$11,300
05.02	Labourer	Hour(s)	20	$75	$1,500
05.03	Engineering Construction Supervision	Hour(s)	20	$195	$3,900
05.04	Environmental Monitor	Hour(s)	20	$195	$3,900
				SubTotal	**$20,600**
				Part A - SubTotal	**$176,300**
	PART B - Enginering and Environmental Expenses				
08	**SECTTION 8 - EXPENSES**				
17.01	Mileage	Each	5100	$0.70	$3,570
17.02	Hotel - Pemberton Valley Inn	Each	14	$300.00	$4,200
17.03	Per Diem	Each	15	$50.00	$750
17.04	Record Survey	L.S.	1	L.S.	$10,000
17.05	Completion Report	L.S.	1	L.S.	$5,000
				SubTotal	**$23,500**
Item#	**Description of Work**	**Unit of Measure**	**Approx. Quantity**	**Unit Price**	**Extended Amount**
18.01	Construction Cost Estimate Including Environmental and Engineering Supervision	L.S.	1	L.S.	$176,300
18.02	Engineering and Environemtnal Expenses (Part B)	L.S.	1	L.S.	$23,500
				SubTotal	**$199,800**
	PART C - CONTINGENCY				
	Class D (+50%)				**$99,900**
	Total Construction Cost (Part A+ Part B + Part C)				**$299,700**

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.

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