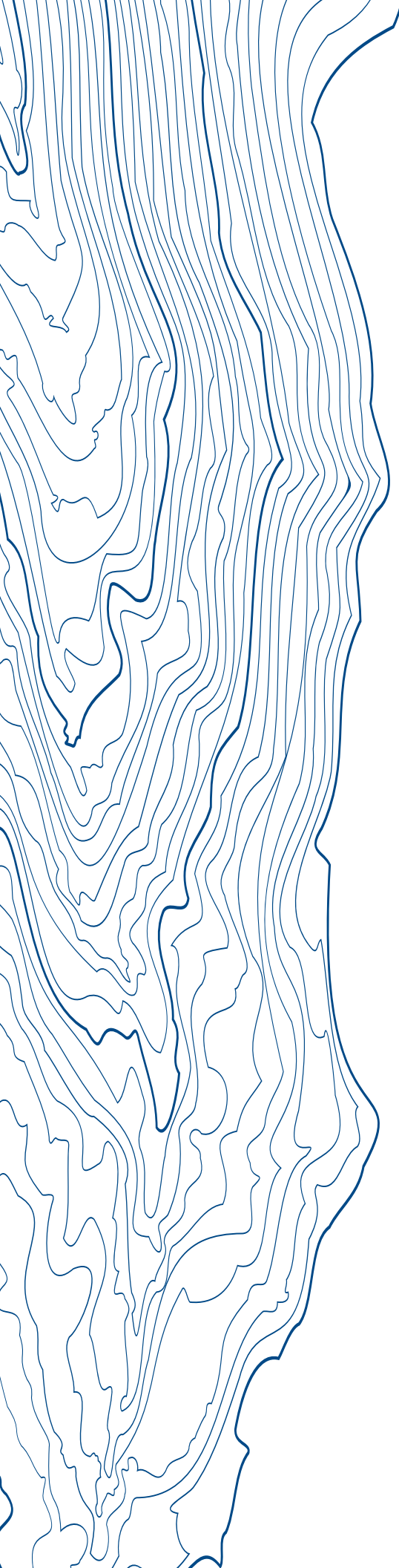


A detailed topographic map of a mountainous region, showing contour lines and a network of ridges and valleys. The map is rendered in a light blue line-art style, occupying the left half of the page.

Shetland Creek Fire (K70910)

Detailed Post-Wildfire Natural Hazard Risk Analysis

Prepared by **BGC Engineering Inc.** for:
British Columbia Ministry of Forests

March 7, 2025

Project 1114021



March 7, 2025

Project 1114021

British Columbia Ministry of Forests
441 Columbia St
Kamloops, British Columbia, V2C 2T3

Attention: Trevor Bohay, Director – All Hazards Response Coordination

Post-Wildfire Natural Hazard Partial Risk Assessment (PWNHRA) for 2024 Shetland Creek Fire (K70910) – Spences Bridge, BC

At the request of the Province of British Columbia, Ministry of Forests (MOF), BGC Engineering Inc. (BGC) has prepared the final version of the post-wildfire natural geohazard partial risk assessment for a portion of the area burned by the 2024 Shetland Creek Fire.

Should you have any questions, please do not hesitate to contact the undersigned.

Yours sincerely,

BGC Engineering Inc.

per:

A handwritten signature in black ink, appearing to read 'CAH', with a stylized flourish extending to the right.

Carie-Ann Hancock, P.Geo., M.Sc.
Senior Geoscientist, Project Manager

SUMMARY

In 2024, the mountainous areas on the west side of the Thompson River between Spence's Bridge and Ashcroft burned during the Shetland Creek Fire. Wildfires in steep terrain can increase the likelihood of geohazards (debris flows, debris floods, floods, and landslides) and geohazard risk to communities.

BGC Engineering Inc. (BGC) was contracted by the BC Ministry of Forests (MOF) to conduct a post-wildfire natural hazard risk assessment for a portion of the Shetland Creek Fire area (Drawing 01). BGC reviewed available datasets (e.g., lidar, orthoimagery, burn severity mapping, terrain mapping) and mapped extents of potential post-wildfire geohazards, including watersheds, alluvial fans, and landslides. BGC estimated hazard likelihood and spatial impact likelihood to evaluate partial risk for elements (buildings, campground, water licenses, addresses, and two resource roads) in the study area (Drawing 01).

This report provides a summary of the:

- Geohazard mapping for watersheds, alluvial fans, and landslides (Drawing 01)
- Burn severity mapping across the wildfire scar (Drawing 02)
- Post-wildfire Hazard Likelihood ratings for 163 watersheds and 14 landslides.
- Estimation of post-wildfire debris flow volumes for 147 watersheds
- Partial risk ratings for 60 buildings, one campground, 36 water licenses and a water source with no license, 24 addresses with no visible elements at risk, and two resource roads (Twaal Creek road and Murray Creek road).

Drawing 03 shows the Post-wildfire Hazard Likelihood ratings for the study area, and the partial risk ratings for the buildings and water licenses. Appendix A provides the partial risk assessment summaries for all elements at risk.

Of the 60 buildings and one campground assessed in this study:

- 20 buildings have a "Very High" Partial Risk ratings, including the Venables Valley school (Govardhan Academy) and the Saraghati Village's Goshala (barn). The campground also has a "Very High" Partial Risk rating.
- 21 buildings have "High" Partial Risk ratings
- 2 buildings have "Moderate" Partial Risk ratings
- No buildings have "Low" or "Very Low" Partial Risk ratings
- 17 buildings are not in a hazard impact area.

BGC estimated an order-of-magnitude life safety risk for these partial risk categories, assuming that post-wildfire debris flows have sufficient depth and velocity to result in life safety threats. Buildings within "Very High", "High", and "Moderate" partial risk ratings potentially have life safety risk that is higher than considered tolerable in other Canadian jurisdictions (typically, an annual life loss risk of 1:10,000 or less from natural hazards is considered tolerable for existing development). Given that life safety risks of post-wildfire geohazards are highly dependent upon the depth, velocity, and extent of geohazards, BGC recommends that MOF obtains lidar data for the study area and re-evaluate the partial risk ratings with runout modelling results.

BGC understands that risks to highway users within the study area are being assessed separately by BC Ministry of Transportation and Transit (MOTT). Risks to cultural areas and non-structural assets, such as archeological sites and traditional harvesting areas, were not assessed during this project.

MOF also requested that BGC provide recommendations for risk reduction measures for “Moderate”, “High”, and “Very High” partial risk ratings. Risk reduction across the wildfire scar can be achieved through the following:

- Hazard avoidance of geohazard areas
- Community education at a public meeting
- Property owner education, including what to do if a geohazard is heard or seen (see highlighted text below)
- Public awareness through signage
- Emergency response planning
- Increased awareness of triggering conditions through early warning systems.

In addition to the above risk reduction measures, the following examples of site-specific risk reduction measures are provided for the Venables, Twaal, and Murray Creek valleys:

- Fan-level channel conveyance, deflection berms, and sediment capture basins
- Maintenance and rehabilitation of resource roads and local roads
- Reduction of upslope hazard likelihood through mulching and reseeding
- Monitoring risks to water licenses
- Developing rockfall and debris slide risk management strategies for resource roads.

The design and construction of site-specific risk reduction measures should be overseen by a Qualified Professional(s). In addition, risk reduction measures should be discussed with property owners and local authorities to evaluate the potential costs (financial, social, and ecological) versus the benefits of the risk reduction measure, and constructed measures should avoid risk transference to other persons or groups downslope.

Important information for building occupants in post-wildfire geohazard areas

Post-wildfire geohazards can occur within minutes of heavy rainfall. If you hear or see a geohazard happening, it is usually too late to evacuate. If it is unsafe to evacuate, shelter up and away in a building (top floor or roof) on the side away from the hillslope. Avoid basements or crawl spaces.

TABLE OF REVISIONS

Date	Revision	Remarks
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February 24, 2025	Rev A	Provided to MOF for review
March 7, 2025	Final	

CREDITS AND ACKNOWLEDGEMENTS

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BGC is grateful for the technical guidance and expertise provided by Gareth Wells, P.Geo., Research Geomorphologist, Ministry of Forests. BGC also thanks the Cook's Ferry Indian Band staff and leadership and the residents of the Venables Valley for their time in speaking with us, recalling these traumatic events, and providing valuable information about observed geohazards.

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1.0 INTRODUCTION

The Shetland Creek fire ignited on July 12, 2024, and was considered held on August 18, 2024. Located on the west side of the Thompson River between Spence's Bridge and Ashcroft, British Columbia (BC), the fire burned nearly 28,000 ha of traditional lands of the Nlaka'pamux Peoples, as well as First Nation reserves and private lands. Many local jurisdictions are present within and downslope of the burned area and include the Cook's Ferry Indian Band (Cook's Ferry), Oregon Jack Creek Band (Oregon Jack), and the Thompson Nicola Regional District (TNRD). The BC Ministry of Forests (MOF) previously completed a post-wildfire natural hazard risk assessment (PWNRA) Level 2 report² (MOF, October 4, 2024) and identified potential elements at risk exposed to post-wildfire geohazards. Based on the findings of the Level 2 report, MOF recommended more detailed (Level 3)³ assessments be completed at selected locations.

MOF engaged BGC Engineering Inc. (BGC) to provide a Level 3 PWNRA for selected locations in the Shetland Creek Fire area. The objective of this work is to identify post-wildfire geohazards that may cause risk to life, property, and infrastructure identified by the MOF. BGC understands that MOF will provide this report to BC Emergency Management and Climate Readiness (EMCR) for dissemination to First Nations and local governments.

1.1 Scope of Work

The following elements at risk (illustrated in Drawing 01) were requested for detailed Level 3 PWNHRA assessment by MOF, as communicated by email to BGC on October 17, 2024:

- In the Twaal Creek watershed:
 - Nicoelton IR 6
 - Twaal Creek Road
 - Hilltop Campground (PID 012-997-005)
 - Water licenses along Twaal Creek.
- In the Murray Creek watershed:
 - Murray Creek Road
 - Water licenses along Murray Creek.
- In the Venables Creek watershed:
 - Peq-Paq IR 22 in the Venables Valley
 - District Lot 383 (PID 003-594-769) and potentially occupied structures
 - Lot 384 (PID 003-594-793) and potentially occupied structures
 - Lot 17 (003-594-726) and potentially occupied structures
 - Lot 18 (PID 003-594-734) and potentially occupied structures
 - Lot 19 (PID 003-594-742) and potentially occupied structures
 - Section 10 (PID 014-497-247) and potentially occupied structures
 - Section 15 (PID 014-598-388) and potentially occupied structures

² Previously termed "preliminary report" (Hope et al., 2015)

³ Previously termed "detailed report" (Hope et al., 2015)

- Water licenses along Venables Creek and the western valley slopes.

Within the study area, BGC's scope of work, as outlined in BGC's proposal (BGC, October 30, 2024), for the PWNHRA is limited to:

- Compilation of existing mapping and background information
- Reconnaissance helicopter overflight
- Preparation of a field-calibrated soil burn severity map
- Examination of roads or other structures which might contribute to potential geohazards
- Partial risk analysis for each applicable post-wildfire geohazard (debris avalanche, landslide, rockfall, debris flow, debris flood, clearwater flood, and water quality effects)
- Conceptual risk mitigation options or strategies for elements at risk with partial risk ratings of moderate or higher
- A one-hour virtual presentation outlining the findings of the assessment to local government and affected communities.

The partial risk method used in this report, as outlined in MOF's Post-Wildfire Natural Hazards Risk Analysis in British Columbia Handbook (Hope et al., 2015) and updated in 2024 (email from MOF on October 17, 2024), is a semi-quantitative partial risk assessment. The approach estimates the likelihood of a post-wildfire event occurring and reaching or otherwise affecting the element at risk. Partial risk assessments do not include the potential consequences and vulnerability of the evaluated elements at risk during geohazards, which is a significant limitation of this method. Partial risk assessments do not provide sufficient information to confidently determine the scale, dimensions, or cost of risk reduction measures. BGC provided partial risk assessment results for occupied structures, water intakes, and two resource roads on streams and alluvial fans below burned watersheds and slopes.

BGC understands that risks to highway users within the study area were assessed by BC Ministry of Transportation and Transit (MOTT). Risks to non-structural assets, such as archeological sites, traditional harvesting areas, and agricultural fields were not assessed during this project.

Given that this assessment is focussed on post-wildfire geohazards that occur in the first few years after the wildfire, BGC did not consider the possible effects of climate change, logging, or future wildfires on the geohazard likelihood ratings. Such work can be included in future detailed assessments.

The work has been carried out under the terms of contract #CS25WHQ0242 between BGC and MOF dated November 13, 2024.

1.2 Engagement Activities

During this work, BGC contacted the following organizations to learn about community concerns surrounding post-wildfire geohazards:

- Cooks' Ferry – Chief Christine Walkem, Fire Chief and Director of Protective Services Steven Sherwood, Lands Manager Scott MacKay, Lands Coordinator Brenda Walkem, and band member TJ Walkem.

- TNRD – Emergency Program Coordinator Mike Knauff, Manager of Community and Emergency Services Kevin Skrepnek.
- Saranagati Village – Mark Greenberg.

BGC thanks the residents and workers who have relived many of these traumatic events in telling us their stories and about observed geohazards.

Where possible, traditional knowledge (TK) from Cook's Ferry band members has been integrated into this report. The integration of TK into the assessment is highlighted as shown below:

Traditional Knowledge of Cook's Ferry Traditional Territory, provided by Band members, is highlighted in this format throughout this report.

1.3 Appropriate Use of This Report

BGC understands that the MOF is concerned about elements at risk (buildings, water intakes, and roads) that could be affected by post-wildfire debris-flow, debris-flood, flood, landslide, and water quality geohazards following the Shetland Creek Fire. BGC has estimated the partial risk rating on alluvial fans and at the base of steep slopes that have potential post-wildfire debris-flow, debris-flood, flood, landslide, and water quality geohazards within study area. Additional geohazards exist in the remainder of the wildfire perimeter in areas not assessed by BGC, and outside of the burned area. The estimation of hazard likelihood and spatial impact likelihood was used to evaluate partial risk ratings. The partial risk ratings can be used to inform risk reduction measures for First Nations, local government, and private property owners. Geohazard extents were delineated primarily from aerial photographs and extents are assumed to be approximate; these extents should not be used for planning purposes. This report is of insufficient detail to provide individual property owners a geotechnical assessment that may be required by First Nations and local governments as part of permitting process.

BGC recognizes that this report uses specialized terms and a number of ratings and tables. Partial risk ratings for individual properties are provided in Section 5.2 and Appendix A. A glossary of terms is provided in Appendix B.

2.0 WILDFIRE EFFECTS ON WATERSHEDS OVER TIME

Wildfires are well-documented to increase the likelihood and magnitude of geohazards (e.g., Gartner et al., 2024) and changes in water quality (Jordan, 2012; Elliot et al., 2024; HealthLink BC, January 2024). Effects can vary greatly but may include those listed in Table 2-1.

Table 2-1 Potential effect of wildfires on geohazards resulting from the Shetland Creek Fire.

Hazard Type	Potential Effects from Wildfire
Steep Creek (debris flow, debris flood)	• Increase in frequency and potential magnitude of debris flood and debris flows due to the increased availability and mobility of sediment and increase in rainfall runoff. • Lower rainfall threshold for erosion and flooding, resulting in more frequent debris flow and debris flood initiation. • Increase in landslide dam and outburst flood potential. • Increased overland flooding and potential related erosion may occur on open slopes, outside of channelized areas.
Flood	• Changes in the timing and magnitude of snowmelt (freschet) processes. • Sediment input from post-wildfire debris flows or debris floods, leading to large water level fluctuations in rivers during convective and frontal storms. • Channel shifts (avulsions) due to increased sediment deposited into flood-prone channels (Owen et al., 2013; Hancock and Włodarczyk, 2025).
Rockfall	• Increase in rockfall frequency due to loss of support from vegetation. • Increase in potential rockfall sources due to heat-related rock spalling and boulder breaks during the fire. • Increase in potential travel distance of rock-fall boulders due to loss of vegetative protection and related terrain roughness.
Earth and Debris Landslides, Earthflows	• Increase in post-wildfire frequency of debris avalanche, boulder fall, and shallow landslides due to loss of soil strength, loss of plant-root support, and mobilization of fine sediment. • Increased groundwater levels due to a reduction in evapotranspiration. • Increase landslide runout distance due to loss of protection and roughness from vegetation. • Increase in soil erosion and dry ravel due to physical changes in the soil structure and loss of vegetative cover.
Bank Erosion	• Increase in post-wildfire bank erosion in small (<1 km²) and medium (1 to 10 km²) size watercourses (e.g., Owen et al. 2013). For example, bank erosion downstream of wildfires during the November 2021 atmospheric river caused infrastructure damage approximately 20 km south of the study area (Hancock and Włodarczyk, 2025) • Increase in erosion to riverbanks due to loss of vegetation. • Increased sediment load may lead to local and/or short-term channel aggradation, which can lead to localized channel widening and bank erosion.
Water quality	• Increased runoff and/or water yield. • Ash and sediment inundation. • Increased suspended sediment, nitrate, phosphorus, and organic carbon concentrations.

The likelihood of a geohazard varies with respect to the magnitude (size) of the geohazard with larger, more destructive events being less frequent than smaller, less destructive events. However, in the case of post-wildfire geohazards, the likelihood and magnitude subside with time, as vegetation re-establishes on hillslopes and soil stability is regained (Figure 2-1).

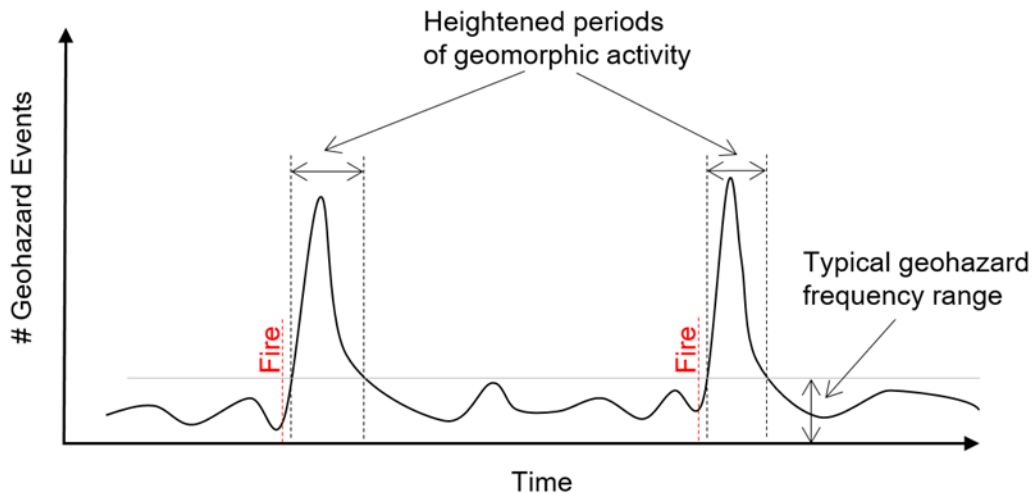


Figure 2-1 Schematic diagram showing the temporary increase in geohazard activity following fire. Depending on the rate of watershed recovery, the peaks can last for one to twenty years following the fire. Schematic prepared by BGC.

Most runoff-generated post-wildfire debris floods and debris flows typically occur within the first two to three years following a fire (Cannon & Gartner, 2005; DeGraff et al., 2015; Graber et al., 2023). For example, the 2017 Elephant Hill Fire (located approximately 20 km north of the study area) experienced post-wildfire debris-flow events most recently in February 2020, nearly three years after the fire. Widespread landslide-generated debris-flow activity is less likely, but possible in the decades following the fire due to the decay of burned or partially burned tree roots, which reduce soil cohesion (DeGraff et al., 2015; Hancock and Włodarczyk, 2025). Therefore, geohazard likelihood in burned watersheds will be elevated above base levels until at least 2027 (three years after the fire) and potentially until after 2045 (20 years after the fire).

Little published information is available to evaluate the persistence of landslide (rockfall, earth and debris slide, earthflow, rockslide) hazards following a wildfire. In general, landslide activity is expected to remain above baseline conditions for some years to decades after the wildfire, due to the tree cover removal and vegetation root mortality (DeGraff et al., 2015; Hancock and Włodarczyk, 2025). BGC's ongoing regional geohazard study for Cook's Ferry has observed increased and sustained movement at earthflows after the 2021 Lytton Creek Fire. More work is required to understand the implications of these observations on geohazard likelihood, frequency, and recommended risk management.

Most post-wildfire impacts on water quality are observed within the first year or two after the wildfire (Jordan, 2012; Raelison et al., 2023), although channel erosion and sediment transport may be elevated for several years after the wildfire (Eaton et al., 2010).

3.0 STUDY AREA BACKGROUND

3.1 Overview

The Shetland Creek Fire burned tributaries on the west side of the Thompson River between Spence's Bridge and Ashcroft, BC (Drawing 01). The wildfire scar occurred in a transitional ecosystem, with the western half of the wildfire in the Pavillion Ranges ecosection of the Interior Transition Ranges, and the eastern half of the wildfire in the Thompson Basin ecosection of the Thompson-Okanagan Plateau (Demarchi, 2011). The terrain encompasses vegetated mountainous watersheds with flatter valley bottoms.

The study area for this work, which is defined as the watersheds draining the west side of the Thompson River and burned by the Shetland Creek Fire, is shown in Drawing 01. Watersheds within the study area include:

- Murray Creek, including its tributaries West Murray Creek, Shetland Creek, and Teit Creek
- Twaal Creek, including its tributaries Nicoelton Creek and Spence Creek
- Venables Creek.

The study area is underlain by various bedrock geology including (Cui et al., 2019):

- Volcanic rocks (andesite, dacite, breccia, and volcaniclastic rocks) of the Pimainus Formation
- Sedimentary rocks (limestone, argillite, chert, and basalt) of the Cache Creek Formation
- Volcanic rocks (basalt, rhyolite, tuff) of the Venables Valley assemblage.

Overlying the bedrock within the study area are deposits of till (materials formed from glacial processes) and colluvium (materials formed by landslide processes) (Ryder, 1976; Ryder, 1981; BC Environment, 1992). The till primarily occurs as blankets or veneer deposits over bedrock slopes in the study area (Ryder, 1976; Ryder, 1981). Within the Venables Creek valley, there is an extensive lacustrine plain and hummocky kame and esker deposits that are unique within the study area (Ryder, 1976). Colluvium is derived from landslide processes, which in the study area include rockfall, rockslides, earthflows, and earth slides. As discussed above in Section 2.0, there are numerous earthflows in burned watersheds above elements at risk that may affect the likelihood and magnitude of post-wildfire geohazards.

Vegetation within the study area includes Interior Douglas Fir and Montane Spruce forests (BC Data Catalogue, October 11, 2024). Historical forest disturbances include forestry and wildfires. Logging has occurred in the study area between 1952 and 2021, with approximately 59 km² (21%) of the wildfire perimeter being logged during this period (data provided by BC Data Catalogue, March 28, 2024). Approximately 24 km² (9%) of the wildfire perimeter has previously burned between 1934 and 2015 (BC Data Catalogue, April 1, 2024).

3.2 Elements at Risk

The Shetland Creek Fire occurred in the traditional territory of the Nlaka'pamux people including the reserves of Cook's Ferry Indian Band, Oregon Jack Creek Band, and Lytton First Nation.

Outside of the reserves, populated areas with the wildfire affected area include properties along Highway 1, and the Saranagati Village within the Venables Creek valley.

As estimated in the 2021 census, 217 persons live close to the wildfire, including the northern portion of Spences Bridge and the Venables Creek valley (Statistics Canada, 2023). Cook's Ferry reserves Nicoelton IR 6 and Peq-Paq IR 22 are presently unoccupied and are used primarily for traditional uses and cattle grazing operations⁴. The Venables Creek valley is the most densely populated portion of the study area, with approximately 70 unique addresses/properties within the valley (TNRD, n.d.). Most residents within the Venables Creek valley live "off-the-grid" in wood-framed homes or mobile homes powered by solar or hydroelectric power. The community also hosts a private K-12 school (Govardhana Academy). The Hilltop Gardens Farm has a seasonal campground along Twaal Creek near its outlet at the Thompson River.

First Nation traditional lands, reserves, communities, farms, ranches, and other assets within the wildfire area are connected by Highway 1, Venables Valley Road, private roads within the Venables Creek valley (Rathayatra Way, Harekrishna Lane, Govardan Hill Terrace, Minnabariet Road, and Prabhupad Place) and forestry resource roads (including Murray Creek Road in the Murray River watershed, and Friesen Road within the Twaal Creek valley).

3.3 Climate and Precipitation

Climate normals for Spences Bridge Nicola station (#1167637), which is the closest weather station to the study area, for the period 1970 to 2010 are provided in Figure 3-1. Based on this data, there are two distinct wet seasons: between November to January and between May to July. Convective rainstorms, which can be associated with high-intensity rainfall that can trigger post-wildfire debris flows, tend to occur from May to October.

The frequency and intensity of storms are characterized by intensity-duration-frequency (IDF) curves. Given that the closest published IDF curve is at Lytton, approximately 30 km southwest of Spences Bridge, BGC utilized gridded IDF curves for ungauged locations (Simonovic et al., 2015). BGC selected a representative location in the study area along the ridge between the Nicoelton 6 I.R. and the Venables Valley at latitude and longitude of 50.55961° N, -121.38885° W. The resultant IDF curve is shown in Figure 3-2.

In the study area, post-wildfire geohazard risks are most likely during the following periods:

- During snowmelt, which typically occurs from March to May. Snowmelt may occur earlier than typical after the wildfire due to loss of vegetation shading the snowpack. Freeze-thaw conditions during this period may also produce rockfall.
- Between May and September, when convective rainstorms may produce high-intensity rainfall. Note the overlapping late spring window when heavy rainfall can fall on late-season snowpack.
- Between September and November when atmospheric rivers can extend inland to the wildfire area.

⁴ Personal communication, Brenda Walkem, September 25, 2024.

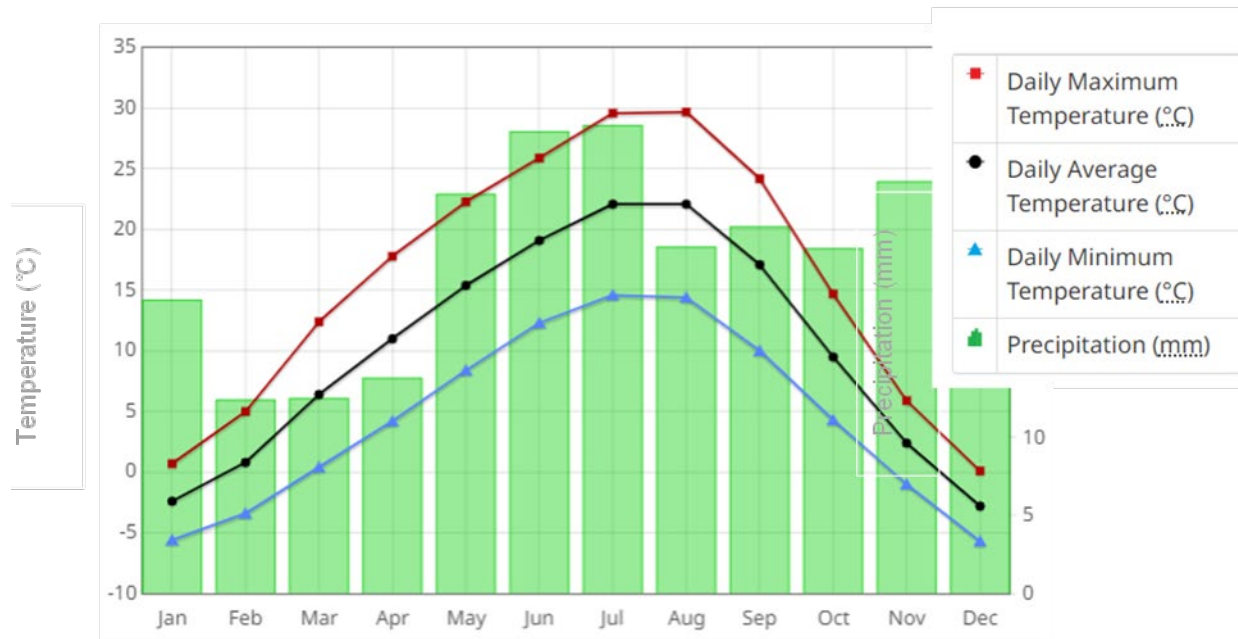


Figure 3-1 Climate data from Spences Bridge Nicola Regional Climate Station (#1167637) at elevation 235 m from 1981 to 2010 (Government of Canada, n.d.).

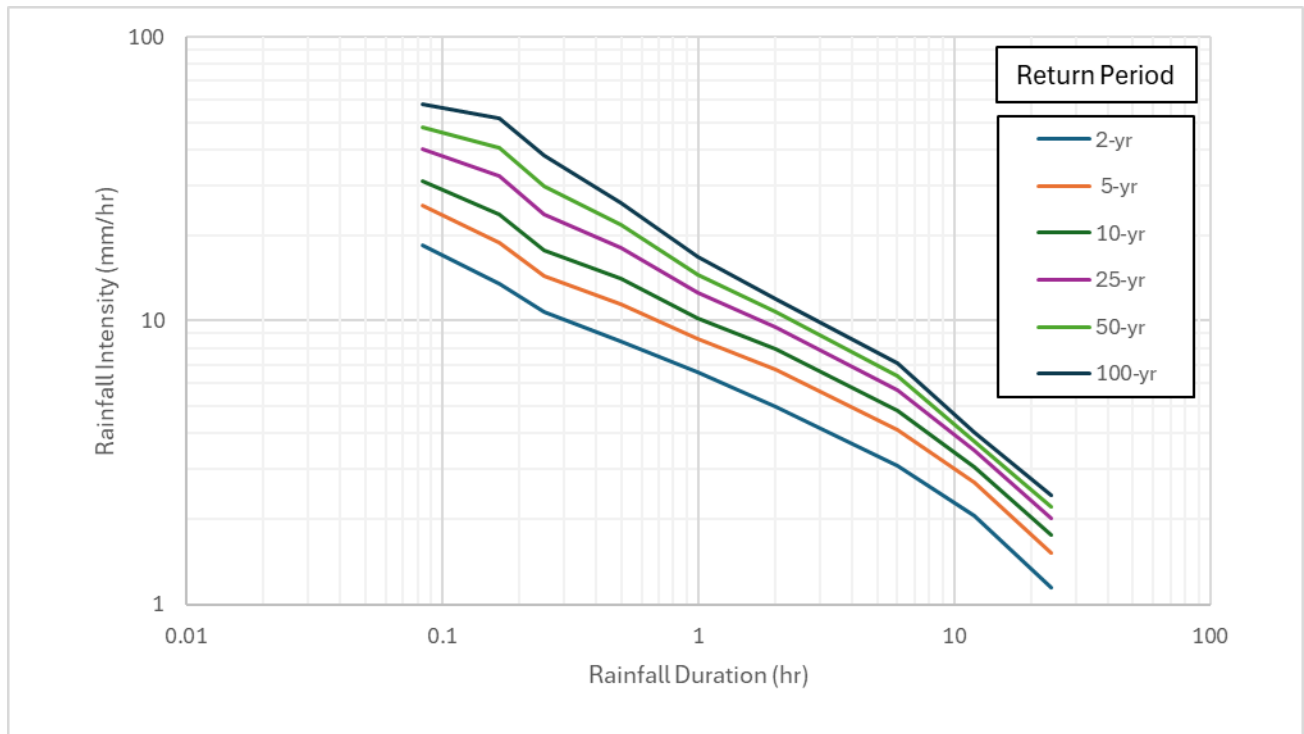


Figure 3-2 IDF curves for representative location between Nicoelton I.R. 6 and the Venables Valley (Simonovic et al., 2015).

3.4 Previous Geohazard Observations in the Study Area

Geohazards have previously occurred in the study area before the wildfire including:

- A large earth slide at Spence's Bridge near Murray Falls occurred on August 13, 1905 (Roden, February 20, 2019)
- Rockslides and rockfall are commonly reported along Highway 1 between Spence's Bridge and Ashcroft (BC Data Catalogue, n.d.). Highway 1 has been closed several times in the last decade (e.g., February 2007, April 2008, February 2013, January 2014, January 2015, June 2016).
- Debris flows and debris floods occurred in the study area after a heavy rainfall in mid to late July 2023. BGC travelled through Spence's Bridge after the rainfall and observed extensive debris flows on alluvial fans along the Thompson River. Murray Creek may have had a flood or debris flood event during this rainfall.

Cook's Ferry uses the Twaal Creek valley for traditional uses, cultural gatherings, and cattle grazing operations. Cook's Ferry band members indicated that Twaal Creek runs year-round and is primarily fed by springs at the base of alluvial fans. Cook's Ferry has observed relatively few historical occurrences of major flooding on Twaal Creek prior to the wildfire.

A Cook's Ferry band member indicated that flooding occurred on Spence Creek (a tributary of Twaal Creek) within the last decade that required re-routing the creek to avoid further erosional damage to the resource road that accesses this watershed.

On September 25, 2024, post-wildfire debris floods occurred in numerous watersheds in the Venables Creek valley⁵ (Figure 3-3). Residents described that the rainfall was intense and short-lived (less than one hour); no rainfall gauges are available in the Venables Valley to quantify the amount of rainfall that occurred. One home in the Venables Valley (4581 Rathayatra Way) was affected by overland flooding that travelled through the property and around the house. BGC is not aware of any additional impacts to properties from this rainfall.

⁵ Personal communication, Mark Greenberg and Radha-Krishna Paquette, November 17, 2024.



Figure 3-3 Overland post-wildfire flooding and sedimentation in the Venables Creek valley from the September 25, 2024 rainfall event. Photo provided by MOF (Gareth Wells).

4.0 METHODS

4.1 Introduction to Post-Wildfire Debris-Flow Partial Risk Assessment

Geohazard risks occur when geohazards have chance of impacting people or valuable assets, such as critical infrastructure, residences, roads, and sites of social, cultural or environmental importance, and when these elements at risk are vulnerable to damage (Strouth et al., 2024).

Risks can be assessed quantitatively, qualitatively, or semi-quantitatively. Quantitative risk assessment involves calculating each of the factors influencing risk (e.g., frequency and size of geohazards, life loss estimation). These risk assessments are sometimes completed for situations where life or other loss is relatively high and to determine the scope and scale of potential mitigation measures. Qualitative risk assessments use matrices with descriptive measures for each of the risk elements and are more practical when the type of risk or information available does not support quantification. A semi-quantitative assessment quantifies some components of the geohazard and risk assessment to determine a rating but does not calculate other factors such as life loss estimation.

Although Hope et al. (2015) uses a qualitative approach to partial risk assessments, MOF provided practitioners guidance during the 2024 wildfire year (email from MOF on October 17, 2024) that improves the PWNHRA to a semi-quantitative approach. As such, this report uses a semi-quantitative partial risk assessment method that estimates the likelihood of a post-wildfire geohazard (“Hazard Likelihood”), and the likelihood of spatial impact for a particular element at risk (“Spatial Impact Likelihood”). shows the matrix provided by MOF used in this partial risk assessment. Further details on how these ratings were evaluated is provided in sections below and in Appendix B.

Table 4-1 Matrix of post-wildfire natural hazard partial risk ratings.

Hazard Likelihood P(HA)	Spatial Impact Likelihood (P(S:H))		
	High	Moderate	Low
Very High	Very High	Very High	High
High	Very High	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Very Low
Very Low	Low	Very Low	Very Low

As described in Appendix B, BGC estimated an order-of-magnitude life safety risk estimate for persons in buildings in post-wildfire debris flow hazard areas, assuming that the debris flows have sufficient depth and velocity to result in life safety threats (typically deeper than 1 m and faster than 2 m/s). The risk estimation informed BGC’s recommendations in Section 6.0, for proportionate response to the risk.

4.2 Data Availability

BGC compiled terrain assessments, geohazard studies, spatial data within the study area. Relevant terrain assessments and geohazard studies in the study area completed in the study area include:

- Surficial geology and terrain of Ashcroft area (Ryder, 1976)
- Surficial geology and terrain of Lytton area (Ryder, 1981)
- Alluvial fan and flood geohazard mapping from the Thompson River watershed geohazard risk prioritization study (BGC, March 31, 2019)
- Observations of post-wildfire geohazards within the nearby 2021 Lytton Creek Fire area (BGC, December 1, 2021; BGC August 8, 2023)
- Ongoing alluvial fan, flood geohazard, and landslide mapping work from Cook's Ferry disaster risk reduction project (in progress)
- Level 2 PWNHRA for the Shetland Creek Fire (October 4, 2024).

The following additional data was used to map post-wildfire geohazards:

- Post-wildfire satellite imagery (acquired September 16, 2024, provided by MOF)
- Preliminary differenced normalized burn ratio (dNBR) and interim vegetation burn severity classes provided by MOF
- Air photos from the UBC Geographic Information Centre.
- Cadastral parcel data, compiled in mid 2024 by BGC for the province of BC
- Address spatial data from the TNRD (n.d.)
- Building footprints derived from satellite imagery (Fortin, 2024)
- Water rights licenses (BC Data Catalogue, March 13, 2024)
- Medium resolution (approximately 30 m resolution) digital elevation model (Government of Canada, 2024)
- Terrain stability mapping (BC Data Catalogue, October 17, 2024)
- Lidar data along the Thompson River valley bottom acquired in 2019 (BC lidar portal), which is restricted in the study area to the Murray Creek, Twaal Creek, and Venables Creek outlets.

4.3 Fieldwork

Fieldwork for this project was undertaken by Carie-Ann Hancock, P.Geo., Patrick Nolan, P.Eng., and Caleb Ring of BGC from November 16, 2024, to November 19, 2024. BGC visited the Venables Creek valley on November 16 and 17, 2024 and Nicoelton 6 IR on November 18 and November 19, 2024 (with band representatives from Cook's Ferry). During these field assessments, BGC completed ten uncrewed aerial vehicle (UAV) surveys. BGC also completed aerial reconnaissance of the study area with Valley Helicopters and a band member of Cook's Ferry on November 18, 2024.

BGC reviewed the satellite-derived burn severity classes provided by MOF at selected locations in the field. BGC completed 15 burn severity checks following the Burn Severity Assessments method in Hope et al. (2015); further details are provided in Appendix B. BGC also checked the proximity to selected elements at risk to the various post-wildfire geohazards. While not every

element at risk was visited during the field assessment, BGC checked representative locations, with an emphasis on elements at risk closest to potential geohazards.

During fieldwork, BGC observed evidence of rilling and sediment mobilization throughout the Venables Valley area and in other parts of the burned area from the September 25, 2024, rainfall event. BGC also observed active salvage logging occurring in the Venables Creek valley.

4.4 Approach

The methodology used in the geohazard and partial risk assessment is outlined in detail in Appendix B. Figure 4-1 outlines BGC's general approach to providing:

- Burn severity maps, which were used to estimate the severity and extent of the wildfire impact on geohazards.
- Geomorphic maps, which were used to evaluate the extent of potential post-wildfire geohazards and the geohazard process type.
- A Post-Wildfire Hazard Likelihood Rating, which estimates of the likelihood of a geohazard occurring (Table 4-2).
- A Spatial Impact Likelihood Rating, which estimates the likelihood that a geohazard will reach an element at risk (Table 4-3)
- A Post-Wildfire Partial Risk Rating, which is a combination of the Post-Wildfire Hazard Likelihood Rating and the Spatial Impact Likelihood Rating (Table 4-1), was estimated for each identified element at risk potentially affected by post-wildfire geohazards.

For this assessment, BGC defined an “event” as a geohazard that is most likely to occur in the time when post-wildfire geohazards are elevated (Section 2.0). For post-wildfire debris flows, this definition was analyzed by assuming the most likely event would be triggered by an intense rainstorm with a two-year return period. Larger events, such as debris flows triggered by a 100-year intense rainstorm, are possible, but were not assessed as part of this study.

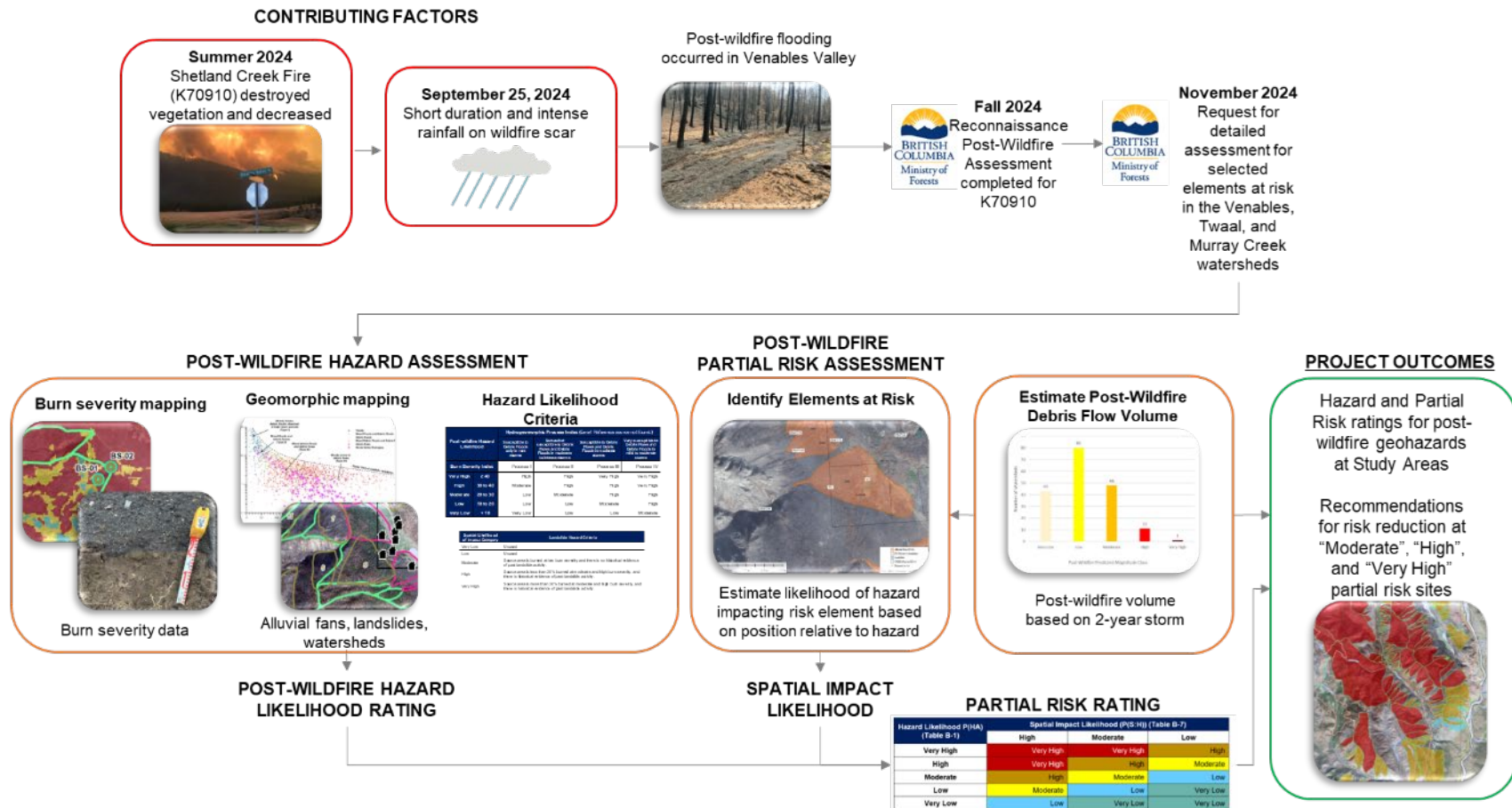


Figure 4-1 Summary of BGC's hazard and partial risk assessment methodology actions.

Table 4-2 Post-wildfire Hazard Likelihood categories and estimated likelihood, adapted from Land Management Handbook 56 (Wise et al., 2004) and Engineers and Geoscientists of BC Landslide Assessment Guidelines (March 1, 2023).

Hazard Likelihood (P(H))	Description ¹	Annual Likelihood Range (Return Frequency)	Five Year Cumulative Likelihood (% / 5 yrs)
Very High	An event is imminent or expected to occur over a 5-year period.	Greater than 20% (Greater than 1:5)	Greater than 67%
High	An event is probable under adverse conditions.	1 to 20% (1:100 to 1:5)	5 to 67%
Moderate	An event could occur under adverse conditions- it's not probable, but possible over a 5-year period.	0.2 to 1% (1:500 to 1:100)	1 to 5%
Low	An event could occur under very adverse conditions - it's considered very unlikely to occur over a 5-year period.	0.04 to 0.2% (1:2,500 to 1:500)	0.2 to 1%
Very Low	An event will not occur; or is conceivable though considered exceptionally unlikely to occur over a 5-year period.	Less than 0.04% (Less than 1:2,500)	<0.2%

Note: 1. Likelihood descriptions per definitions provided by International Panel on Climate Change (2010).

Table 4-3 Description for Spatial Impact Likelihood ratings and associated likelihood ranges for each rating, adapted from Land Management Handbook 56 (Wise et al., 2004).

Spatial Impact Likelihood	Description	Likelihood Range
High	It is probable that the element at risk will be impacted by the hazard.	> 0.5
Moderate	It is possible that the element at risk will be impacted by the hazard.	0.5 - 0.1
Low	It is unlikely that the element at risk will be impacted by the hazard.	<0.1

5.0 RESULTS

Geohazard ratings were assigned to 163 watersheds and 43 landslide-prone areas identified within the study area (Drawing 01). Partial risk ratings were assigned to buildings, campgrounds, water licenses, addresses with no elements at risk within the study area, and two resource roads, as outlined in Section 1.1. This section provides a summary of the results of both the geohazard and risk assessment. Detailed summaries of the partial risk assessments are provided in Appendix A. Breakdowns of the hazard assessment results for each watershed are provided in Appendix C.

5.1 Geohazard Assessment

This section describes the results of the geohazard assessment, which encompassed the burn severity mapping, geomorphic mapping, and Post-Wildfire Hazard Likelihood Ratings. This section is supported by the following information:

- Drawing 01 shows the geomorphic map of the study area
- Drawing 02 shows the burn severity mapping for the wildfire perimeter and location of burn severity field checks
- Drawing 03 shows the post-wildfire debris flow likelihood for the 157 watersheds interpreted as likely to produce post-wildfire debris flows
- Appendix C provides a summary table of the hazard assessment results for each watershed
- Appendix D provides representative photographs from the field work.

5.1.1 Burn Severity

The potential for post-wildfire geohazard response can be estimated by how severely the vegetation and soils have burned using a combination of satellite-derived difference normalized burn ratio (dNBR) and field observations; this process produces a “Burn Severity Map”. Burn severity is a relative measure of fire-induced ecological changes, typically reported as Low, Moderate, and High.

BGC compared the satellite-derived dNBR values (provided by MOF), the interim vegetation burn severity classes (provided by MOF), and field observations of soil burn severity, as discussed in Appendix B. Table 5-1 summarizes the field observations compared to the interim dNBR and burn severity classes provided by MOF. Note that between burn severity check sites BS-3 and BS-6, BGC completed a transect to evaluate the range of burn severity observations over a short distance. Detailed observations of soil burn severity are provided in Appendix B and Appendix E.

Table 5-1 Summary of field observations of vegetation and soil burn severity within the Shetland Creek Fire.

Observation number	dNBR value	MOF burn severity class	Observed vegetation burn severity	Observed soil burn severity	Notes
BS-1	0.51	Moderate	Moderate	Moderate	
BS-2	0.84	High	High	High	
BS-3	1.02	High	High	Moderate	Wide range of dNBR values reported across transect
BS-4	0.47	Moderate	Moderate	Low	Wide range of dNBR values reported across transect
BS-5	0.15	Low	Low	Low	Wide range of dNBR values reported across transect
BS-6	1.05	High	High	Moderate	Wide range of dNBR values reported across transect
BS-7	0.79	High	High	Moderate-High	
BS-8	0.90	High	High	High	
BS-9	0.08	Low	Moderate	Moderate	
BS-10	0.07	Unburned	Low	Low	
BS-11	-0.06	Unburned	Unburned	Unburned	
BS-12	0.22	Low	Moderate	Moderate	
BS-13	0.88	High	High	High	
BS-14	0.19	Low	Low	Low	
BS-15	-0.03	Unburned	Unburned	Unburned	

At the unburned and low burn severity sites, BGC made the following observations of the background vegetation and soil characteristics:

- Outside of burned areas, the forest floor generally consists of leaf and needle litter (generally less than 3 cm thick); moss was also observed at some locations.
- The transition to mineral soil was within 5 cm of the forest floor and was demarked by a thin (less than 3 cm) duff layer of partially decomposed organic material.
- No natural water repellency (hydrophobicity) was observed within the soil column; weak and spatially inconsistent hydrophobicity was only observed at the contact between the organic litter and duff layers in the soil column.

At the moderate and high burn severity sites, BGC made the following observations:

- The litter and duff layers were extensively consumed during the wildfire, particularly in high burn severity locations.
- Mineral soil, comprised of glacial deposits and colluvium, is now exposed on the surface in areas of high burn severity.

- Dominantly black ash, with rare locations of white ash, was extensively deposited across the wildfire and was generally less than 2 cm thick.
- At high burn severity sites, observed hydrophobicity was weak to moderate within the upper 3 cm of the mineral soil, but this observation was spatially inconsistent across the wildfire.
- Recent rilling, which represents increased overland flow during intense rainfall events, was observed at high burn severity sites in the Venables and Twaal Creek valleys.

Based on the above observations, BGC interpreted that the background soil repellency was low to non-existent before the wildfire. Given the extensive alteration to the vegetation and soils within the burned area, BGC is of the opinion that wildfire has increased the likelihood of post-wildfire geohazards, particularly due to increased runoff during high intensity rainfall. In general, BGC expects the Shetland Creek Fire scar to have similar post-wildfire geohazard response as nearby wildfire scars (2017 Elephant Hill Fire and 2021 Lytton Creek Fire) that have produced numerous post-wildfire debris flows, debris floods, floods, and landslides.

Because the observed soil burn severity generally matched the satellite-derived vegetation burn severity, BGC did not modify the burn severity class values provided by MOF. Drawing 02 shows the burn severity classes across the Shetland Creek Fire and the location of the soil burn severity field checks. The MOF burn severity classes were used in the hazard assessment.

5.1.2 Geomorphic Mapping

From the aerial photographs and the medium resolution DEM, BGC mapped watersheds, alluvial fans, and landslides in the study area, which were used in the hazard assessment and partial risk assessment. Details of the methods used for this are provided in Appendix B.

Drawing 01 shows the extent of these landforms. In total BGC mapped:

- 163 watersheds, ranging in size from 0.01 km² to 148 km²
- 140 alluvial fans, subject to debris flow, debris flood, and flood geohazards
- 20 earthflows, primarily in watersheds upslope of elements at risk
- 11 rockfall-prone slopes
- 2 rock-slide prone slopes
- 2 rock-slope deformation slopes
- 7 debris slide-prone slopes
- 1 debris fall prone slope.

Of the 163 watersheds in the study area, BGC interpreted:

- 154 are potentially subject to debris flow hazards, ranging in size from 0.01 to 8.1 km²
- Eight are potentially subject to debris flood hazards, ranging in size from 14 to 148 km²
- One is potentially subject to flood hazards, with a watershed size of 42 km².

5.1.3 Post-Wildfire Hazard Likelihood

Post-Wildfire Hazard Likelihoods were generated from empirical relationships that use data about the burn severity extent and watershed characteristics (Appendix B). A summary of the

Post-Wildfire Hazard Likelihood ratings for each of the 163 watersheds is shown in Figure 5-1. The ratings for debris-flow prone catchments are shown in Drawing 03.

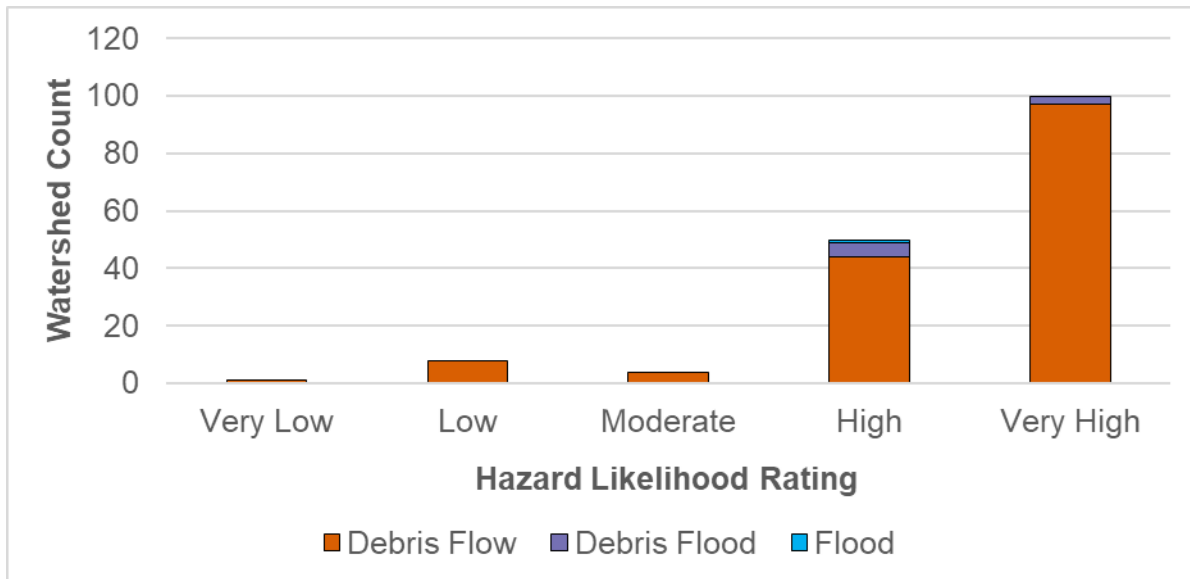


Figure 5-1 Distribution of the “Very Low” to “Very High” Post-Wildfire Hazard Likelihood ratings for the 163 watersheds in the study area.

BGC assigned Post-Wildfire Hazard Likelihood ratings to three landslides close to buildings in the Venables Creek valley, as well as 11 landslides along the Twaal Creek Road and Murray Creek Road. Given that all these hazards were burned at moderate and high severity and displayed evidence of past landslide activity, they were all assigned “High” Post-Wildfire Hazard Likelihood ratings. The ratings for the evaluated landslide hazards are shown on Drawing 03 and approximate extents of landslides near elements at risk are shown in Appendix A.

BGC evaluated that nine watersheds are likely to be subject to flood or debris flood hazard processes. Table 5-2 summarizes the assessment for these catchments, with notes on sediment transfer potential downstream. The hazard likelihood ratings for post-wildfire debris floods and floods are shown in Drawing 03.

Table 5-2 Summary of post-wildfire flood and debris flood likelihood ratings

Watershed name	Watershed Number (Drawing 01)	Size (km ²)	Low burn severity (%)	Medium burn severity (%)	High burn severity (%)	Total burned area (%)	Interpreted geohazard process	Post-wildfire Hazard Likelihood	Notes
Venables Creek (entirety)	162	41	9	24	49	85	Flood	Very High	Downstream of the alluvial fan at Blue Earth Farm, the creek flows into a broad valley with several lakes. The broad valley will likely attenuate debris flow and debris flood hazards from the upslope watershed and generate a flood within the valley. The lakes may also influence flood magnitude and sediment transfer downstream.
Twaal Creek (above Nicoelton Creek)	44	22	9	27	45	81	Debris flood	Very High	Debris flows from tributary catchments likely to introduce significant debris into Twaal Creek.
Spence Creek (tributary of Twaal Creek)	55	20	12	35	34	81	Debris flood	Very High	Debris flows from tributary catchments likely to introduce significant debris into Spence Creek. Previous floods at Spence Creek within the last decade have damaged resource road on alluvial fan.
Twaal Creek (entirety)	161	96	13	27	49	89	Debris flood	Very High	Debris flows from tributary catchments likely to introduce significant debris into Twaal Creek and transfer downstream towards Twaal Creek's outlet at the Thompson River (and the Hilltop Campground).
East Murray Creek (tributary of Murray Creek)	159	11	13	24	19	56	Debris flood	High	Tributaries near watershed outlet are likely to produce post-wildfire debris flow hazards and will likely introduce debris into Murray Creek.
Murray Creek (above East Murray Creek)	160	74	7	12	10	29	Debris flood	High	Tributaries near watershed outlet are likely to produce post-wildfire debris flow hazards and will likely introduce debris into Murray Creek.
Murray Creek (above Teit Creek)	164	128	12	20	14	46	Debris flood	High	Tributary catchments are likely to produce post-wildfire debris floods that will introduce sediment into Murray Creek.
Teit Creek (tributary of Murray Creek)	158	14	15	38	45	98	Debris flood	Very High	Sediment from this tributary is likely to continue downstream in the main channel of Murray Creek.
Murray Creek (entirety)	163	148	13	22	16	51	Debris flood	High	Tributary catchments (described above) are likely to produce post-wildfire debris flows and debris floods that will introduce sediment into Murray Creek and transfer downstream towards Murray Creek's outlet at the Thompson River.

5.2 Post-Wildfire Debris Flow Volume Estimation

Of the 154 catchments that are subject to post-wildfire debris flows, 147 catchments were burned sufficiently enough (greater than 20%) to support an evaluation of post-wildfire debris flow volume, as described in Appendix B. Figure 5-2 summarizes the results of this assessment, which assumed that the debris flows are triggered by a 2-year return period rainstorm event. This information was considered in the partial risk assessment (Section 5.3) and risk management recommendations (Section 6.0), as described in Appendix B.

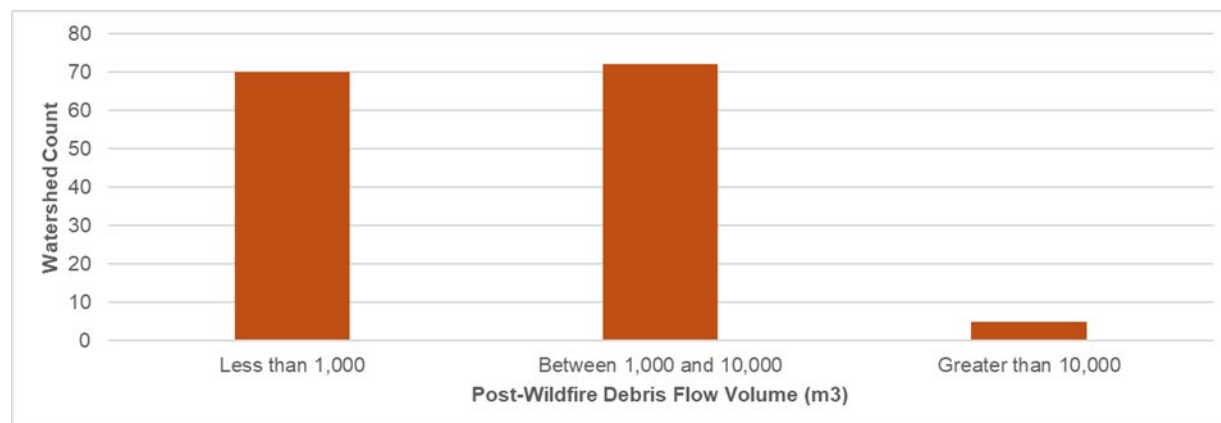


Figure 5-2 Distribution of predicted post-wildfire debris-flow volumes for a 2-year return period rainfall event.

5.3 Partial Risk Assessment Results

For the partial risk assessment, BGC assessed a total of:

- 60 buildings (houses, school, agricultural buildings, RV)
- One campground
- 36 water licenses and one water source with no water license
- 24 addresses with no visible elements at risk
- Two resource roads (Twaal Creek Road and Murray Creek Road).

Table 5-3 summarizes the results of the partial risk assessment for buildings, campground, water licenses, and addresses with no visible elements at risk. Summaries of each site are provided in Appendix A, including the partial risk assessments for the two resource roads.

Of the 60 buildings and one campground assessed in this study:

- 20 buildings have a “Very High” Partial Risk ratings, including the school (Govardhan Academy) and the Goshala (barn). The campground also has a “Very High” Partial Risk rating.
- 21 buildings have “High” Partial Risk ratings
- 2 buildings have “Moderate” Partial Risk ratings
- No buildings have “Low” or “Very Low” Partial Risk ratings
- 17 buildings are not in a hazard impact area.

Some buildings are exposed to more than one geohazard type (e.g., cabin at location A2 on Bhumi Farm), as outlined in Appendix A. The above summary provides the highest partial risk rating for these buildings.

As described in Appendix B, BGC estimated an order-of-magnitude life safety risk estimate for persons in buildings in post-wildfire debris flow hazard areas, assuming that the debris flows have sufficient depth and velocity to result in life safety threats. Typically, these depths and velocities are observed from post-wildfire debris flows that are larger than 1,000 m³ (see photographs in Appendix B). Most watersheds above buildings at risk in the study area could produce these debris flow volumes (see details in Appendix A and Appendix C). Larger volume debris flows are more likely to involve deeper flows, higher velocities, and further runout distances. Life loss risk also depends on the location of buildings relative to the primary inundation area.

Recognizing that TNRD and the Province of BC do not have tolerance thresholds for geohazard life loss risk, BGC compared these order-of-magnitude estimates to other jurisdictions in Canada with tolerable life loss risk levels (District of North Vancouver, 2009a; 2009b, District of Squamish, 2018, and Town of Canmore, 2016)⁶. In these jurisdictions, an annual life loss risk of 1:10,000 or less from natural hazards is considered tolerable for existing development. BGC notes that individual risk tolerance varies from person to person and may differ from tolerance thresholds developed by local government jurisdictions (Strouth & McDougall, 2022).

From this estimate, BGC makes the following observations:

- Buildings with “Very High” and “High” partial risk ratings may be more than ten times higher than Tolerable, particularly if post-wildfire debris flows are deep (greater than 1 m) and fast (greater than 2 m/s).
- Buildings with “Moderate” and “Low” partial risk ratings may be higher than Tolerable, particularly if post-wildfire debris flows are deep (greater than 1 m) and fast (greater than 2 m/s).
- Buildings with “Very Low” partial risk ratings most likely lower than Tolerable.

Given that life safety risks of post-wildfire geohazards are highly dependent upon the depth, velocity, and extent of geohazards, BGC recommends that MOF obtains lidar data for the study area and re-evaluate the partial risk ratings with runout modelling results.

The risk estimation informed BGC’s recommendations in Section 6.0, for proportionate response to the risk.

⁶ In other jurisdictions in Canada, an annual life loss risk of 1:10,000 or less from natural hazards is considered tolerable for existing development.

Table 5-3 Partial Risk Assessment Results for buildings, homes, and water licensees.

Site Name (Appendix A)	Watershed ID	Hazard Type	Post-wildfire Hazard Likelihood	Parcel ID	Risk Element ID	Element at Risk Type	Spatial Impact Likelihood	Partial Risk Rating
Water licenses along Venables Creek and Lake	162	Flood	High	003594734	PD47111	Water license	High	Very High
	162	Flood	High	003594734	PD47135	Water license	High	Very High
	162	Flood	High	003594734	PD47136	Water license	High	Very High
	162	Flood	High	N/A	PD47138	Water license	High	Very High
Water licenses in south Venables Creek valley	4	Debris Flow	Very High	N/A	PD47107	Water license	High	Very High
	7	Debris Flow	Very High	N/A	PD47108	Water license	High	Very High
	7	Debris Flow	Very High	N/A	PD47109	Water license	High	Very High
Venables - Peq-Paq	38	Debris Flow	Very High	N/A	Peq-Paq No 22	Cook's Ferry reserve	Low	High
	38	Debris Flow	Very High	N/A	PD47144	Licensed water source	Not in hazard impact area	Not in hazard impact area
	39	Debris Flow	Very High	N/A	PD47179	Licensed water source	High	Very High
	40	Debris Flow	Very High	N/A	PD47178	Licensed water source	High	Very High
	40	Debris Flow	Very High	N/A	PD47180	Licensed water source	High	Very High
East side of Venables Lake	48	Debris Flow	High	003594734	5012 Venables Valley Rd	No apparent element	Low	Moderate
	49	Debris Flow	High	003594734	5028 Venables Valley Rd	Building	Moderate	High
	51	Debris Flow	High	003594734	A6	Building	Moderate	High
	N/A	No mapped hazard	No mapped hazard	003594734	4812 Venables Valley Rd	Building	Not in hazard impact area	Not in hazard impact area
	N/A	No mapped hazard	No mapped hazard	003594734	4852 Venables Valley Rd	Building	Not in hazard impact area	Not in hazard impact area
	N/A	No mapped hazard	No mapped hazard	003594734	5044 Venables Valley Rd	No apparent element	Not in hazard impact area	Not in hazard impact area
	N/A	No mapped hazard	No mapped hazard	003594734	5072 Venables Valley Rd	No apparent element	Not in hazard impact area	Not in hazard impact area
	N/A	No mapped hazard	No mapped hazard	003594734	5232 Venables Valley Rd	No apparent element	Not in hazard impact area	Not in hazard impact area
	N/A	No mapped hazard	No mapped hazard	003594726	5280 Venables Valley Rd	Building	Not in hazard impact area	Not in hazard impact area
Venables - Blue Earth Farm	38	Debris Flow	Very High	014598388	A4	Building	Moderate	Very High
	38	Debris Flow	Very High	014598388	W1	Water source - no license	High	Very High
	38	Debris Flow	Very High	014598388	PD47140	Water license	High	Very High
Venables - Bhumi Farm	56	Debris Flow	Very High	014497247	A2	Building	High	Very High
	56	Debris Flow	Very High	014497247	A3	Building	Moderate	Very High
	56	Debris Flow	Very High	014497247	A10	Buildings (burned)	Moderate	Very High
	56	Debris Flow	Very High	014497247	PD47142	Water license	High	Very High
	56	Debris Flow	Very High	014497247	PD80552	Water license	Moderate	Very High
	N/A	Debris slide	High	014497247	A2	Building	Low	Moderate

Table 5-3 (continued).

General Area (Appendix A)	Watershed ID	Hazard Type	Post-wildfire Hazard Likelihood	Parcel ID	Risk Element ID	Element at Risk Type	Spatial Impact Likelihood	Partial Risk Rating
Venables - 4700 block Rathayatra Way	13	Debris Flow	Very High	003594726	4665 Rathayatra Way	Building	Low	High
	13	Debris Flow	Very High	003594769	4697 Rathayatra Way	No apparent element	Low	High
	13	Debris Flow	Very High	003594769	4709 Rathayatra Way	No apparent element	Low	High
	13	Debris Flow	Very High	003594769	4672 Rathayatra Way	No apparent element	Not in hazard impact area	Not in hazard impact area
Venables - 4700 Block Minnabariet Road	8	Debris Flow	Very High	003594793	A7	Building; likely burned down	Moderate	Very High
	162	Flood	High	003594793	4788 Minnabariet Rd	Building	Moderate	High
	Slope east of home	Rockfall	High	003594793	4788 Minnabariet Rd	Building	Moderate	High
	Slope north of watershed 8	Debris Slide	High	003594793	4721 Minnabariet Road	Building	Low	Moderate
	Slope north of watershed 8	Debris Slide	High	003594793	4745 Minnabariet Road	Building	Not in hazard impact area	Not in hazard impact area
Venables - 4700 block Govardan Hill Terr	12	Debris Flow	Very High	003594769	4745 Govardan Hill Terr	Building	Moderate	Very High
	12	Debris Flow	Very High	003594769	A9	RV	Low	High
	12	Debris Flow	Very High	003594769	A5	Building	Low	High
Venables - 4600 block Minnabariet Road	9	Debris Flow	Very High	003594793	4665 Minnabariet Rd	Building	Low	High
	162	Flood	High	003594793	4680 Minnabariet Rd	No apparent element	Low	Moderate
	162	Flood	High	003594793	4728 Minnabariet Rd	No apparent element	Low	Moderate
	No mapped watershed	No mapped hazard	Very Low	003594793	4660 Minnabariet Rd	Building	Not in hazard impact area	Not in hazard impact area
	No mapped watershed	No mapped hazard	Very Low	003594793	A1	Building	Not in hazard impact area	Not in hazard impact area
Venables - 4500 block Minnabariet Road	11	Debris Flow	Very High	003594769	4757 Govardan Hill Terr	Building	Low	High
	11	Debris Flow	Very High	003594769	4789 Govardan Hil Terr	Building	Low	High
	11	Debris Flow	Very High	003594769	4501 Minnabariet Rd	Building	Low	High
Venables - 4500 block Rathayatra Way	15	Debris Flow	Very High	003594726	4581 Rathayatra Way	Building	Moderate	Very High
	15	Debris Flow	Very High	003594726	4561 Rathayatra Way	Building	Moderate	Very High
	15	Debris Flow	Very High	003594726	4540 Harekrishna Lane	Building	Not in hazard impact area	Not in hazard impact area
	16	Debris Flow	Very High	003594726	4549 Rathayatra Way	Building (burned)	High	Very High
	17	Debris Flow	Very High	003594734	4521 Rathayatra Way	Building (burned)	High	Very High
	17	Debris Flow	Very High	003594734	4540 Rathayatra Way	Building (burned)	Low	High

Table 5-3 (continued).

General Area (Appendix A)	Watershed ID	Hazard Type	Post-wildfire Hazard Likelihood	Parcel ID	Risk Element ID	Element at Risk Type	Spatial Impact Likelihood	Partial Risk Rating
Venables - 4600 block Rathayatra Way	14	Debris Flow	Very High	003594726	4653 Rathayatra Way	Building	Moderate	Very High
	14	Debris Flow	Very High	003594726	4641 Rathayatra Way	Building	Moderate	Very High
	14	Debris Flow	Very High	003594726	4640 Rathayatra Way	School (Govardhan Academy)	Moderate	Very High
	14	Debris Flow	Very High	003594726	4625 Rathayatra Way	No apparent element	Moderate	Very High
	14	Debris Flow	Very High	003594726	A8	Barn (goshala)	Moderate	Very High
	14	Debris Flow	Very High	003594726	4609 Rathayatra Way	Building	Moderate	Very High
	14	Debris Flow	Very High	003594726	4632 Rathayatra Way	Building	Not in hazard impact area	Not in hazard impact area
	14	Debris Flow	Very High	003594726	4620 Rathayatra Way	Building	Not in hazard impact area	Not in hazard impact area
	14	Debris Flow	Very High	003594726	4604 Rathayatra Way	Building	Not in hazard impact area	Not in hazard impact area
	14	Debris Flow	Very High	003594726	4593 Rathayatra Way	No apparent element	Low	High
	14	Debris Flow	Very High	003594726	PD47110	Licensed water source	High	Very High
Venables - 4400 block Rathayatra Way	17	Debris Flow	Very High	003594734	4544 Talavan Cres	Building	Not in hazard impact area	Not in hazard impact area
	19	Debris Flow	Very High	003594734	4500 Rathayatra Way	Building	Low	High
	32	Debris Flow	Very High	N/A	PD20745	Licensed water source	High	Very High
	32	Debris Flow	Very High	N/A	PD208661	Licensed water source	High	Very High
	32	Debris Flow	Very High	003594734	4469 Rathayatra Way	Building	Not in hazard impact area	Not in hazard impact area
	32	Debris Flow	Very High	003594734	4485 Rathayatra Way	No apparent element	Low	High
Venables - 4400 block Jaganatha Trail	18	Debris Flow	Very High	003594734	4432 Rathayatra Way	No apparent element	Low	High
	31	Debris Flow	Very High	003594734	4453 Rathayatra Way	Building (partially burned, demolished)	Moderate	Very High
	31	Debris Flow	Very High	003594734	4461 Rathayatra Way	Building (burned)	Moderate	Very High
	31	Debris Flow	Very High	003594734	4460 Rathayatra Way	Building	Low	High
	31	Debris Flow	Very High	003594734	4452 Rathayatra Way	Building	Low	High
	31	Debris Flow	Very High	003594734	4489 Jaganatha Trail	Building	Low	High
	31	Debris Flow	Very High	003594734	4496 Jaganatha Trail	Building	Low	High
	31	Debris Flow	Very High	003594734	4433 Bhakti Blvd	Building	Not in hazard impact area	Not in hazard impact area
	34	Debris Flow	Very High	003594734	4448 Rathayatra Way	No apparent element	Moderate	Very High
	32	Debris Flow	Very High	003594734	4493 Bhatki Blvd	No apparent element	Not in hazard impact area	Not in hazard impact area
Venables - 4300 block Rathayatra Way	26	Debris Flow	Very High	003594734	4340 Rathayatra Way	No apparent element	Low	High
	26	Debris Flow	Very High	003594734	4320 Rathayatra Way	Building	Low	High

Table 5-3 (continued).

General Area (Appendix A)	Watershed ID	Hazard Type	Post-wildfire Hazard Likelihood	Parcel ID	Risk Element ID	Element at Risk Type	Spatial Impact Likelihood	Partial Risk Rating
Venables - 4000 block Prabhupad PI	35	Debris Flow	Very High	003594742	4089 Prabhupad PI	Building	Low	High
	35	Debris Flow	Very High	003594742	4087 Prabhupad PI	Building	Not in hazard impact area	Not in hazard impact area
	35	Debris Flow	Very High	003594742	4641 Prabhupad PI	Building	Not in hazard impact area	Not in hazard impact area
	35	Debris Flow	Very High	003594742	4088 Prabhupad PI	Building	Not in hazard impact area	Not in hazard impact area
Venables - 4200 block Bhaktivedanta PI	28	Debris Flow	Very High	003594742	4140 Bhaktivedanta PI	Building (burned)	Moderate	Very High
	28	Debris Flow	Very High	003594742	4165 Bhaktivedanta PI	No apparent element	Moderate	Very High
	28	Debris Flow	Very High	003594742	4185 Bhaktivedanta PI	No apparent element	Moderate	Very High
	28	Debris Flow	Very High	003594742	4209 Bhaktivedanta PI	No apparent element	Moderate	Very High
	28	Debris Flow	Very High	003594742	4219 Bhaktivedanta PI	No apparent element	Moderate	Very High
	28	Debris Flow	Very High	003594742	4229 Bhaktivedanta PI	No apparent element	Moderate	Very High
	28	Debris Flow	Very High	003594742	4228 Prabhupad PI	No apparent element	Not in hazard impact area	Not in hazard impact area
	28	Debris Flow	Very High	003594742	4180 Prabhupad PI	Building	Low	High
	28	Debris Flow	Very High	003594742	4169 Prabhupad PI	No apparent element	Low	High
	28	Debris Flow	Very High	003594742	4221 Rathayatra Way	Building	Not in hazard impact area	Not in hazard impact area
	29	Debris Flow	Very High	003594742	4277 Talavan Cres	Building	High	Very High
	162	Flood	High	003594742	4240 Rathayatra Way	Building	Low	Moderate
	29	Debris Flow	Very High	003594742	4285 Rathayatra Way	Building	Low	High
	29	Debris Flow	Very High	003594742	4280 Rathayatra Way	Building (partially burned)	Low	High

Table 5-3 (continued).

General Area (Appendix A)	Watershed ID	Hazard Type	Post-wildfire Hazard Likelihood	Parcel ID	Risk Element ID	Element at Risk Type	Spatial Impact Likelihood	Partial Risk Rating
Water licenses along Twaal Creek outside debris flow hazard zones and Spence Creek	161	Debris Flood	High	Nicoelton No 6	PD45748	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD45749	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD45750	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD45751	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD47019	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD47021	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD47022	Water license	High	Very High
	161	Debris Flood	High	Nicoelton No 6	PD47025	Water license	High	Very High
Water license in Twaal Creek watershed	119	Debris Flow	High	N/A	PD74780	Water license	High	Very High
Twaal - Yellow Cabin	55	Debris Flood	Very High	Nicoelton No 6	PD47026	Water license	Moderate	Very High
	55	Debris Flood	Very High	Nicoelton No 6	PD47027	Water license	High	Very High
	55	Debris Flood	Very High	Nicoelton No 6	Yellow Cabin	Building	High	Very High
	55	Debris Flood	Very High	Nicoelton No 6	Road	Road	High	Very High
Twaal – Hilltop Campground	161	Debris Flood	High	012997005	PD45752	Water license	High	Very High
	161	Debris Flood	High	012997005	6545 Trans-Canada Highway	Campground	High	Very High
	161	Debris Flood	High	N/A	PD73266	Water license	Not in hazard impact area	Not in hazard impact area
Water licenses along Murray Creek	152	Debris Flow	High	N/A	PD45758	Water license	High	Very High
	159	Debris Flood	High	N/A	PD47114	Water license	High	Very High
	163	Debris Flood	High	N/A	PD45760	Water license	High	Very High
	163	Debris Flood	High	N/A	PD45761	Water license	High	Very High
	163	Debris Flood	High	N/A	PD45762	Water license	High	Very High
	164	Debris Flood	High	N/A	PD45759	Water license	High	Very High

6.0 RISK MANAGEMENT RECOMMENDATIONS

BGC was requested by MOF to identify risk reduction measures for “Moderate”, “High”, and “Very High” partial risk ratings. The following sections identify general risk reduction measures for the Shetland Creek Fire scar (Section 6.1) and for site-specific locations (Section 6.2).

6.1 Overview of Risk Reduction Measures

Reducing post-wildfire geohazard risk is challenging because the elevated hazard is present immediately after the landscape has burned. Furthermore, rainfall that can trigger geohazard does not have to be extraordinary to trigger an extraordinary geohazard. For example, debris flows that have resulted in life loss and extensive damage to infrastructure have been triggered by storms with return periods of less than two years (Staley et al., 2020). As a result, there can be very little time to design and implement risk reduction measures that effectively reduce risk to tolerable levels.

The following sections summarize risk reduction measures that could be implemented in areas with post-wildfire geohazard risk.

6.1.1 Hazard Avoidance

Hazard avoidance is the most effective way to reduce risk in areas where post-wildfire geohazard risk is intolerable. Avoiding the post-wildfire hazard areas during the period when post-wildfire geohazard activity is most elevated, which is typically two to five years following the fire (Section 2.0), is the only way to not be affected by a post-wildfire geohazard.

Residents occupying buildings in post-wildfire geohazard areas may opt to leave the hazard areas rather than pursue other risk reduction options, which can be costly and take time to implement. However, long-term building evacuations can be highly disruptive and costly to building occupants, especially if the home is occupied full-time or if the home is a source of income.

6.1.2 Awareness and Education

Awareness and education of post wildfire geohazards can reduce life safety risk, as actions taken when debris flows are heard or seen form an important part of reducing the chances of life safety risks (Wartman and Pollock, 2020). As described in Section 2.0, post-wildfire geohazards typically occur in the first two to five years of a wildfire and there is typically very little time between heavy rainfall and post-wildfire debris flows occurring. Therefore, property owners and members of the public should be made aware of these risks as soon as practical. BGC assumes that this awareness and education would be implemented by First Nations (Cook’s Ferry), local governments (TNRD), and provincial agencies (MOF and MOTT).

Improving awareness of post-wildfire geohazards may be achieved by:

- **Community meetings** to inform residents of the potential for post-wildfire geohazards in and downslope of the burned area, where post-wildfire geohazards are anticipated, and when post-wildfire geohazards may occur. The results presented in this report and

infographic examples provided in Appendix E can be leveraged for these purposes. The following is important information to communicate to the public:

Post-wildfire geohazards can occur within minutes of heavy rainfall. If you hear or see a geohazard happening, it is usually too late to evacuate. If it is unsafe to evacuate, shelter up and away in a building (top floor or roof) on the side away from the hillslope. Avoid basements or crawl spaces. If in a vehicle, do not attempt to cross debris deposits, and do not exit the vehicle.

- **Signage** in areas with moderate to very high post-wildfire geohazard partial risk, signs that inform people in the area of the hazard can help prevent people from stopping in geohazard area and unnecessarily exposing themselves to geohazard impacts (Figure 6-1).



Figure 6-1 Educational/warning signage in the Elephant Hill Fire area.

6.1.3 Warning systems

Warning systems can reduce risk by alerting people within the wildfire scar when rainfall conditions are most likely to trigger post-wildfire debris flows. BGC assumes that this system would need to be operated by a provincial or federal agency. Rainfall gauges are not present in the wildfire area and the radar quality within the wildfire from available radar is relatively poor. Additional equipment may need to be installed prior to the development of an early warning system.

BGC recommends that warning systems should not be used as the sole risk reduction measure to achieve lower risk levels (e.g., through temporary evacuations). Warning systems are only as good as the weather forecast and can lead to evacuation fatigue if too many warnings are issued for storms that do not trigger a post-wildfire geohazard. In addition, convective rainfall can develop with little notice and can trigger post-wildfire geohazards before a warning system is able to identify the hazardous weather conditions. If the warning system supports emergency response planning, specific actions taken by property owners in the event of a weather warning should be planned and tested in advance.

6.1.4 Emergency Response Planning

Emergency preparedness and planning can reduce the impacts of post-wildfire geohazards. Examples include staging equipment to quickly clear roads and properties from debris, developing plans and protocols for effective actions to take during post-wildfire geohazard events, and identifying procedures for area and/or roads closures when the wildfire is more susceptible to post-wildfire geohazards. BGC assumes that emergency response planning would be the responsibility of First Nations (Cook's Ferry), local government (TNRD), and provincial entities (MOF).

In the event of an evacuation, people may travel through higher risk areas and should be advised of the risks in the area through signage or other communication approaches. Emergency response plans for persons in buildings, pedestrians, and persons in vehicles are particularly important and should consider that evacuation routes may become blocked by post-wildfire geohazards.

6.1.5 Construction of Risk Reduction Mitigation

Mitigation structures that deflect and/or capture post-wildfire geohazards can be very effective at reducing geohazard risk. However, because post-wildfire geohazards can occur immediately after a fire, construction of these mitigation structures before a post-wildfire geohazard impact is very challenging. Constructing risk reduction mitigation requires additional work including detailed assessment, engineering design, permitting, funding and construction. Therefore, post-wildfire geohazards may impact the area before mitigation structures can be completed. Section 6.2 provides some examples of site-specific risk reduction measures that could be implemented in the study area. As discussed in this section, BGC assumes that construction of

risk reduction measures is generally the responsibility of property owners and lease holders (forestry and range).

Other risk reduction measures that can be rapidly implemented, such as sandbags and lock blocks (sometimes referred to as jersey barriers), do not provide significant risk reduction. In some cases, these measures can reduce impacts of sedimentation from non-life-threatening flows. However, sandbags and lock block walls are largely ineffective at reducing life safety risks posed by a deep and fast flowing debris flow. Furthermore, these measures may provide a false sense of security and increase risk by making people think post-wildfire geohazards have been mitigated in their area.

6.2 Site-Specific Risk Reduction Measures

In addition to the risk reduction options presented in 6.1, this section provides site-specific risk reduction measures for applicable watersheds in the Venables Creek, Twaal Creek, and Murray Creek valleys.

The following guidance is provided for constructing risk reduction measures:

- Additional study or site reviews by Qualified Professional(s) are recommended to locate and design engineered structures and local protection.
- Risk reduction measures should be discussed with property owners and local authorities to evaluate the potential costs (financial, social, and ecological) versus the benefits of the risk reduction measure.
- Design and construction of risk reduction structures should not transfer risk to other persons or groups downslope.

The costs associated with risk reduction measures are generally the responsibility of property owners and lease holders (forestry and range), even though the hazard may originate in other areas (e.g., provincially regulated lands). Given the potentially large size of post-wildfire debris flows, engineered risk reduction measures may be unaffordable for individual property owners and not feasible to be constructed before post-wildfire geohazards occur.

Table 6-1 Site-specific risk reduction recommendations for the study area.

Action	Description	Applicable Watershed Number	Elements at Risk (Table 5-3)	Notes and Assumptions	Estimated Relative Cost
Fan-level channel conveyance	Improving channel conveyance and redirecting flows by excavating channels to be deeper and wider that are less likely to avulse and result in flows reaching assets.	14, 38, 56	Nine buildings with Moderate to Very High Partial Risk	Assumed to be the responsibility of property owners and lease holders. Only three alluvial fans (watersheds 14, 38, and 56) had incised channels; the remainder of the alluvial fans were difficult to discern the channel from orthoimagery. Design of risk reduction measure requires site-specific assessment of flow depths and velocities to design appropriate measures. Improved channel conveyance should avoid risk transference to other persons or groups downstream.	High
Fan-level debris deflection or sediment capture	Construction of engineered works (deflection berms, debris catchment basin) to reduce sediment inundation and impacts at buildings	9, 11, 12, 13, 14, 15, 19, 26, 28, 29, 31, 35, 38, 49, 51, 55, 56, 162	30 buildings with Moderate to Very High Partial Risk	Assumed to be the responsibility of property owners and lease holders. Design of risk reduction measure requires site-specific assessment of flow depths and velocities to design appropriate measures.	High
Building-level risk reduction	Construction of local protection adjacent to buildings (engineered block walls, ditches, deflection berms, etc.). Examples shown in United States Geological Survey (2008).	9, 11, 12, 13, 14, 15, 19, 26, 28, 29, 31, 35, 38, 49, 51, 55, 56, 162	30 buildings with Moderate to Very High Partial Risk	Assumed to be the responsibility of property owners. Design of building-level risk reduction requires site-specific assessment of flow depths and velocities to select appropriate risk reduction measures. Inappropriate design of building-level risk reduction may not reduce life safety risks and would create a false sense of security.	Moderate to High
Rockfall risk management	Signage, rock scaling, rockfall protection berm, or rockfall mesh. Monitor stability of rockfall prone faces with site inspections by a qualified professional.	N/A	One building with High Partial Risk; Twaal Creek Road; Murray Creek Road	Assumed to be the responsibility of property owners, First Nations (Cook’s Ferry) and provincial agency (MOF). Design of building-level risk reduction requires site-specific assessment of rockfall characteristics. Reduce risks to road users through implementation of signage indicating “no stopping” zones.	Moderate to High
Debris slide risk management	Signage, drainage improvement, and debris nets. Monitor stability of debris slide prone areas.	N/A	Two buildings with Moderate Partial Risk, Twaal Creek Road; Murray Creek Road	Assumed to be the responsibility of property owners, First Nations (Cook’s Ferry) and provincial agency (MOF). Design of building-level risk reduction requires site-specific assessment of debris slide characteristics. Reduce risks to road users through implementation of “no stopping” zones. Road damage (cracking, displacement) due to earth slide was observed to the Twaal Creek road approximately 3 km upstream of the Spence Creek confluence. Design of risk reduction measure at this site will require further assessment.	Moderate to High
Rockslide and rock slope deformation risk management	Monitor ongoing movement of slopes above Murray Creek road to evaluate potential response actions.	N/A	Murray Creek Road	Assumed to be the responsibility of provincial agency (MOF). Wildfire may influence groundwater levels within the slope and may increase flow in Murray Creek and subsequent erosion at the toe of the landslide. These two factors may impact rockslide and rock slope deformation activity. Given the relatively large size of these hazards, costs to engineer risk reduction measures are likely to be extremely high. As such, risk monitoring may be a more appropriate action.	Moderate
Maintain and rehabilitate resource road drainage	Measures could include the construction of ditches, culverts, silt fences, debris basins, etc. Examples of these measures are provided in Folz et al. (2009).	N/A	Twaal Creek Road, Murray Creek Road, additional resource roads upslope of elements at risk (including road accessing 4544 Talavan Cres)	Assumed to be the responsibility of First Nations (Cook’s Ferry), property owners, lease holders, and provincial agency (MOF).	High

Action	Description	Applicable Watershed Number	Elements at Risk (Table 5-3)	Notes and Assumptions	Estimated Relative Cost
Reduce upslope hazard likelihood	Encourage upslope hazard reduction through reseeding or mulching. Examples are provided in Robichaud et al. (2013) and Pacific Salmon Foundation (October 2024).	N/A	45 buildings at Moderate to Very High Partial Risk, Twaal Creek Road, Murray Creek Road.	Assumed to be the responsibility of First Nations, lease holders, and provincial agencies (MOF). BGC understands that aerial reseeding occurred in the nearby 2017 Elephant Hill Fire and 2021 Lytton Creek Fire, and that a non-persistent grass seed mix is potentially available for aerial reseeding.	Moderate to High
Monitor risks to water licenses	Monitor water quality parameters (turbidity, nutrients, contaminants) to evaluate potential response as required. Implement risk reduction measures to maintain water availability for domestic and agricultural use.	N/A	35 water licence and water intake locations	Assumed to be the responsibility of First Nations and water license holders. A limited number of water licenses were observed by BGC during the field work. BGC understands that water intakes in the Venables Creek valley are primarily for domestic and agricultural use. Intakes and water storage structures may require ongoing maintenance due to sedimentation and/or erosion. Within the Twaal Creek valley licenses are primarily for agricultural use and consist primarily of ditches. Ditches may require ongoing maintenance to due to sedimentation and/or erosion.	Moderate to High

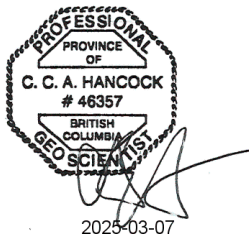
7.0 CLOSURE

This report contains sections under the supervision of different individuals. Carie-Ann Hancock is the responsible author for the Sections 1.0 through 5.0 (Introduction, Wildfire Effects on Watersheds Over Time, Study Area Background, Methods, and Results). Joseph Gartner is the responsible author for Section 6.0 (Risk Management Recommendations).

We trust the above satisfies your requirements. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

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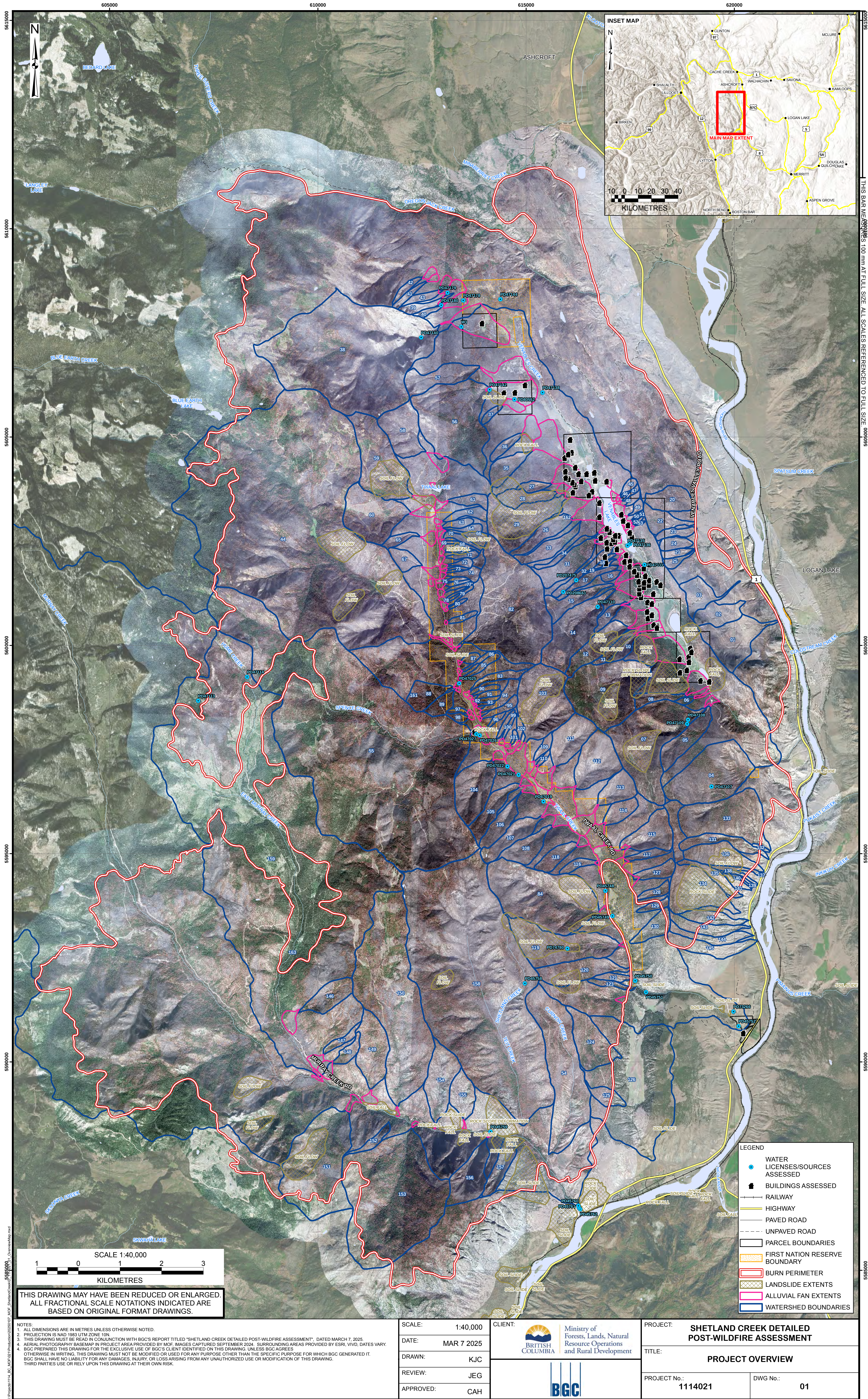
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DRAWINGS





NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. PROJECTION IS NAD 1983 UTM ZONE 10N.
3. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "SHETLAND CREEK DETAILED POST-FIRE ASSESSMENT", DATED MARCH 7, 2025.
4. THIS DRAWING IS BASED ON A PROJECT AREA PROVIDED BY MR. JACQUES CAPTURED IN SEPTEMBER 2024. SURROUNDING AREAS PROVIDED BY ESRI, VARIOUS DATES VARY.
5. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING.
6. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:40,000
DATE:	MAR 7 2025
DRAWN:	KJC
REVIEW:	JEG
APPROVED:	CAH

CLIENT:



BRITISH
COLUMBIA



Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development



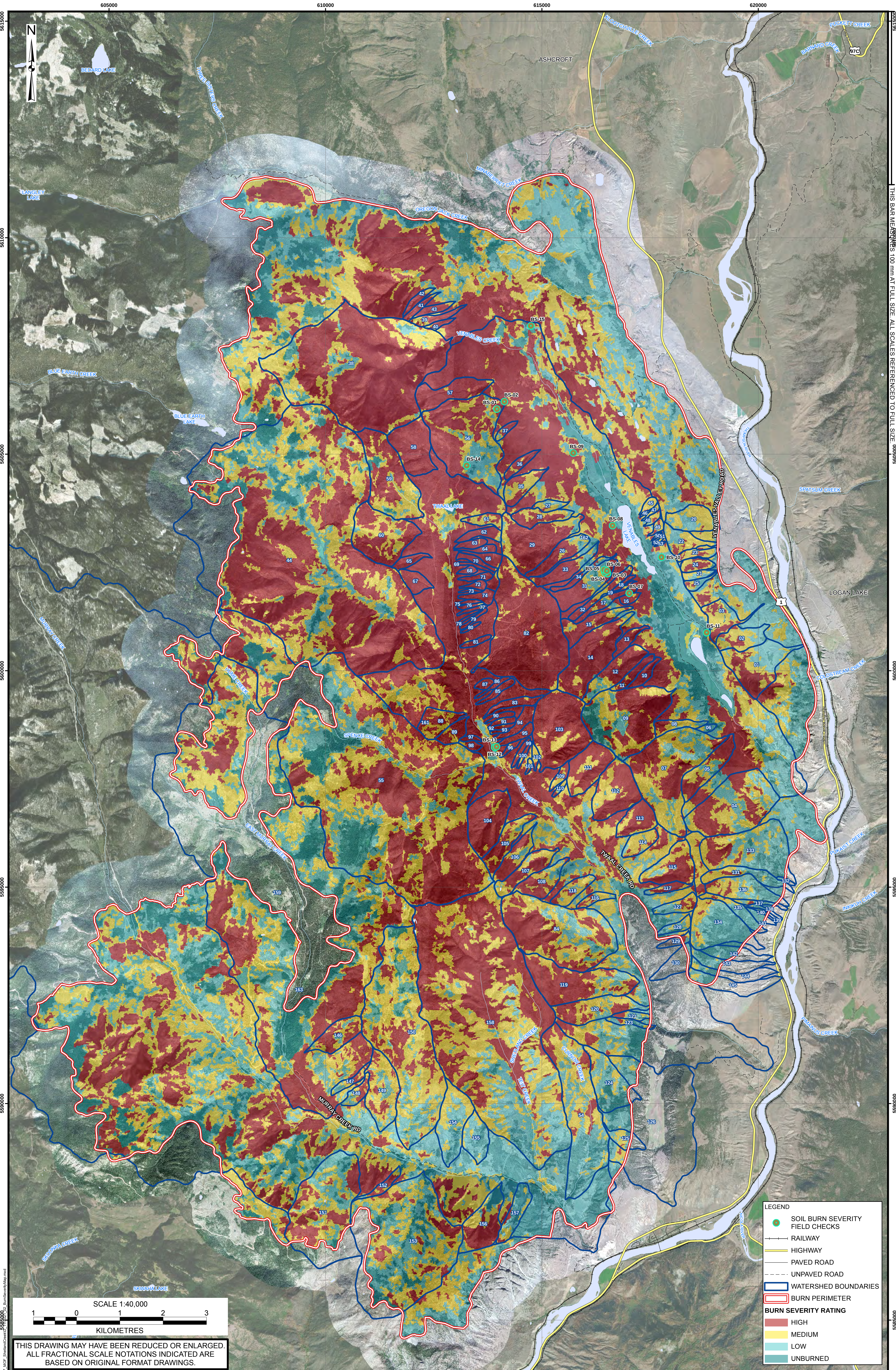
BGC

PROJECT: **SHETLAND CREEK DETAILED
POST-WILDFIRE ASSESSMENT**

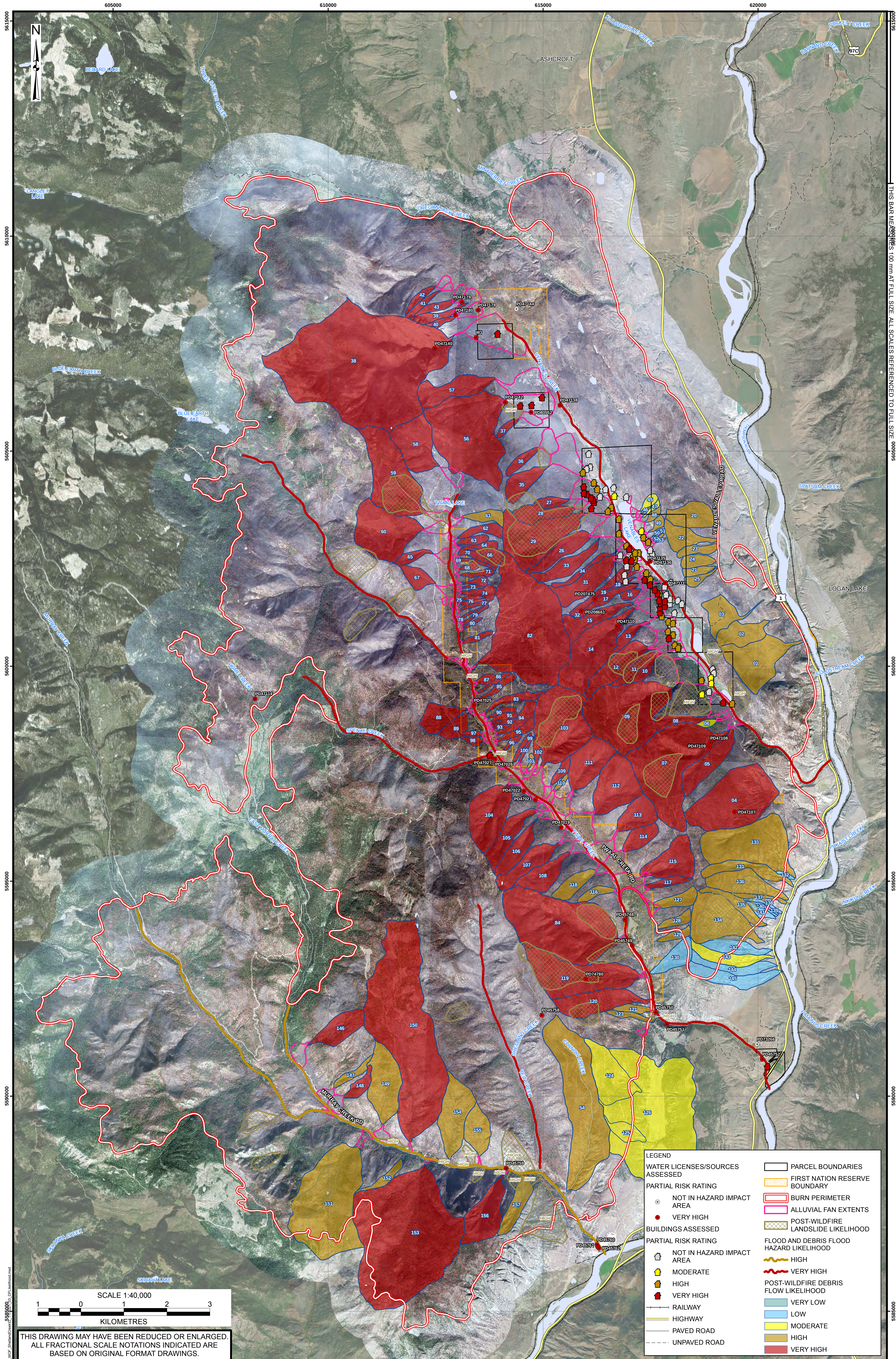
PROJECT OVERVIEW

PROJECT No.:
1114021

DWG No.: **01**



NOTES: 1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED. 2. PROJECTION IS NAD 1983 UTM ZONE 10N. 3. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "SHETLAND CREEK DETAILED POST-WILDFIRE ASSESSMENT", DATED MARCH 7, 2025. 4. AERIAL PHOTOGRAPHY BASEMAP IN PROJECT AREA PROVIDED BY MOF. IMAGES CAPTURED SEPTEMBER 2024. SURROUNDING AREAS PROVIDED BY ESRI. VIVID DATES VARY. 5. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.	SCALE: 1:40,000		CLIENT:  Ministry of Forests, Lands, Natural Resource Operations and Rural Development 	PROJECT: SHETLAND CREEK DETAILED POST-WILDFIRE ASSESSMENT	
	DATE: MAR 7 2025			TITLE: BURN SEVERITY MAP	
	DRAWN: KJC			PROJECT No.: 1114021	
	REVIEW: JEG			DWG No.: 02	
	APPROVED: CAH				



APPENDIX A

PARTIAL RISK ASSESSMENT SUMMARY



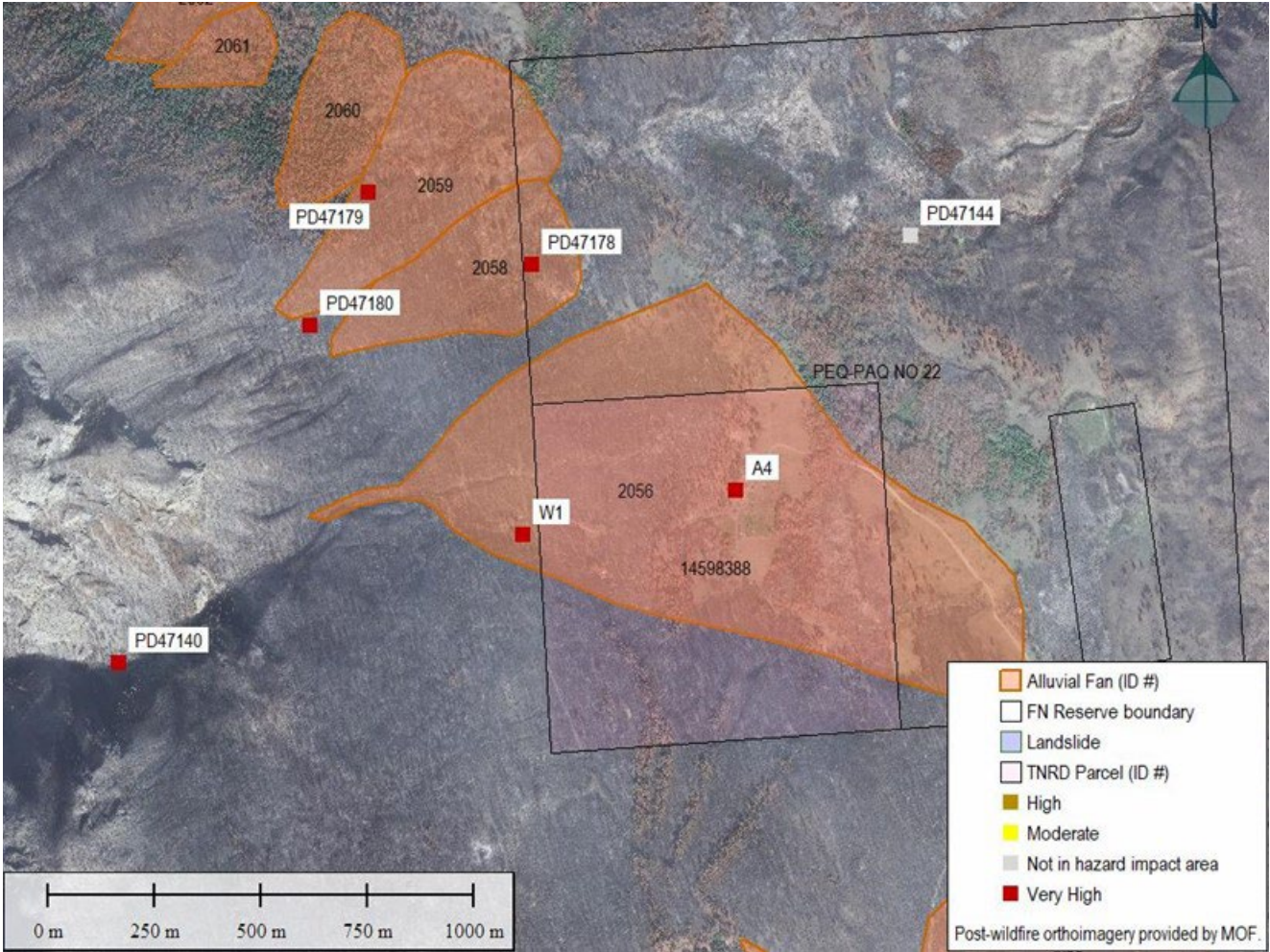
SITE INFORMATION			
Site Name	Blue Earth Farm		

HAZARD ASSESSMENT			
Alluvial Fan ID	2056	2056	2056
Watershed ID	38	38	38
Stream Name	Venables Creek	Venables Creek	Venables Creek
Burn Severity - Unburned (%)	2%	2%	2%
Burn Severity - Low (%)	4%	4%	4%
Burn Severity - Moderate (%)	20%	20%	20%
Burn Severity - High (%)	73%	73%	73%
Geohazard Type	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	>10,000	>10,000	>10,000
Geohazard Likelihood	Very High	Very High	Very High

ELEMENTS AT RISK			
Parcel ID	014598388	014598388	014598388
Site Identifier	A4	W1	PD47140
Risk Element Type	Building	Water source - no license	Water license

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	Yes	Yes	Yes
Fan Position	Distal (Lower 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)
Channel Position	1/3 to 2/3 of active channel	Beyond 1/3 of active channel	Within 1/3 of active channel
Additional Considerations (+/-)		Diversion channel present that may direct flow towards asset	
Spatial Impact Likelihood	Moderate	High	High
Comments	Large volume debris flow (>10,000 m³) will likely reach lower fan. House is within 150 m of active channel.	Diversion channel constructed at fan apex. BGC was not able to assess the channel capacity or how much may divert from main channel. As such, BGC increased the spatial impact from Moderate to High.	Site was not visited during field work. The water license was assumed to be in channel.

PARTIAL RISK ASSESSMENT			
Partial Risk Rating	Very High	Very High	Very High
Comments			

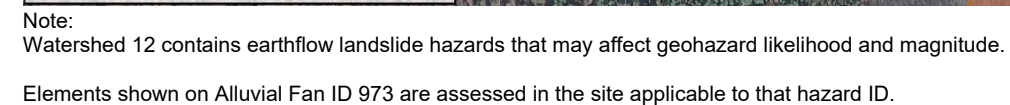


Note:
A historical debris flow or debris flood deposit was observed in the main channel at mid fan. The house at location A4 is within 150 m of an active channel. A diversion channel constructed at fan apex is visible in orthoimagery.

Elements shown on Alluvial Fan IDs 2058 and 2059, and Peq-Paq No 22 are assessed in the site applicable to that hazard ID or element.

HAZARD ASSESSMENT					
Hazard ID	2031			2154	
Watershed ID	8	Slope north of watershed 8	Slope north of watershed 8	162	Slope east of home
Stream Name	N/A	N/A	N/A	Venables Creek	
Burn Severity - Unburned (%)	0%			14%	
Burn Severity - Low (%)	16%			13%	
Burn Severity - Moderate (%)	56%			24%	
Burn Severity - High (%)	28%			49%	
Geohazard Type	Debris Flow	Debris Slide	Debris Slide	Flood	Rockfall
Estimated Post-wildfire Debris Flow Volume (m^3)	1,000-10,000	N/A	N/A	N/A	N/A
Geohazard Likelihood	Very High	High	High	High	High

SPATIAL IMPACT ASSESSMENT					
Presence of incised channel on fan	Yes				
Fan Position	Distal (Lower 3rd)				
Channel Position	Within 1/3 of active channel				
Additional Considerations (+/-)				Home in proximity to floodplain	Rockfall deposits observed in proximity to home
Spatial Impact Likelihood	Moderate	Low	Not in hazard impact area	Moderate	Moderate
Comments		At margin of debris slide hazard area	Outside of mapped hazard area. May be impacted by overland flooding.	Home in proximity to floodplain	Rockfall deposits observed in proximity to home – home is at distal end of rockfall deposit

BGC Engineering

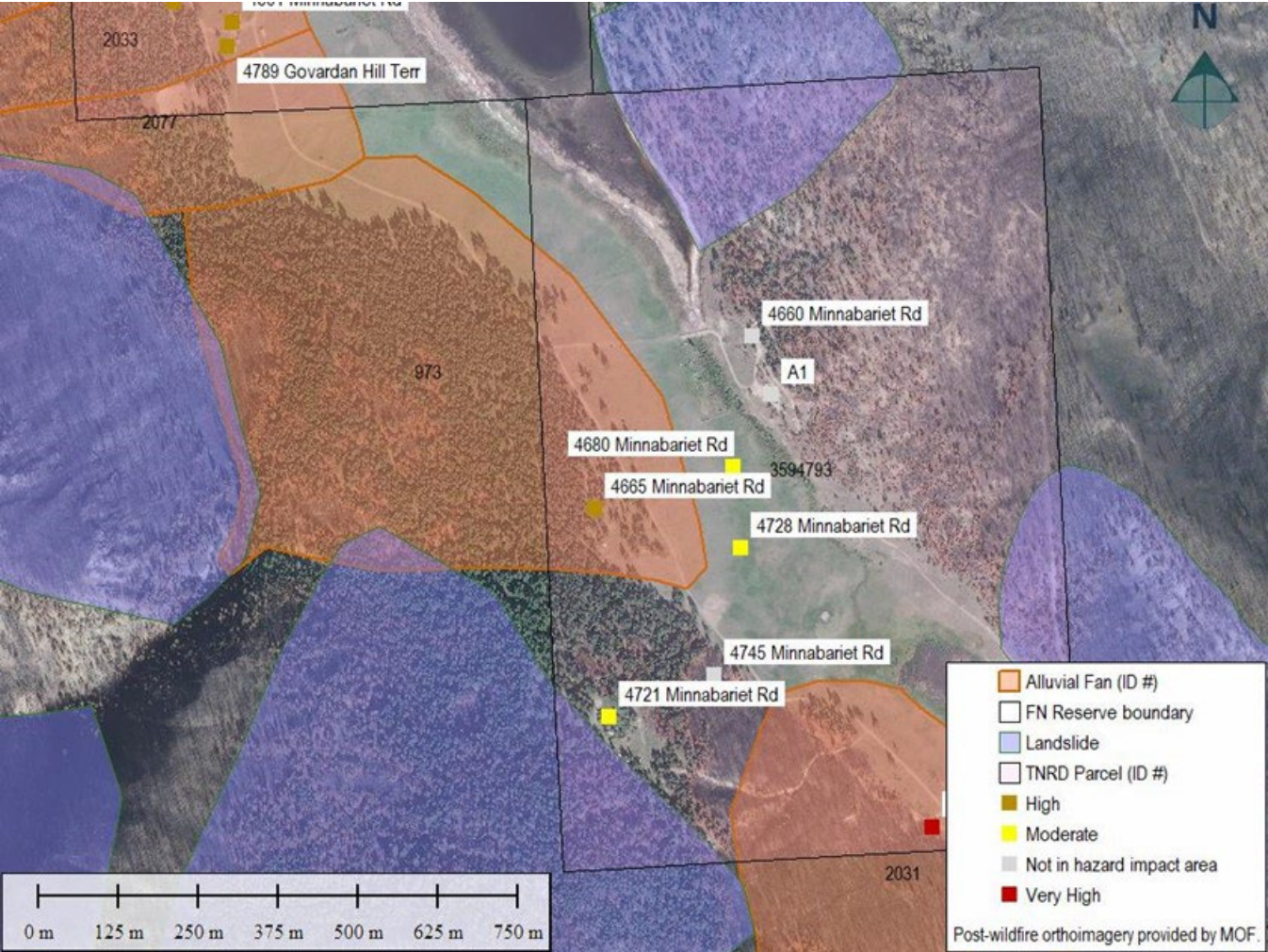
SITE INFORMATION					
Site Name	4600 block Minnabariet Road				

HAZARD ASSESSMENT					
Hazard ID	973	2154	2154	No mapped hazard	No mapped hazard
Watershed ID	9	162	162	No mapped watershed	No mapped watershed
Stream Name	N/A	Venables Creek	Venables Creek		
Burn Severity - Unburned (%)	10%	14%	14%		
Burn Severity - Low (%)	12%	13%	13%		
Burn Severity - Moderate (%)	27%	24%	24%		
Burn Severity - High (%)	51%	49%	49%		
Geohazard Type	Debris Flow	Flood	Flood		
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	N/A	N/A		
Geohazard Likelihood	Very High	High	High		

ELEMENTS AT RISK					
Parcel ID	003594793	003594793	003594793	003594793	003594793
Site Identifier	4665 Minnabariet Rd	4680 Minnabariet Rd	4728 Minnabariet Rd	4660 Minnabariet Rd	A1
Risk Element Type	Building	No apparent element	No apparent element	Building	Building

SPATIAL IMPACT ASSESSMENT					
Presence of incised channel on fan	No				
Element position in relation to fan apex	Distal (Lower 3rd)				
Element position in relation to active channel					
Additional Considerations (+/-)					
Spatial Impact Likelihood	Low	Low	Low	Not in hazard impact area	Not in hazard impact area
Comments		Element is in flood plain of Venables Creek	Element is in flood plain of Venables Creek		

PARTIAL RISK ASSESSMENT					
Partial Risk Rating	High	Moderate	Moderate	Not in hazard impact area	Not in hazard impact area
Comments					



Note:
Watershed 9 contains earthflow and rock slope deformation landslide hazards that may affect geohazard likelihood and magnitude. BGC observations recent rilling in the watershed.

Elements shown on Alluvial Fan IDs 2031, 2033, and 2077 are assessed in the site applicable to that hazard ID.

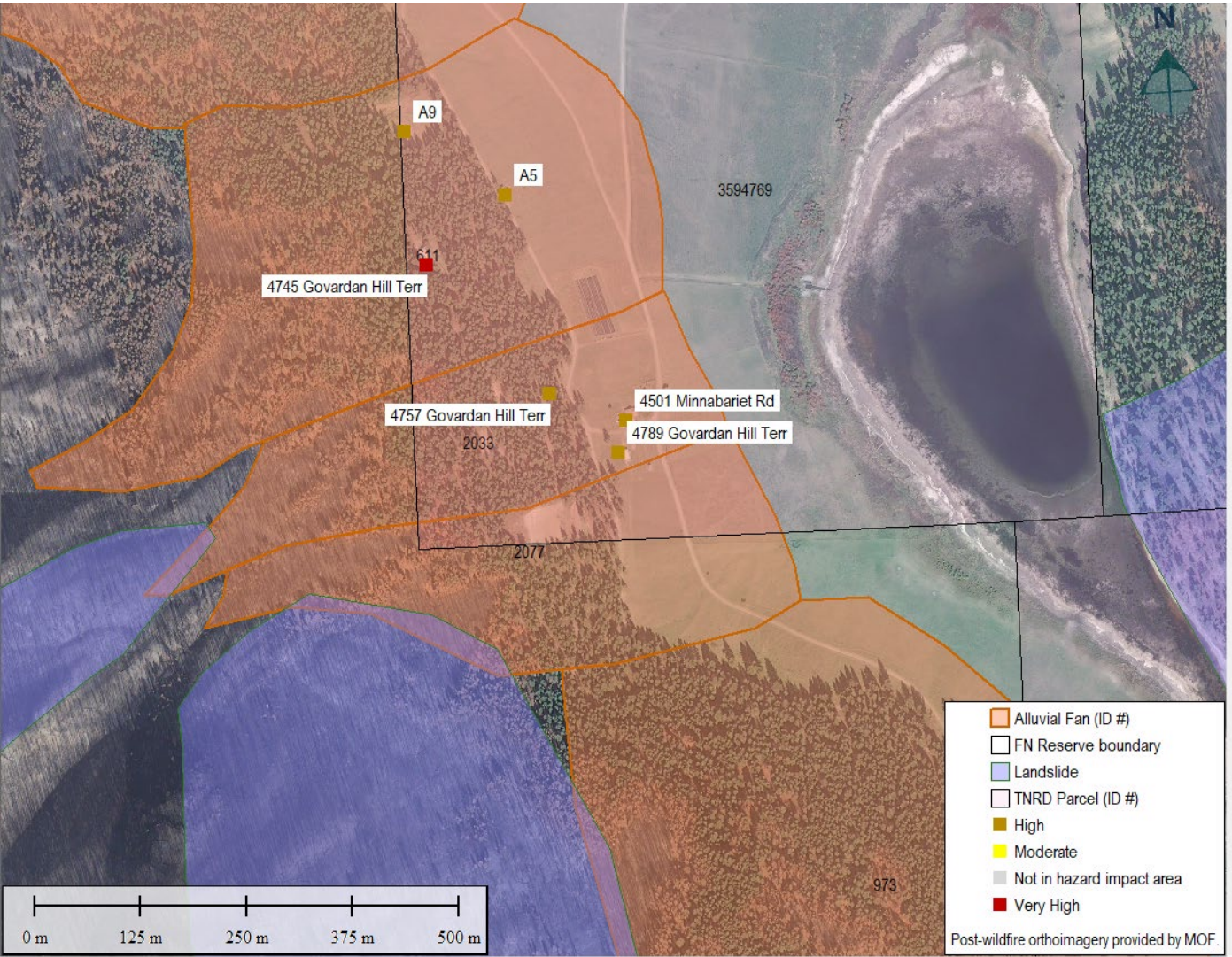
SITE INFORMATION			
Site Name	4500 block Minnabariet Road		

HAZARD ASSESSMENT			
Hazard ID	2033	2033	2033
Watershed ID	11	11	11
Stream Name			
Burn Severity - Unburned (%)	0%	0%	0%
Burn Severity - Low (%)	1%	1%	1%
Burn Severity - Moderate (%)	13%	13%	13%
Burn Severity - High (%)	87%	87%	87%
Process Type	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High

ELEMENTS AT RISK			
Parcel ID	003594769	003594769	003594769
Site Identifier	4757 Govardan Hill Terr	4789 Govardan Hil Terr	4501 Minnabariet Rd
Risk Element Type	Building	Building	Building

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	No	No	No
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)
Element position in relation to active channel			
Additional Considerations (+/-)			
Spatial Impact Likelihood	Low	Low	Low
Comments			

PARTIAL RISK ASSESSMENT			
Partial Risk Rating	High	High	High
Comments			



Note:
Watershed 11 contains earthflow landslide hazards that may affect geohazard likelihood and magnitude.

Elements shown on Alluvial Fan IDs 611 and 2034 are assessed in the site applicable to that hazard ID.

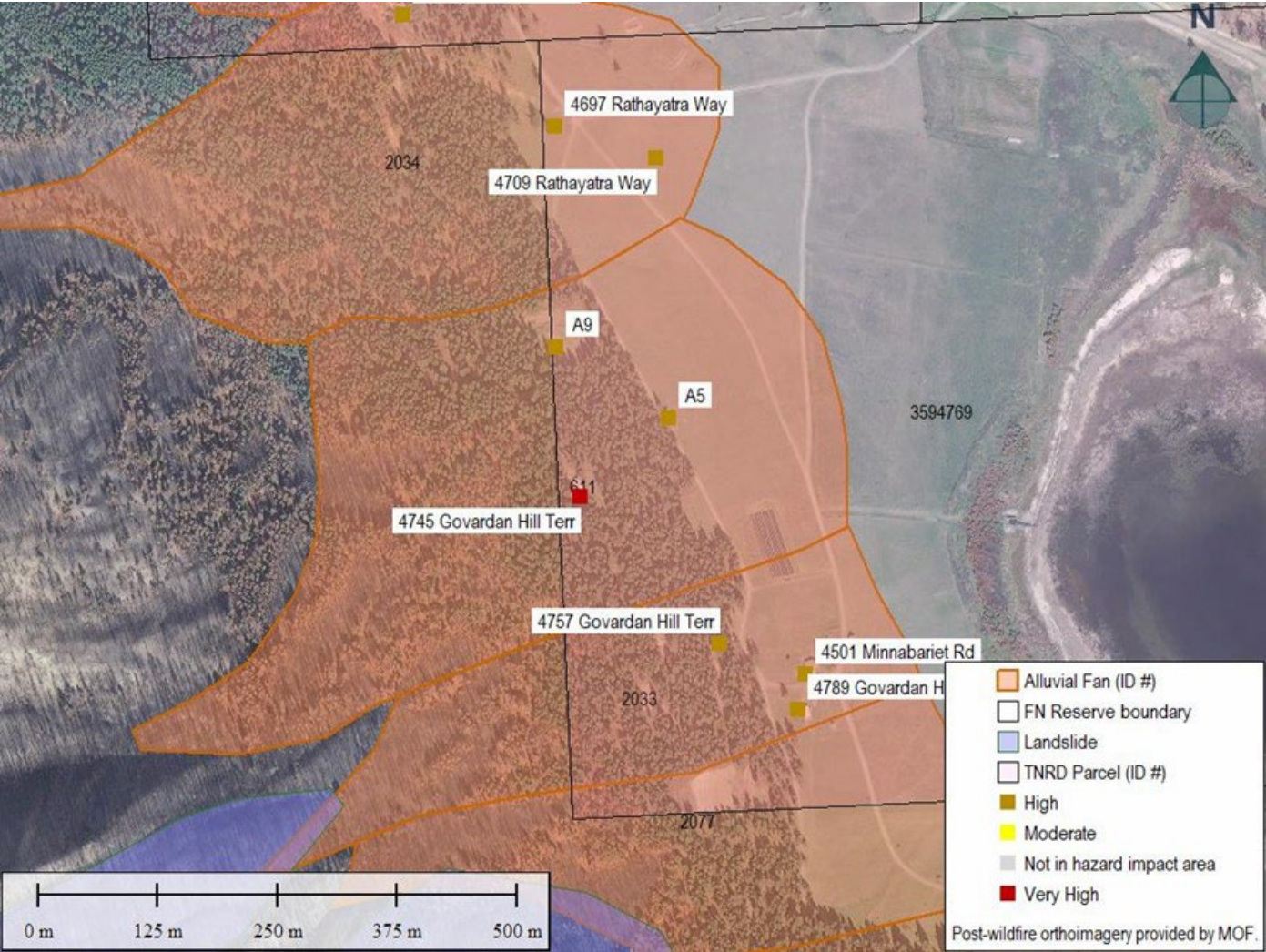
SITE INFORMATION			
Site Name	4700 block Govardan Hill Terr		

HAZARD ASSESSMENT			
Hazard ID	611	611	611
Watershed ID	12	12	12
Stream Name	N/A	N/A	N/A
Burn Severity - Unburned (%)	1%	1%	1%
Burn Severity - Low (%)	11%	11%	11%
Burn Severity - Moderate (%)	21%	21%	21%
Burn Severity - High (%)	67%	67%	67%
Process Type	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High

ELEMENTS AT RISK			
Parcel ID	003594769	003594769	003594769
Site Identifier	4745 Govardan Hill Terr	A9	A5
Risk Element Type	Building	RV	Building

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	No	No	No
Element position in relation to fan apex	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)
Element position in relation to active channel			
Additional Considerations (+/-)			
Spatial Impact Likelihood	Moderate	Low	Low
Comments			

PARTIAL RISK ASSESSMENT			
Partial Risk Rating	Very High	High	High
Comments			



Note:
Watershed 12 contains earthflow landslide hazards that may affect geohazard likelihood and magnitude.

Elements shown on Alluvial Fan IDs 2034, 2033, and 2077 are assessed in the site applicable to that hazard ID.

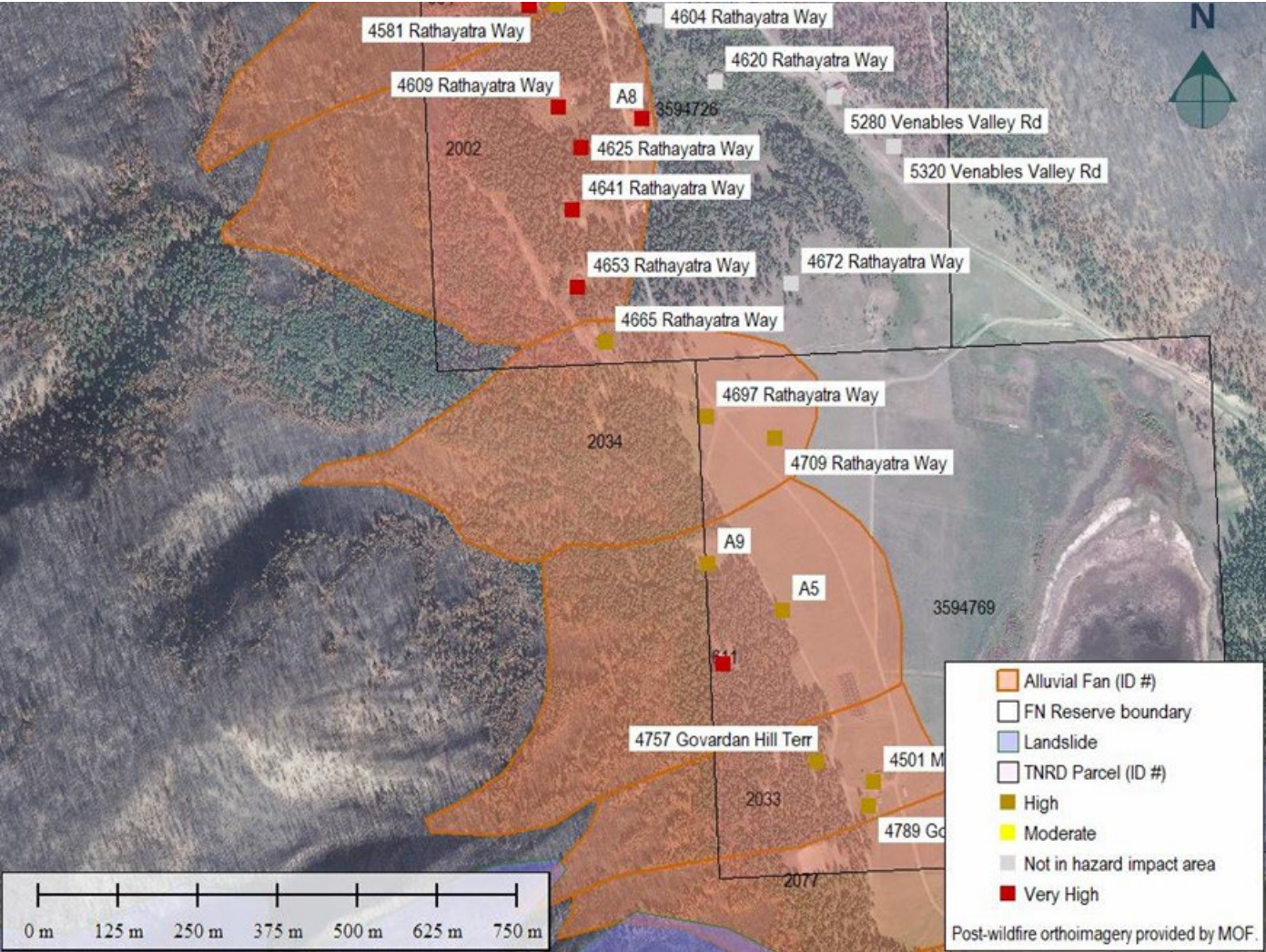
SITE INFORMATION				
Site Name	4700 block Rathayatra Way			

HAZARD ASSESSMENT				
Hazard ID	2034	2034	2034	2034
Watershed ID	13	13	13	13
Stream Name				
Burn Severity - Unburned (%)	0%	0%	0%	0%
Burn Severity - Low (%)	0%	0%	0%	0%
Burn Severity - Moderate (%)	4%	4%	4%	4%
Burn Severity - High (%)	96%	96%	96%	96%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High

ELEMENTS AT RISK				
Parcel ID	003594726	003594769	003594769	003594769
Site Identifier	4665 Rathayatra Way	4697 Rathayatra Way	4709 Rathayatra Way	4672 Rathayatra Way
Risk Element Type	Building	No apparent element	No apparent element	No apparent element

SPATIAL IMPACT ASSESSMENT				
Presence of incised channel on fan	No	No	No	No
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Beyond fan boundary
Element position in relation to active channel				
Additional Considerations (+/-)				
Spatial Impact Likelihood	Low	Low	Low	Not in hazard impact area
Comments				

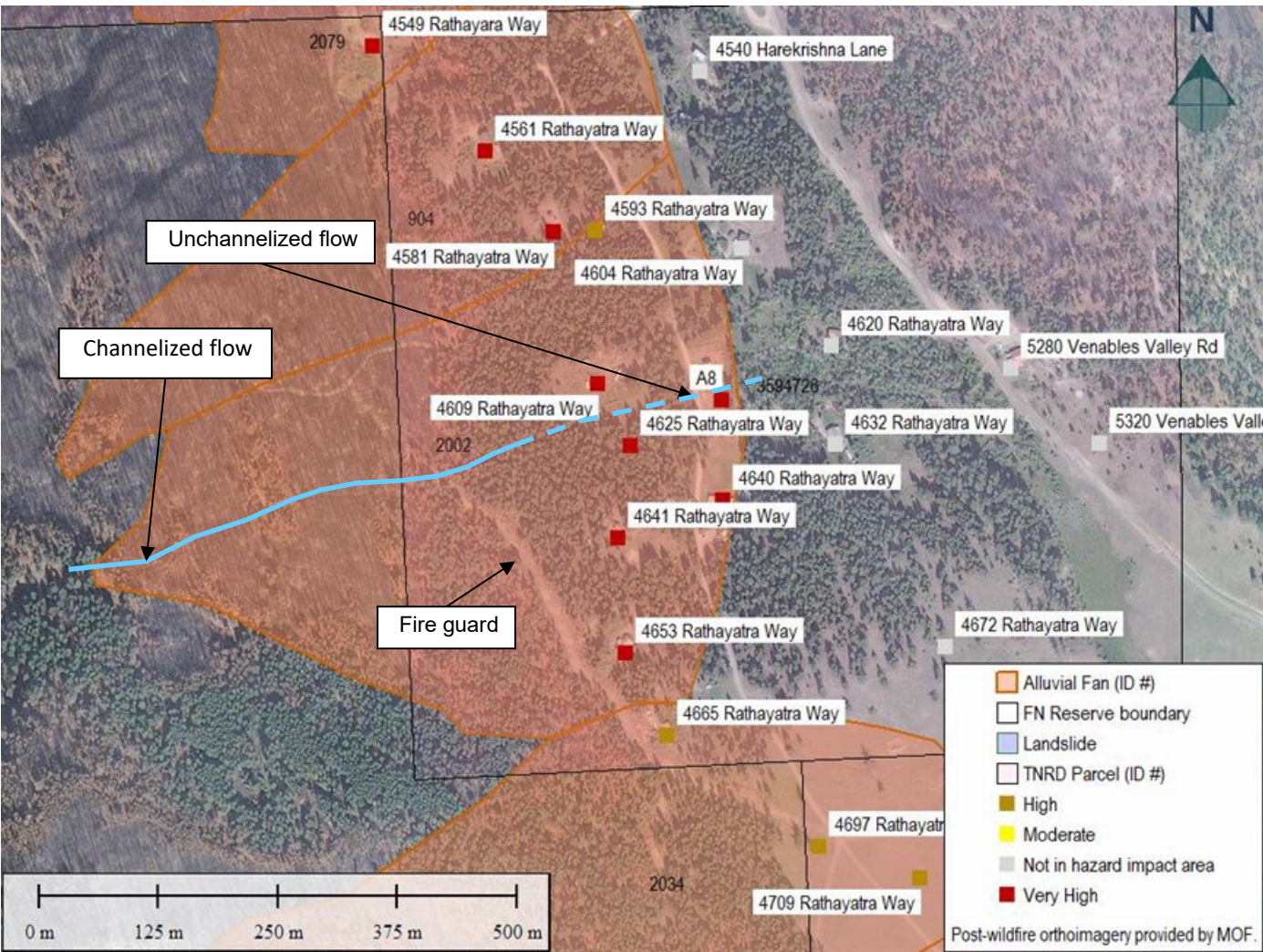
PARTIAL RISK ASSESSMENT				
Partial Risk Rating	High	High	High	Not in hazard impact area
Comments	This property may also be subject to hazards from the fan to the north (watershed 14).			



Note:
4665 Rathayatra Way may also be exposed to hazards from watershed 14 to the north.

Elements shown on Alluvial Fan IDs 2002, 611, 2033, 2002, and 2077 are assessed in the site applicable to that hazard ID.

SITE INFORMATION								
Site Name	4600 block Rathayatra Way - Govardhan and Goshala (page 1 of 2)							
HAZARD ASSESSMENT								
Hazard ID	2002	2002	2002	2002	2002	2002	2002	2002
Watershed ID	14	14	14	14	14	14	14	14
Stream Name								
Burn Severity - Unburned (%)	0%	0%	0%	0%	0%	0%	0%	0%
Burn Severity - Low (%)	1%	1%	1%	1%	1%	1%	1%	1%
Burn Severity - Moderate (%)	10%	10%	10%	10%	10%	10%	10%	10%
Burn Severity - High (%)	89%	89%	89%	89%	89%	89%	89%	89%
Geohazard Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK								
Parcel ID	003594726	003594726	003594726	003594726	003594726	003594726	003594726	003594726
Site Identifier	4653 Rathayatra Way	4641 Rathayatra Way	4640 Rathayatra Way	4625 Rathayatra Way	A8	4609 Rathayatra Way	4632 Rathayatra Way	4620 Rathayatra Way
Risk Element Type	Building	Building	School (Govardhan Academy)	No apparent element	Barn (goshala)	Building	Building	Building
SPATIAL IMPACT ASSESSMENT								
Presence of incised channel on fan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Beyond fan boundary	Beyond fan boundary
Element position in relation to active channel	Beyond 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel		
Additional Considerations (+/-)	Channels are present between main channel and house.	Channels are present between main channel and house.		Old road is present and low confinement of creek was observed here.				
Spatial Impact Likelihood	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Not in hazard impact area	Not in hazard impact area
Comments					Farm building is east of school		Element is off fan boundary.	Element is off fan boundary.
PARTIAL RISK ASSESSMENT								
Partial Risk Rating	Very High	Very High	Very High	Very High	Very High	Very High	Not in hazard impact area	Not in hazard impact area
Comments								



Notes:
There is evidence of historical debris flows or debris floods on the proximal fan (see photo D-14). There is little evidence of recent flow in the channelized section. Several small channels are visible in MOF provided imagery in proximity to 4641 and 4653 Rathayatra Way, as such, the spatial impact likelihood is considered Moderate for 4653 Rathayatra Way as well. A fireguard runs across the alluvial fan. The channel was difficult to follow in the unchannelized area; extents of channel shown are approximate. 4665 Rathayatra Way may also be subject to hazards from watershed to the south (watershed 13). 4593 Rathayatra Way may be subject to hazards from watershed to the north (watershed 15).

PD 47110 is not shown in the above map and is shown in Drawing 03. Elements shown on Alluvial Fan IDs 2034, 904, and 2079 are assessed in the site applicable to that hazard ID.

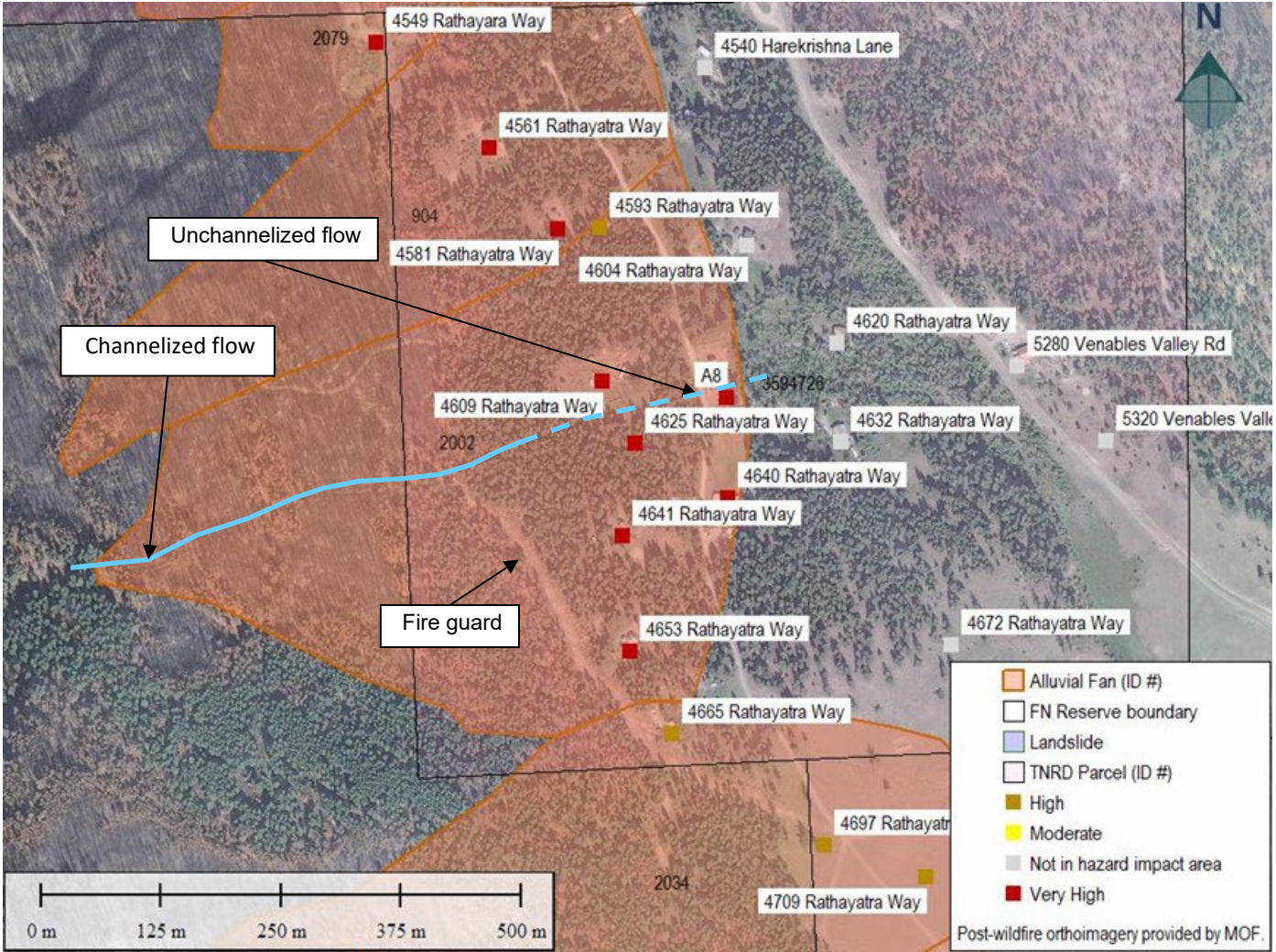
SITE INFORMATION			
Site Name	4600 block Rathayatra Way - Govardhan and Goshala (page 2 of 2)		

HAZARD ASSESSMENT			
Hazard ID	2002	2002	2002
Watershed ID	14	14	14
Stream Name			
Burn Severity - Unburned (%)	0%	0%	0%
Burn Severity - Low (%)	1%	1%	1%
Burn Severity - Moderate (%)	10%	10%	10%
Burn Severity - High (%)	89%	89%	89%
Geohazard Type	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High

ELEMENTS AT RISK			
Parcel ID	003594726	003594726	003594726
Site Identifier	4604 Rathayatra Way	4593 Rathayatra Way	PD47110
Risk Element Type	Building	No apparent element	Water license

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	Yes	Yes	Yes
Element position in relation to fan apex	Beyond fan boundary	Distal (Lower 3rd)	Proximal (Upper 3rd)
Element position in relation to active channel		Beyond 1/3 of active channel	Within 1/3 of active channel
Additional Considerations (+/-)			
Spatial Impact Likelihood	Not in hazard impact area	Low	High
Comments	Element is off fan boundary.	Element is on edge of adjacent fan.	Water source is within the channel and in proximal fan zone. Water quality may also be affected.

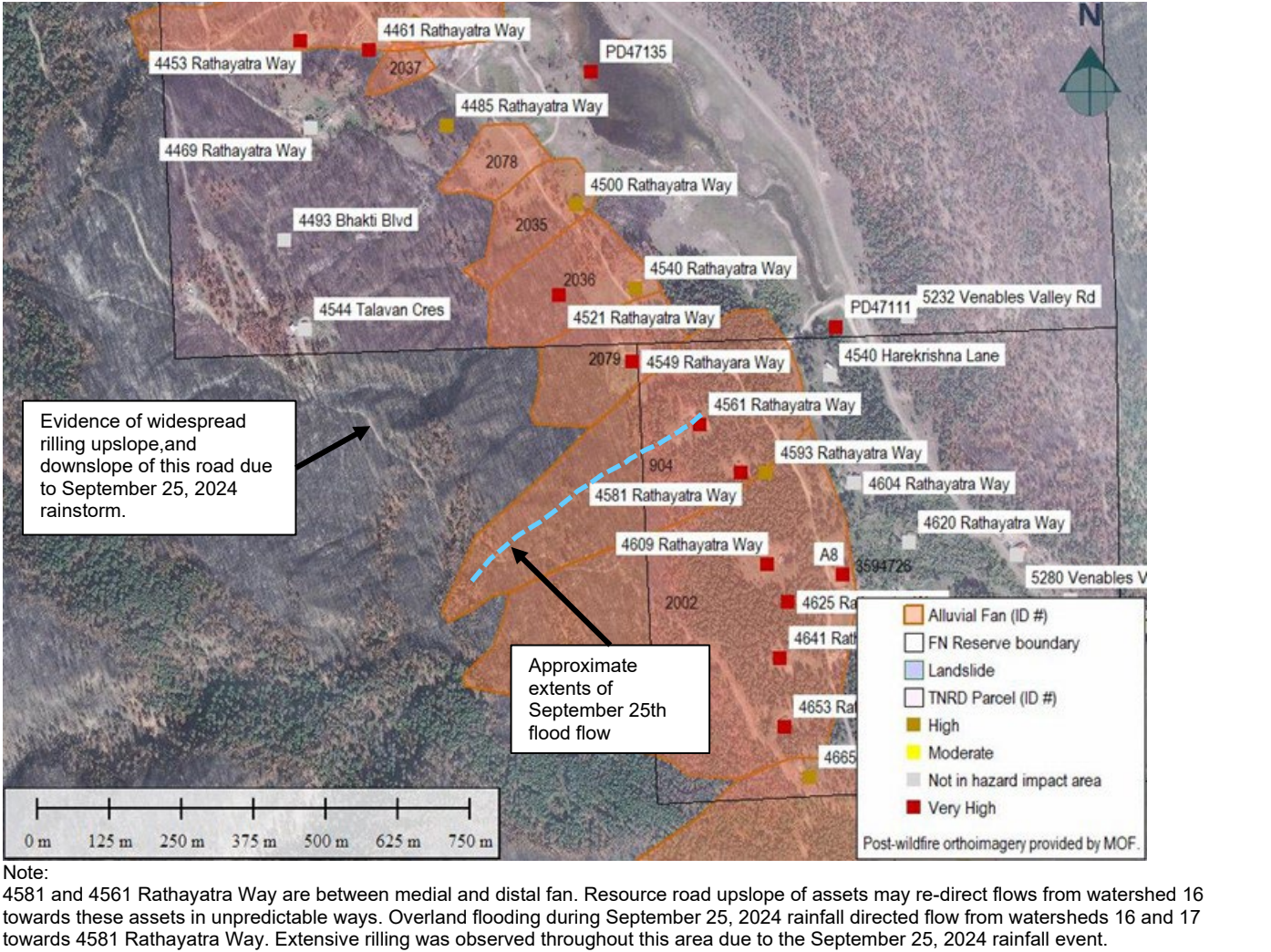
PARTIAL RISK ASSESSMENT			
Partial Risk Rating	Not in hazard impact area	High	Very High
Comments			



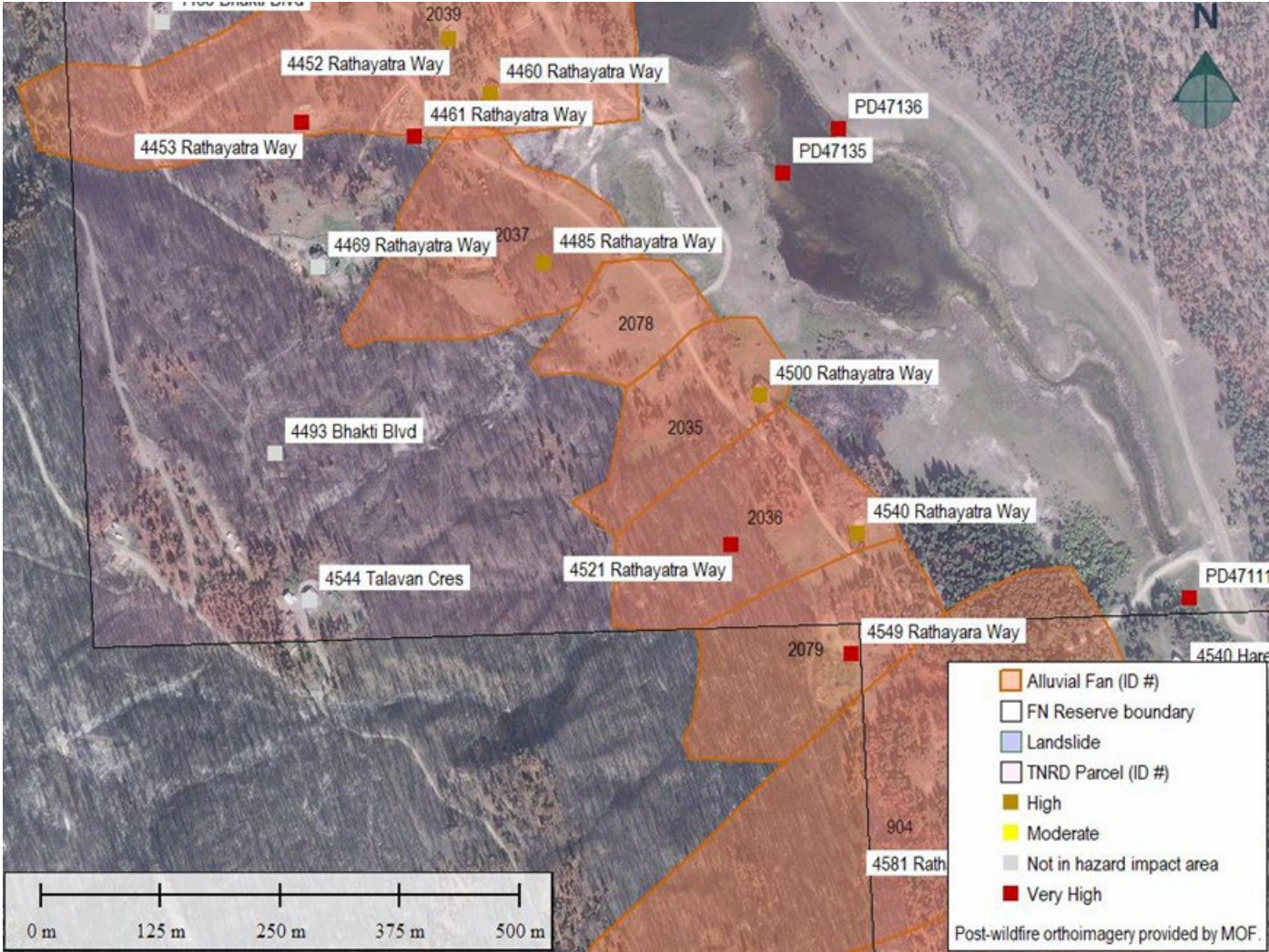
Notes:
There is evidence of historical debris flows or debris floods on the proximal fan. There is little evidence of recent flow in channelized section. Several small channels are visible in MOF provided imagery in proximity to 4641 and 4653 Rathayatra Way. A fireguard runs across the alluvial fan. The channel was difficult to follow in the unchannelized area; extents of channel are approximate. 4665 Rathayatra Way may also be subject to hazards from watershed to the south (watershed 13). 4593 Rathayatra Way may be subject to hazards from watershed to the north (watershed 15).

PD 47110 is not shown in the above map and is shown in Drawing 03. Elements shown on Alluvial Fan IDs 2034, 904, and 2079 are assessed in the site applicable to that hazard ID.

SITE INFORMATION						
Site Name	4500 block Rathayatra Way					
HAZARD ASSESSMENT						
Hazard ID	904	904	904	2079	2036	2036
Watershed ID	15	15	15	16	17	17
Stream Name						
Burn Severity - Unburned (%)	0%	0%	0%	0%	1%	1%
Burn Severity - Low (%)	4%	4%	4%	0%	8%	8%
Burn Severity - Moderate (%)	21%	21%	21%	10%	17%	17%
Burn Severity - High (%)	75%	75%	75%	90%	74%	74%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000	<1000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK						
Parcel ID	003594726	003594726	003594726	003594726	003594734	003594734
Site Identifier	4581 Rathayatra Way	4561 Rathayatra Way	4540 Harekrishna Lane	4549 Rathayatra Way	4521 Rathayatra Way	4540 Rathayatra Way
Risk Element Type	Building	Building	Building	Building (burned)	Building (burned)	Building (burned)
SPATIAL IMPACT ASSESSMENT						
Presence of incised channel on fan	Yes	Yes	Yes	Yes	Yes	Yes
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)	Beyond fan boundary	Medial (Middle 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)
Element position in relation to active channel	Within 1/3 of active channel	Within 1/3 of active channel	Beyond fan boundary	Within 1/3 of active channel	Within 1/3 of active channel	Beyond 1/3 of active channel
Additional Considerations (+/-)	Upslope road network may re-direct flows.	Upslope road network may re-direct flows.				
Spatial Impact Likelihood	Moderate	Moderate	Not in hazard impact area	High	High	Low
Comments		May also be affected by fan to the north (watershed 16)				
PARTIAL RISK ASSESSMENT						
Partial Risk Rating	Very High	Very High	Not in hazard impact area	Very High	Very High	High
Comments						



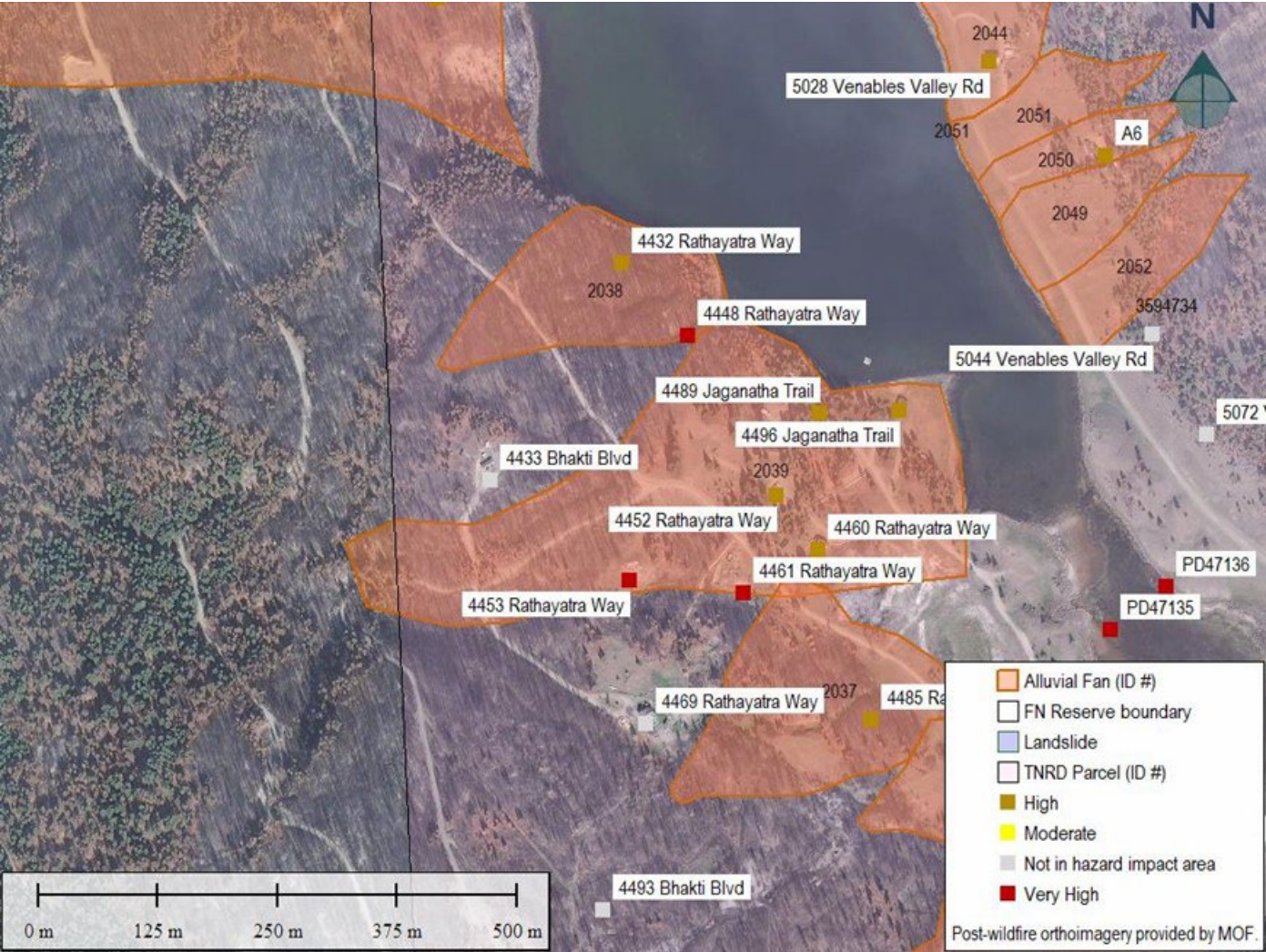
SITE INFORMATION						
Site Name	4400 block Rathayatra Way					
HAZARD ASSESSMENT						
Hazard ID	2035	2036	2037	2037	2037	2037
Watershed ID	19	17	32	32	32	32
Stream Name						
Burn Severity - Unburned (%)	3%	1%	1%	1%	1%	1%
Burn Severity - Low (%)	0%	8%	1%	1%	1%	1%
Burn Severity - Moderate (%)	29%	17%	27%	27%	27%	27%
Burn Severity - High (%)	67%	74%	71%	71%	71%	71%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	<1000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK						
Parcel ID	003594734	003594734	003594734	003594734	N/A	N/A
Site Identifier	4500 Rathayatra Way	4544 Talavan Cres	4469 Rathayatra Way	4485 Rathayatra Way	PD208661	PD20745
Risk Element Type	Building	Building	Building	No apparent element	Water license	Water license
SPATIAL IMPACT ASSESSMENT						
Presence of incised channel on fan	No	No		No	Yes	Yes
Element position in relation to fan apex	Distal (Lower 3rd)	Beyond fan boundary		Distal (Lower 3rd)		
Element position in relation to active channel		Beyond fan boundary			Within 1/3 of active channel	Within 1/3 of active channel
Additional Considerations (+/-)						
Spatial Impact Likelihood	Low	Not in hazard impact area	Not in hazard impact area	Low	High	High
Comments		Drainage paths above house are altered - homeowner indicated channel flows to south of house. Element does not intersect mapped alluvial fan, but may be affected by overland flooding.	Element does not intersect mapped alluvial fan. May be affected by overland flooding.		Upstream of fan apex, and within channel	Upstream of fan apex, and within channel
PARTIAL RISK ASSESSMENT						
Partial Risk Rating	High	Not in hazard impact area	Not in hazard impact area	High	Very High	Very High
Comments						



Note:
4544 Talavan Cres located above main valley on terrace. There are several small and ill-defined watersheds near the home and no apparent alluvial fans. Homeowner indicated that stream flows are predominantly to the south of the home. Access to 4544 Talavan Cres may be affected by debris flows in adjacent watersheds. The resource road leading to 4544 Talavan Cres may direct debris flows or other watershed processes in unpredictable ways towards adjacent watersheds.

PD208661 and PD20745 are west of the map above and are displayed in Drawing 03. Elements shown on Alluvial Fan IDs 2079, 2036, and 904 are assessed in the site applicable to that hazard ID.

SITE INFORMATION								
Site Name	4400 block Jaganatha Way (page 1 of 2)							
HAZARD ASSESSMENT								
Hazard ID	2039	2039	2039	2039	2039	2039	2039	2038
Watershed ID	31	31	31	31	31	31	31	34
Stream Name								
Burn Severity - Unburned (%)	2%	2%	2%	2%	2%	2%	2%	0%
Burn Severity - Low (%)	20%	20%	20%	20%	20%	20%	20%	27%
Burn Severity - Moderate (%)	17%	17%	17%	17%	17%	17%	17%	13%
Burn Severity - High (%)	61%	61%	61%	61%	61%	61%	61%	61%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK								
Parcel ID	003594734	003594734	003594734	003594734	003594734	003594734	003594734	003594734
Site Identifier	4453 Rathayatra Way	4461 Rathayatra Way	4460 Rathayatra Way	4452 Rathayatra Way	4489 Jaganatha Trail	4496 Jaganatha Trail	4433 Bhakti Blvd	4448 Rathayatra Way
Risk Element Type	Building (partially burned, demolished)	Building (burned)	Building	Building	Building	Building	Building	No apparent element
SPATIAL IMPACT ASSESSMENT								
Presence of incised channel on fan	No	No	No	No	No	No	No	Yes
Element position in relation to fan apex	Medial (Middle 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Beyond fan boundary	Distal (Lower 3rd)
Element position in relation to active channel								Within 1/3 of active channel
Additional Considerations (+/-)								
Spatial Impact Likelihood	Moderate	Moderate	Low	Low	Low	Low	Not in hazard impact area	Moderate
Comments							Element does not intersect mapped alluvial fan. May be affected by overland flooding.	
PARTIAL RISK ASSESSMENT								
Partial Risk Rating	Very High	Very High	High	High	High	High	Not in hazard impact area	Very High
Comments								



Note:
Access to 4544 Talavan Cres may be affected by debris flows in adjacent watersheds. The resource road leading to 4544 Talavan Cres may direct debris flows or other watershed processes in unpredictable ways towards adjacent watersheds.

Elements shown on Alluvial Fan IDs 2037, 2044, 2051, 2050, 2049, and 2052 are assessed in the site applicable to that hazard ID.

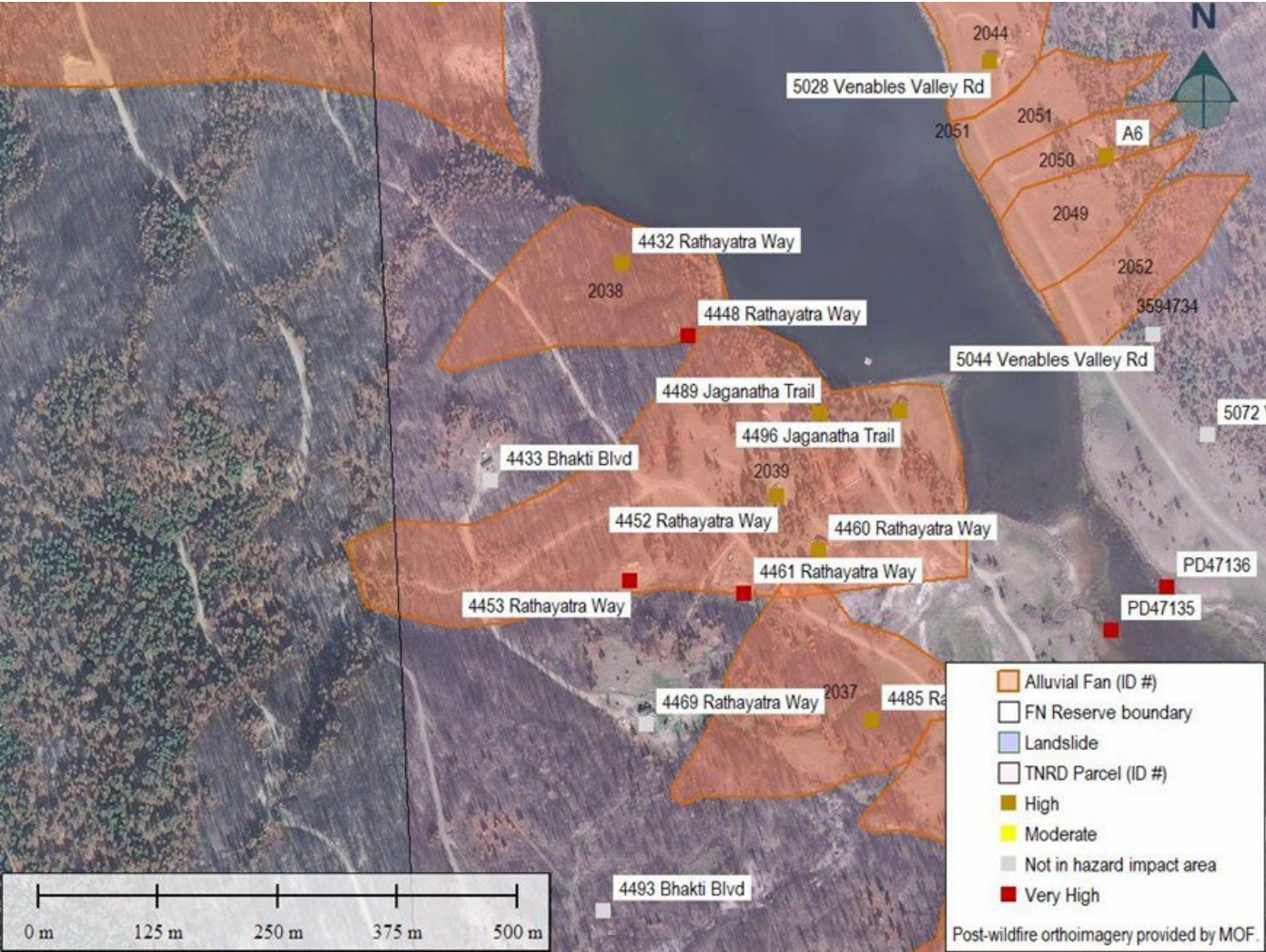
SITE INFORMATION		
Site Name	4400 block Jaganatha Way (page 2 of 2)	

HAZARD ASSESSMENT		
Hazard ID	2038	2037
Watershed ID	34	32
Stream Name		
Burn Severity - Unburned (%)	0%	1%
Burn Severity - Low (%)	27%	1%
Burn Severity - Moderate (%)	13%	27%
Burn Severity - High (%)	61%	71%
Process Type	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High

ELEMENTS AT RISK		
Parcel ID	003594734	003594734
Site Identifier	4432 Rathayatra Way	4493 Bhatki Blvd
Risk Element Type	No apparent element	No apparent element

SPATIAL IMPACT ASSESSMENT		
Presence of incised channel on fan	Yes	
Element position in relation to fan apex	Distal (Lower 3rd)	
Element position in relation to active channel	Beyond 1/3 of active channel	
Additional Considerations (+/-)		
Spatial Impact Likelihood	Low	Not in hazard impact area
Comments		Element does not intersect mapped alluvial fan. Element may be affected by overland flooding.

PARTIAL RISK ASSESSMENT		
Partial Risk Rating	High	Not in hazard impact area
Comments		



Note:
Access to 4544 Talavan Cres may be affected by debris flows in adjacent watersheds. The resource road leading to 4544 Talavan Cres may direct debris flows or other watershed processes in unpredictable ways towards adjacent watersheds.

Elements shown on Alluvial Fan IDs 2037, 2044, 2051, 2050, 2049, and 2052 are assessed in the site applicable to that hazard ID.

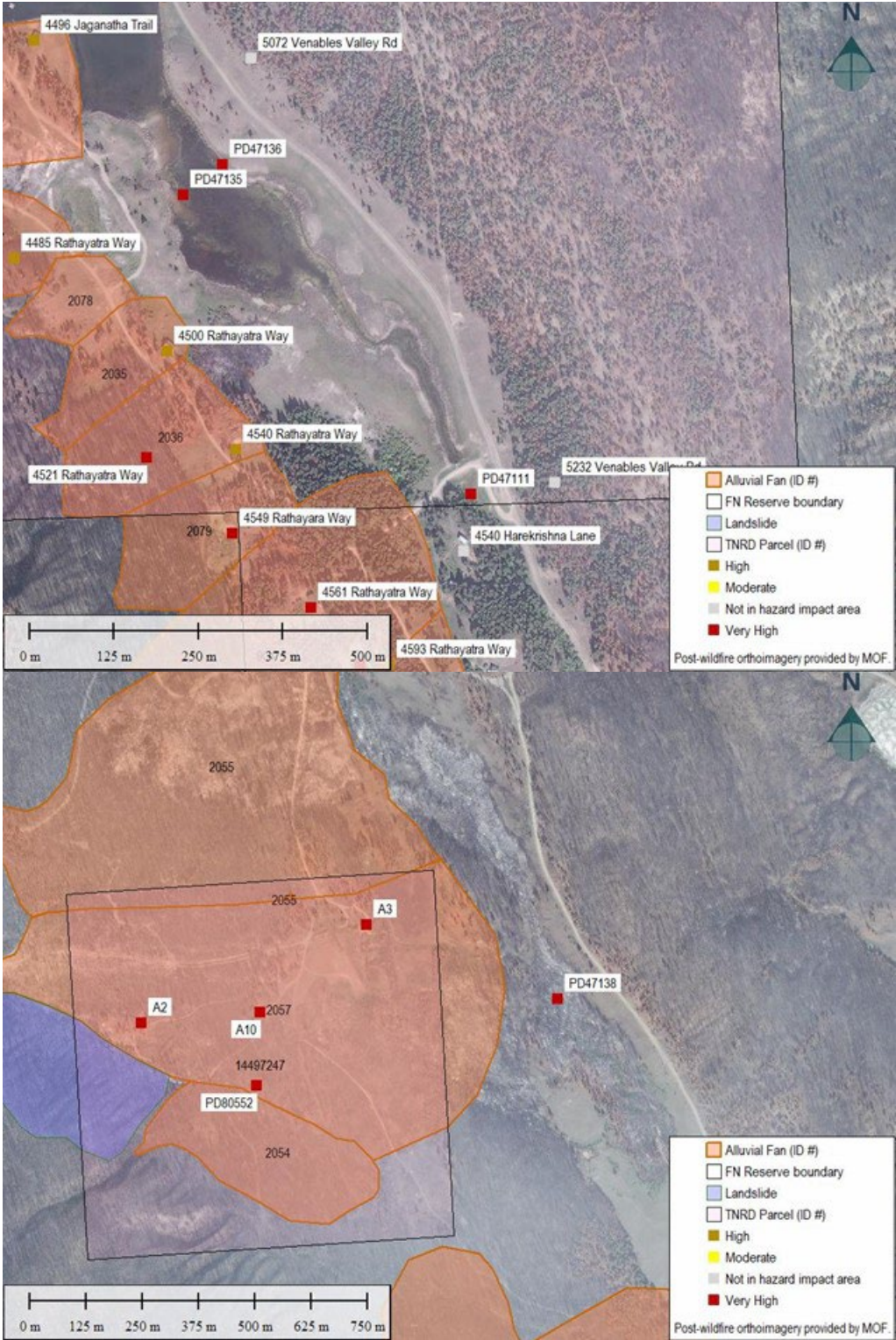
SITE INFORMATION				
Site Name	Water licenses along Venables Creek and Lake outside of alluvial fans			

HAZARD ASSESSMENT				
Hazard ID	2154	2154	2154	2154
Watershed ID	162	162	162	162
Stream Name				
Burn Severity - Unburned (%)	14%	14%	14%	14%
Burn Severity - Low (%)	13%	13%	13%	13%
Burn Severity - Moderate (%)	24%	24%	24%	24%
Burn Severity - High (%)	49%	49%	49%	49%
Process Type	Flood	Flood	Flood	Flood
Estimated Post-wildfire Debris Flow Volume (m³)	N/A	N/A	N/A	N/A
Geohazard Likelihood	High	High	High	High

ELEMENTS AT RISK				
Parcel ID		003594734	003594734	003594734
Site Identifier	PD47138	PD47135	PD47136	PD47111
Risk Element Type	Water license	Water license	Water license	Water license

SPATIAL IMPACT ASSESSMENT				
Presence of incised channel on fan				
Element position in relation to fan apex	Beyond fan boundary	Beyond fan boundary	Beyond fan boundary	Beyond fan boundary
Element position in relation to active channel				
Additional Considerations (+/-)				
Spatial Impact Likelihood	High	High	High	High
Comments	Water license is downstream of Fan 2057. The intake may be affected by increased sediment and floods.	The intake may be affected by increased sediment and flood flows.	The intake may be affected by increased sediment and flood flows.	Water license is downstream of Fan 904. The intake may be affected by increased sediment and flood flows.

PARTIAL RISK ASSESSMENT				
Partial Risk Rating	Very High	Very High	Very High	Very High
Comments				



Notes:
Water licenses are located in flood hazard areas of Venables Creek and are outside of debris flow hazard areas.

Elements shown on Alluvial Fan IDs 2078, 2035, 2036, 2079, 2054, 2057, and 2055 are assessed in the site applicable to that hazard ID.

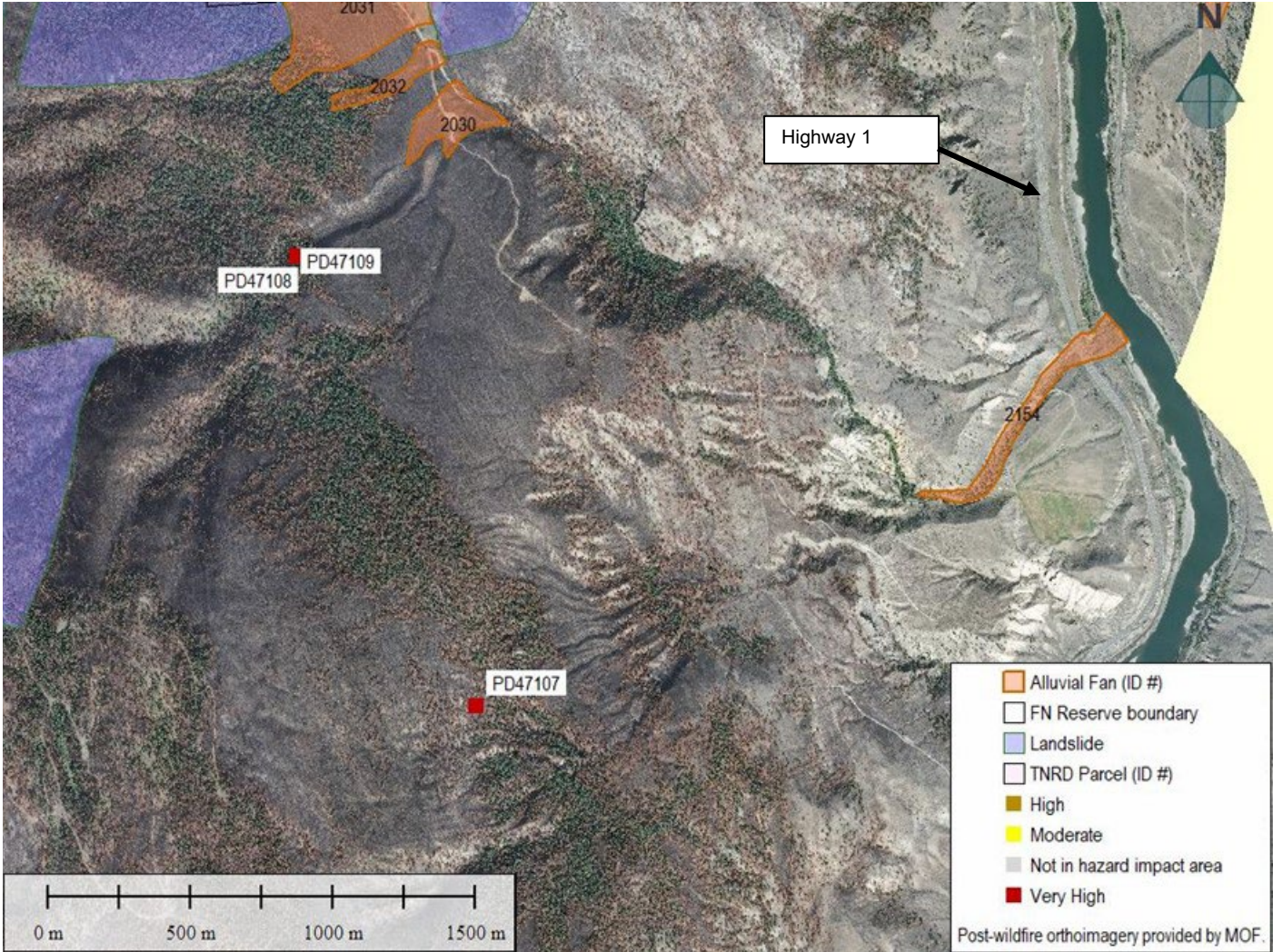
SITE INFORMATION			
Site Name	Water licenses in south Venables Creek valley		

HAZARD ASSESSMENT			
Hazard ID	2030	2030	No mapped fan
Watershed ID	7	7	4
Stream Name	N/A	N/A	N/A
Burn Severity - Unburned (%)	1%	1%	0%
Burn Severity - Low (%)	19%	19%	26%
Burn Severity - Moderate (%)	47%	47%	36%
Burn Severity - High (%)	33%	33%	37%
Process Type	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High

ELEMENTS AT RISK			
Parcel ID	N/A	N/A	N/A
Site Identifier	PD47108	PD47109	PD47107
Risk Element Type	Water license	Water license	Water license

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	Yes	Yes	
Element position in relation to fan apex			
Element position in relation to active channel			
Additional Considerations (+/-)			
Spatial Impact Likelihood	High	High	High
Comments	Water license is within and along section of incised channel flow.	Water license is within and along section of incised channel flow.	The channel structure in this watershed is unclear.

PARTIAL RISK ASSESSMENT			
Partial Risk Rating	Very High	Very High	Very High
Comments			



Note:
Elements at the outlet of Venables Creek at Highway 1, and Highway 1 itself was not included in the list of assets for this study.

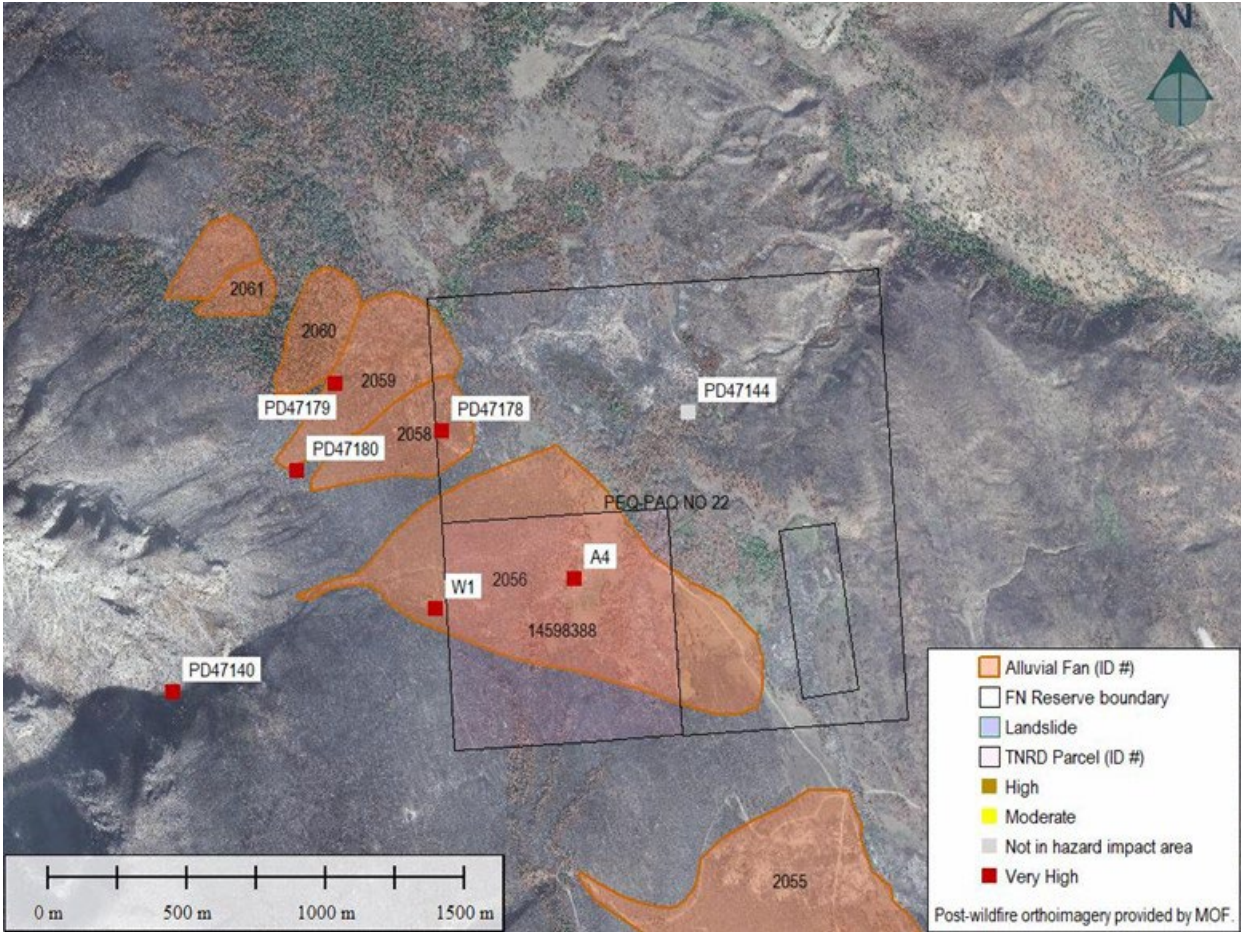
SITE INFORMATION					
Site Name	Peq Paq				

HAZARD ASSESSMENT					
Hazard ID	2056	2059	2058	2058	2056
Watershed ID	38	39	40	40	38
Stream Name					
Burn Severity - Unburned (%)	2%	0%	0%	0%	2%
Burn Severity - Low (%)	4%	0%	0%	0%	4%
Burn Severity - Moderate (%)	20%	28%	20%	20%	20%
Burn Severity - High (%)	73%	72%	80%	80%	73%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	>10,000	1,000-10,000	<1000	<1000	>10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High

ELEMENTS AT RISK					
Parcel ID	N/A				
Site Identifier	Peq-Paq No 22	PD47179	PD47178	PD47180	PD47144
Risk Element Type	Cook's Ferry reserve	Water license	Water license	Water license	Water license

SPATIAL IMPACT ASSESSMENT					
Presence of incised channel on fan	Yes	Yes	Yes	Yes	Yes
Element position in relation to fan apex	Distal (Lower 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Beyond fan boundary
Element position in relation to active channel	Beyond 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Beyond fan boundary
Additional Considerations (+/-)					
Spatial Impact Likelihood	Low	High	High	High	Not in hazard impact area
Comments					Sediment-laden flooding from Venables Creek may transfer through reserve boundary.

PARTIAL RISK ASSESSMENT					
Partial Risk Rating	High	Very High	Very High	Very High	Not in hazard impact area
Comments					



Note:
Watersheds 39 and 40 are subject to rockfall hazard and display evidence of debris flow activity along channel.

Elements A4, W1, and PD47140 are assessed with Blue Earth site.

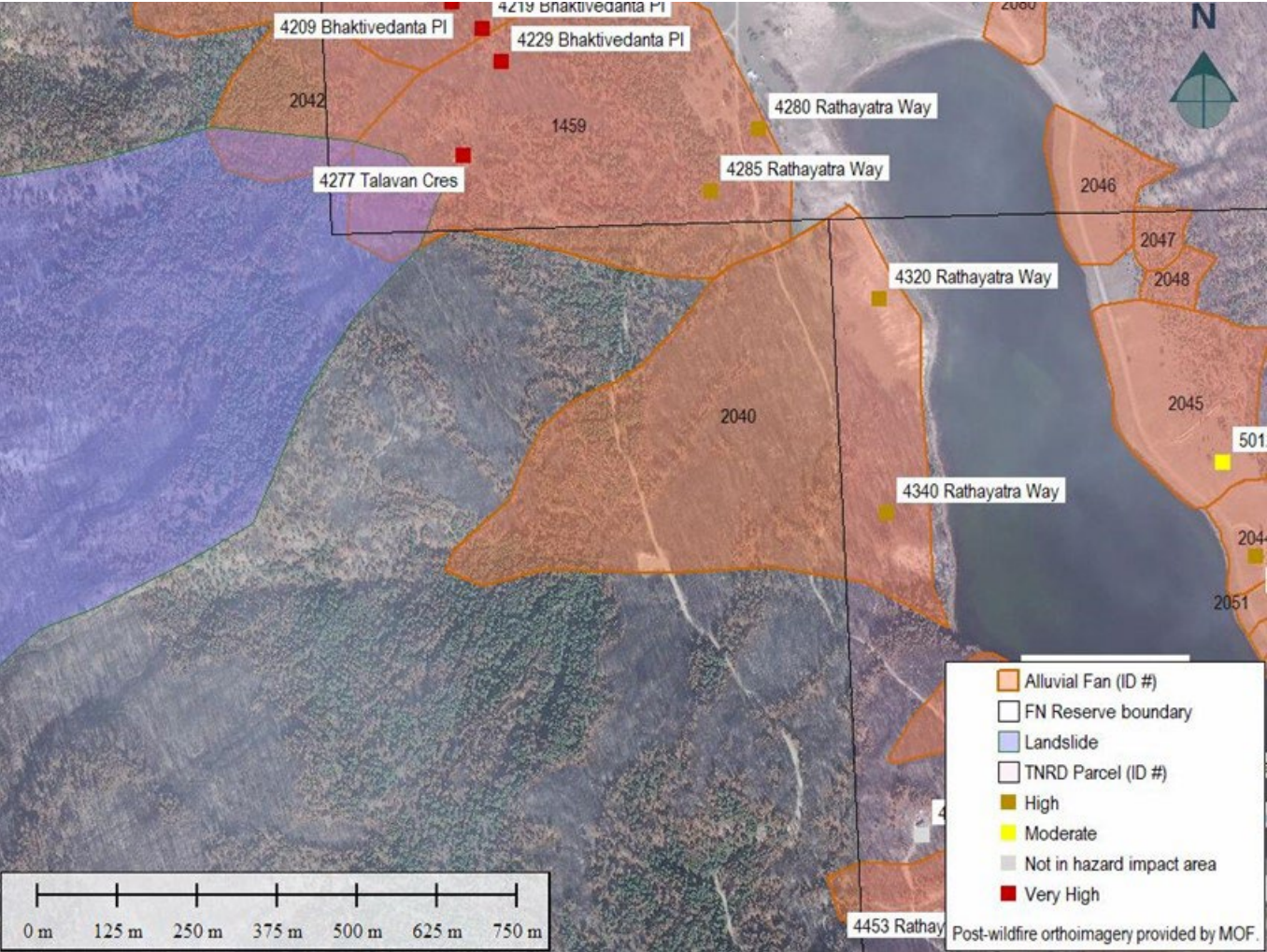
SITE INFORMATION		
Site Name	4300 block Rathayatra Way	

HAZARD ASSESSMENT		
Hazard ID	2040	2040
Watershed ID	26	26
Stream Name		
Burn Severity - Unburned (%)	1%	1%
Burn Severity - Low (%)	9%	9%
Burn Severity - Moderate (%)	21%	21%
Burn Severity - High (%)	69%	69%
Process Type	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High

ELEMENTS AT RISK		
Parcel ID	003594734	003594734
Site Identifier	4340 Rathayatra Way	4320 Rathayatra Way
Risk Element Type	No apparent element	Building

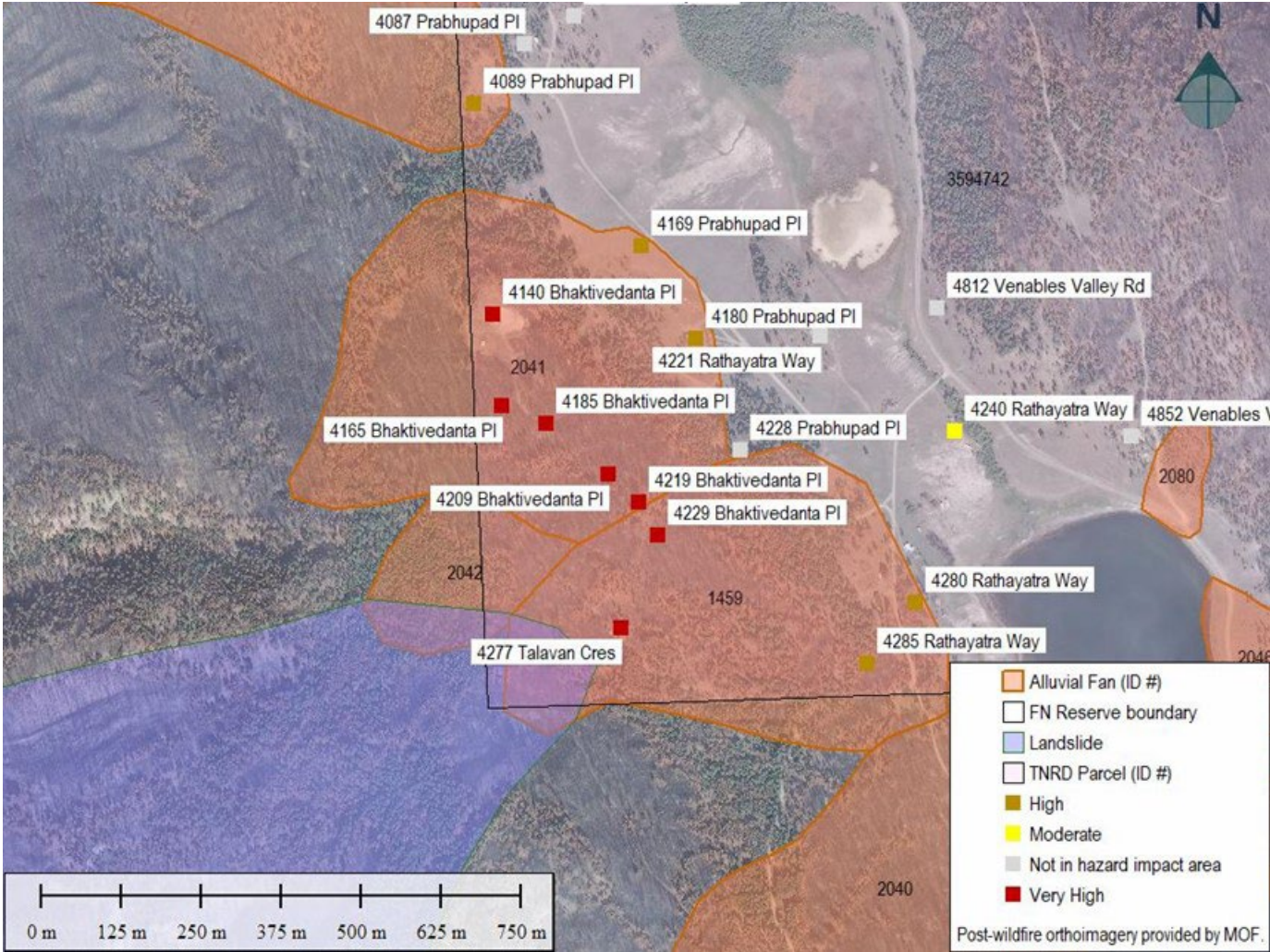
SPATIAL IMPACT ASSESSMENT		
Presence of incised channel on fan	No	No
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)
Element position in relation to active channel		
Additional Considerations (+/-)		
Spatial Impact Likelihood	Low	Low
Comments		Element assumed to be the home north of TNRD address location.

PARTIAL RISK ASSESSMENT		
Partial Risk Rating	High	High
Comments		



Note:
Address locations shown were provided by TNRD and may not reflect the location of buildings observed during field work.
Elements shown on Alluvial Fan IDs 2042, 1459, 2045, 2044, and 2051 are assessed in the site applicable to that hazard ID.

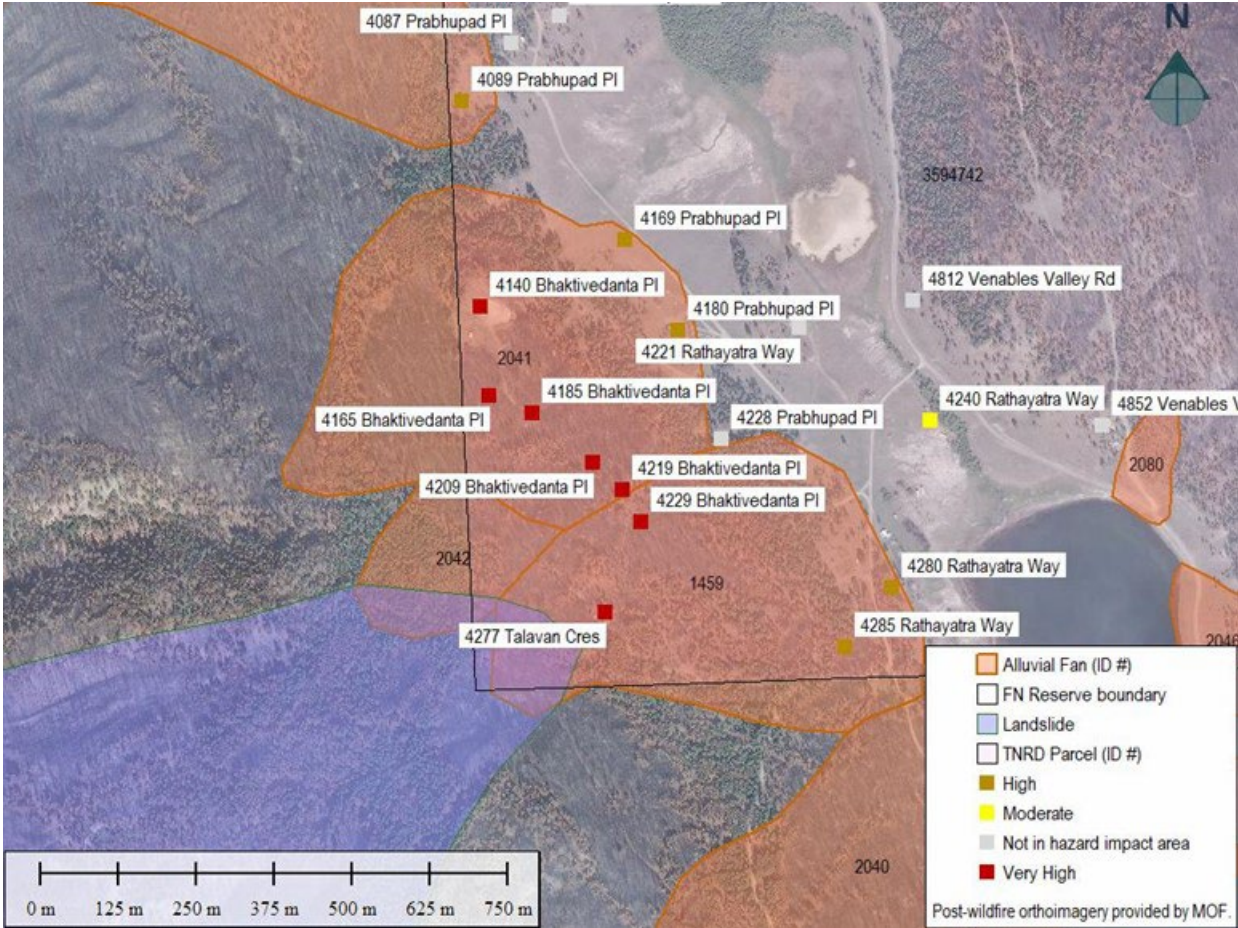
SITE INFORMATION								
Site Name	4200 block Rathayatra Way (page 1 of 2)							
HAZARD ASSESSMENT								
Hazard ID	1459	1459	1459	1459	2042	2042	2042	2042
Watershed ID	29	29	29	29	28	28	28	28
Stream Name								
Burn Severity - Unburned (%)	0%	0%	0%	0%	0%	0%	0%	0%
Burn Severity - Low (%)	3%	3%	3%	3%	5%	5%	5%	5%
Burn Severity - Moderate (%)	19%	19%	19%	19%	37%	37%	37%	37%
Burn Severity - High (%)	77%	77%	77%	77%	58%	58%	58%	58%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m²)	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK								
Parcel ID	003594742	003594742	003594742	003594742	003594742	003594742	003594742	003594742
Site Identifier	4277 Talavan Cres	4229 Bhaktivedanta PI	4285 Rathayatra Way	4280 Rathayatra Way	4140 Bhaktivedanta PI	4165 Bhaktivedanta PI	4185 Bhaktivedanta PI	4209 Bhaktivedanta PI
Risk Element Type	Building	No apparent element	Building	Building (partially burned)	Building (burned)	No apparent element	No apparent element	No apparent element
SPATIAL IMPACT ASSESSMENT								
Presence of incised channel on fan	No	No	No	No	No	No	No	No
Element position in relation to fan apex	Proximal (Upper 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)
Element position in relation to active channel								
Additional Considerations (+/-)								
Spatial Impact Likelihood	High	Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate
Comments	Historical debris flow deposits observed within 10 m of home.		Element assumed to be home north of the TNRD address location.	Element assumed to be home north of the TNRD address location.				
PARTIAL RISK ASSESSMENT								
Partial Risk Rating	Very High	Very High	High	High	Very High	Very High	Very High	Very High
Comments								



Note:
Watersheds 28 and 29 contains earthflow landslide hazards that may affect geohazard likelihood and magnitude. Evidence of historical debris flow or debris flood deposits were observed within 10 m of the home at 4277 Talavan Cres.

Elements 4087 and 4089 Prabhupad PI are assessed in the site applicable to that element ID.

SITE INFORMATION						
Site Name	4200 block Rathayatra Way (page 2 of 2)					
HAZARD ASSESSMENT						
Hazard ID	2042	2154	2042	2042	2042	2042
Watershed ID	28	162	28	28	28	28
Stream Name						
Burn Severity - Unburned (%)	0%	14%	0%	0%	0%	0%
Burn Severity - Low (%)	5%	13%	5%	5%	5%	5%
Burn Severity - Moderate (%)	37%	24%	37%	37%	37%	37%
Burn Severity - High (%)	58%	49%	58%	58%	58%	58%
Process Type	Debris Flow	Flood	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000		1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	High	Very High	Very High	Very High	Very High
ELEMENTS AT RISK						
Parcel ID	003594742	003594742	003594742	003594742	003594742	003594742
Site Identifier	4219 Bhaktivedanta PI	4240 Rathayatra Way	4228 Prabhupad PI	4180 Prabhupad PI	4169 Prabhupad PI	4221 Rathayatra Way
Risk Element Type	No apparent element	Building	No apparent element	Building	No apparent element	Building
SPATIAL IMPACT ASSESSMENT						
Presence of incised channel on fan	No		No	No	No	No
Element position in relation to fan apex	Medial (Middle 3rd)	Beyond fan boundary	Beyond fan boundary	Distal (Lower 3rd)	Distal (Lower 3rd)	Beyond fan boundary
Element position in relation to active channel						
Additional Considerations (+/-)						
Spatial Impact Likelihood	Moderate	Low	Not in hazard impact area	Low	Low	Not in hazard impact area
Comments		Element does not intersect mapped alluvial fan. Element may be affected by flooding along Venables Creek and other water flows.	Element does not intersect mapped alluvial fan. Element may be affected by overland flooding.			Element does not intersect mapped alluvial fan. Element may be affected by overland flooding.
PARTIAL RISK ASSESSMENT						
Partial Risk Rating	Very High	Moderate	Not in hazard impact area	High	High	Not in hazard impact area
Comments						



Note:
Watersheds 28 and 29 contain earthflow landslide hazards that may affect geohazard likelihood and magnitude. Evidence of historical debris flow or debris flood deposits were observed within 10 m of the home at 4277 Talavan Cres.

Elements 4087 and 4089 Prabhupad PI are assessed in the site applicable to that element ID.

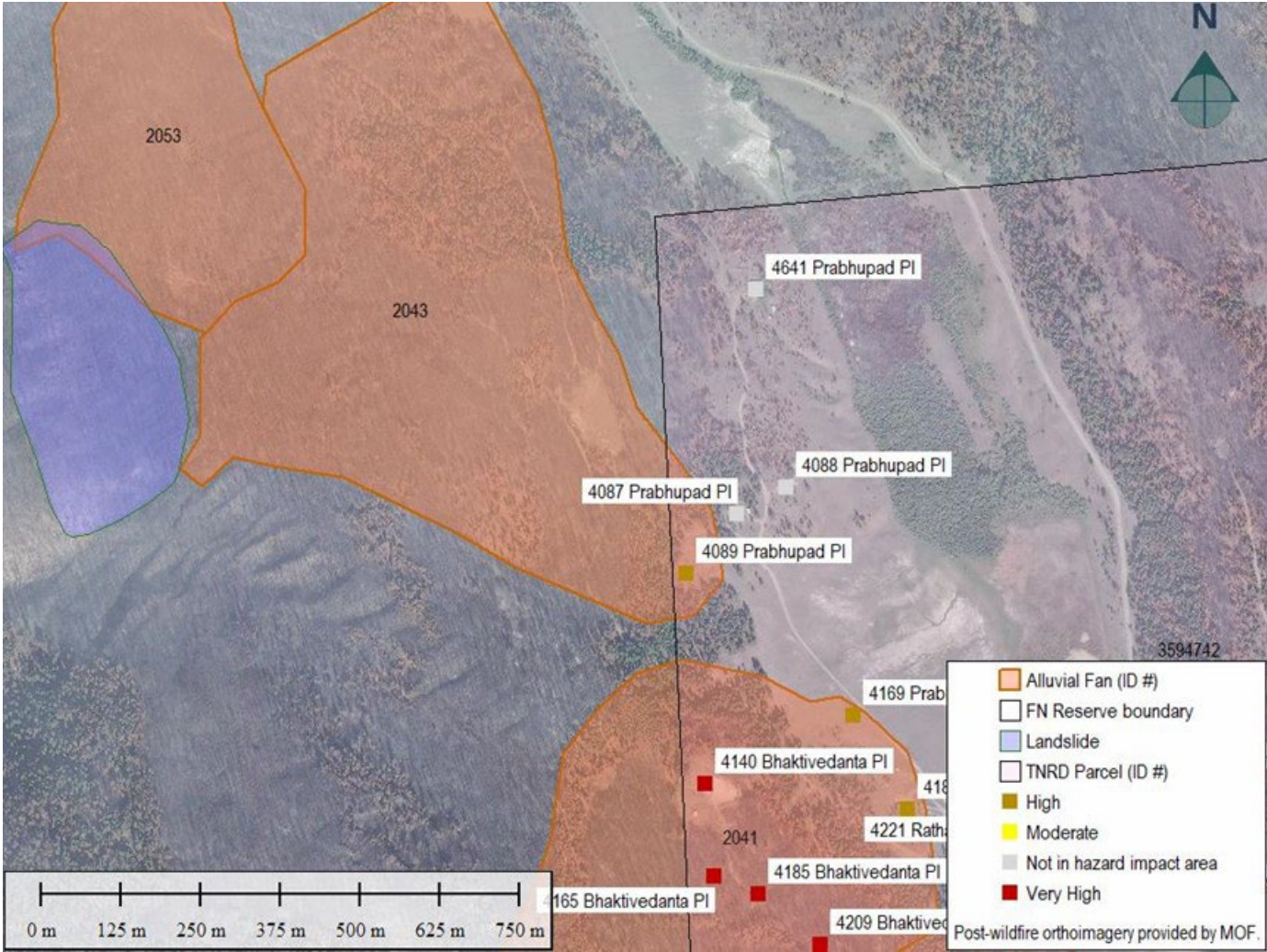
SITE INFORMATION				
Site Name	4000 block Prabhupad PI			

HAZARD ASSESSMENT				
Hazard ID	2043	2043	2043	2043
Watershed ID	35	35	35	35
Stream Name				
Burn Severity - Unburned (%)	0%	0%	0%	0%
Burn Severity - Low (%)	3%	3%	3%	3%
Burn Severity - Moderate (%)	53%	53%	53%	53%
Burn Severity - High (%)	43%	43%	43%	43%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	Very High	Very High	Very High

ELEMENTS AT RISK				
Parcel ID	003594742	003594742	003594742	003594742
Site Identifier	4089 Prabhupad PI	4087 Prabhupad PI	4641 Prabhupad PI	4088 Prabhupad PI
Risk Element Type	Building	Building	Building	Building

SPATIAL IMPACT ASSESSMENT				
Presence of incised channel on fan	No	No	No	No
Element position in relation to fan apex	Distal (Lower 3rd)	Beyond fan boundary	Beyond fan boundary	Beyond fan boundary
Element position in relation to active channel				
Additional Considerations (+/-)				
Spatial Impact Likelihood	Low	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area
Comments		Element on glacial landform above alluvial fan	Element on glacial landform above alluvial fan	Element on glacial landform above alluvial fan

PARTIAL RISK ASSESSMENT				
Partial Risk Rating	High	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area
Comments				



Note:
Addresses 4087, 4088, and 4641 Prabhupad PI are located on a glacial deposit and are elevated above the alluvial fan.

Elements shown on Alluvial Fan ID 2041 are assessed on the site applicable to that hazard ID.

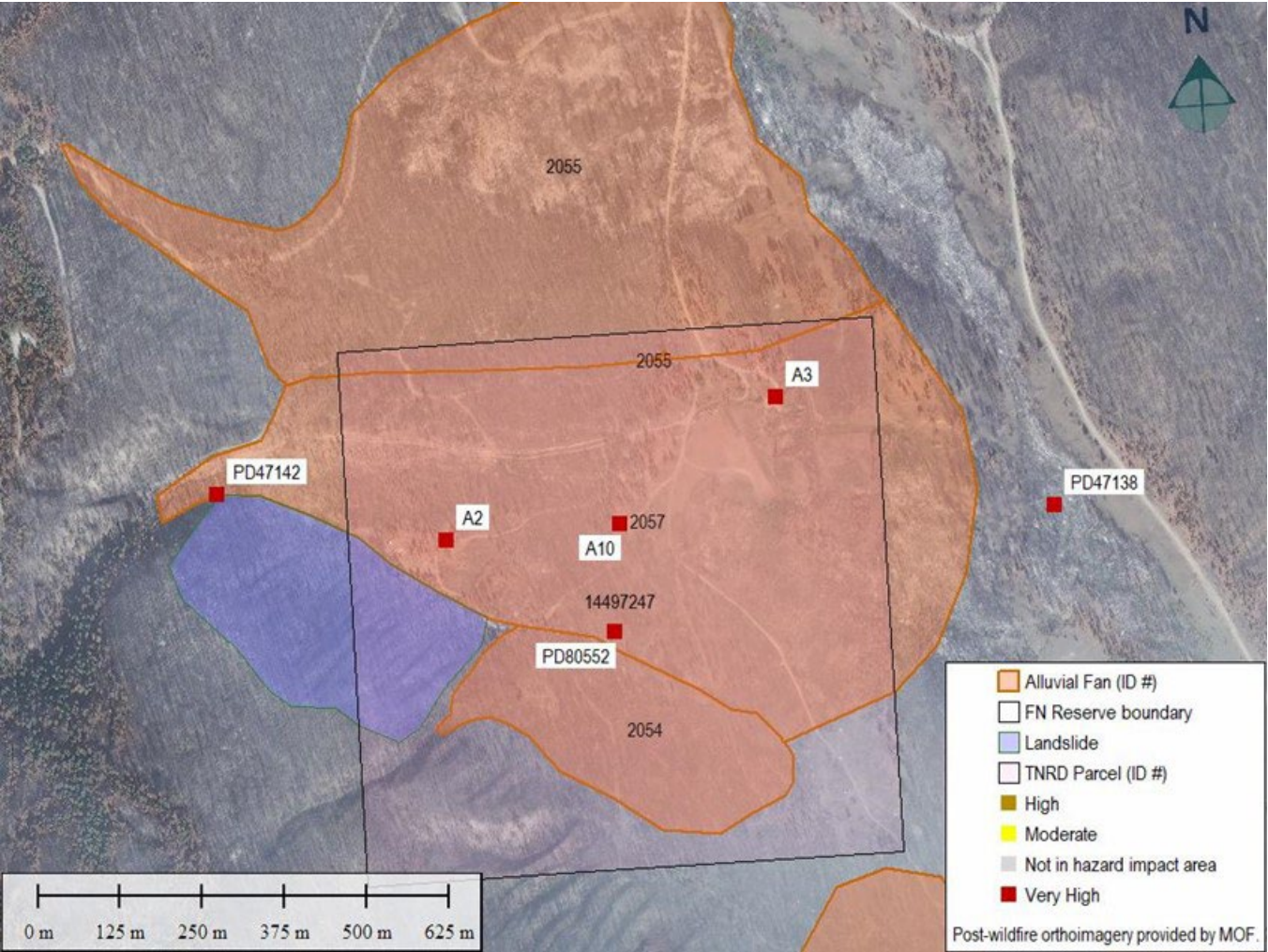
SITE INFORMATION						
Site Name	Bhumi Farm					

HAZARD ASSESSMENT						
Hazard ID	2057		2057	2057	2057	2057
Watershed ID	56		56	56	56	56
Stream Name						
Burn Severity - Unburned (%)	1%		1%	1%	1%	1%
Burn Severity - Low (%)	20%		20%	20%	20%	20%
Burn Severity - Moderate (%)	26%		26%	26%	26%	26%
Burn Severity - High (%)	52%		52%	52%	52%	52%
Process Type	Debris Flow	Debris Slide	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	N/A	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000
Geohazard Likelihood	Very High	High	Very High	Very High	Very High	Very High

ELEMENTS AT RISK						
Parcel ID	014497247	014497247	014497247	014497247	014497247	014497247
Site Identifier	A2	A2	A3	PD47142	PD80552	A10
Risk Element Type	Building	Building	Building	Water license	Water license	Buildings (burned)

SPATIAL IMPACT ASSESSMENT						
Presence of incised channel on fan	No		No	Yes	No	No
Element position in relation to fan apex	Proximal (Upper 3rd)		Distal (Lower 3rd)		Medial (Middle 3rd)	Medial (Middle 3rd)
Element position in relation to active channel						
Additional Considerations (+/-)		A2 is at the margin of a debris slide hazard area.	The resource road to the fan apex may deflect flows towards the A3 house			
Spatial Impact Likelihood	High	Low	Moderate	High	Moderate	Moderate
Comments						

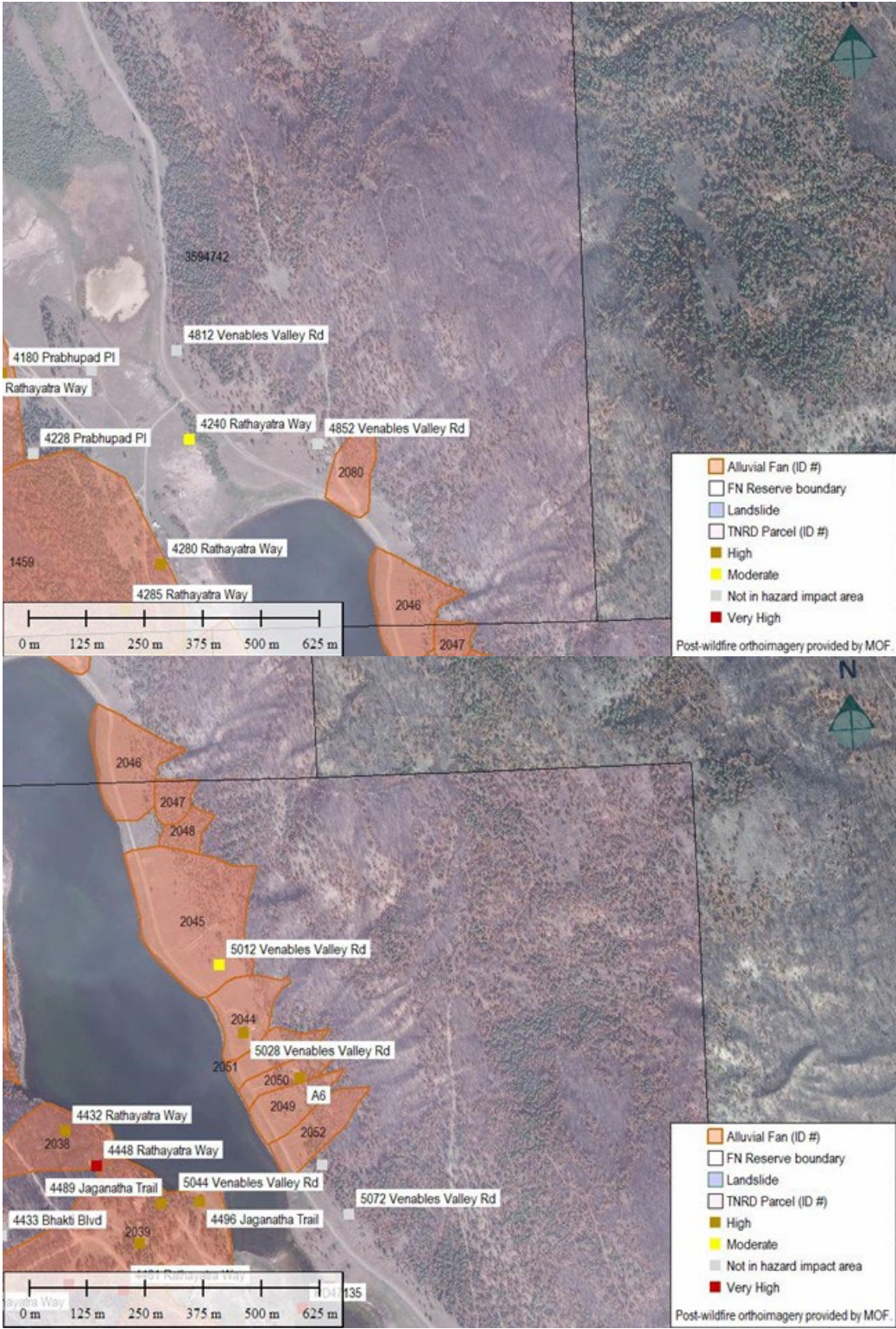
PARTIAL RISK ASSESSMENT						
Partial Risk Rating	Very High	Moderate	Very High	Very High	Very High	Very High
Comments	Element has two partial risk ratings.	Element has two partial risk ratings.				



Note:
Several cabins (no known address) burned down on the property with an estimated location of A10. Additional cabin locations were not included in the partial risk assessment. Watershed 56 contains resource roads in the upper watershed, which may affect the hazard likelihood and/or magnitude. These roads were not observed during BGC's field program. Property may be affected by additional hazards from watershed 57, which contains a resource road that may alter drainage patterns on the alluvial fan.

Elements in the floodplain of Venables Creek are assessed in the site applicable to that hazard ID.

SITE INFORMATION								
Site Name	East side of Venables Lake (page 1 of 2)							
HAZARD ASSESSMENT								
Hazard ID	2045	2044	2050	No mapped hazard	No mapped hazard	No mapped hazard	No mapped hazard	No mapped hazard
Watershed ID	48	49	51	No mapped watershed	No mapped watershed	No mapped watershed	No mapped watershed	No mapped watershed
Stream Name								
Burn Severity - Unburned (%)	0%	0%	0%					
Burn Severity - Low (%)	13%	10%	25%					
Burn Severity - Moderate (%)	64%	60%	55%					
Burn Severity - High (%)	23%	30%	20%					
Process Type	Debris Flow	Debris Flow	Debris Flow					
Estimated Post-wildfire Debris Flow Volume (m³)	<1000	<1000	<1000					
Geohazard Likelihood	High	High	High					
ELEMENTS AT RISK								
Parcel ID	003594734	003594734	003594734	003594734	003594734	003594734	003594734	003594734
Site Identifier	5012 Venables Valley Rd	5028 Venables Valley Rd	A6	4812 Venables Valley Rd	4852 Venables Valley Rd	5044 Venables Valley Rd	5072 Venables Valley Rd	5232 Venables Valley Rd
Risk Element Type	No apparent element	Building	Building	Building	Building	No apparent element	No apparent element	No apparent element
SPATIAL IMPACT ASSESSMENT								
Presence of incised channel on fan	Yes	No	No					
Element position in relation to fan apex	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)					
Element position in relation to active channel								
Additional Considerations (+/-)	A diversion channel is dug through centre of fan.							
Spatial Impact Likelihood	Low	Moderate	Moderate	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area
Comments		Evidence of recent overland flooding directed towards home.	Evidence of recent overland flooding directed towards home.					
PARTIAL RISK ASSESSMENT								
Partial Risk Rating	Moderate	High	High	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area	Not in hazard impact area
Comments								



Note:
Evidence of recent overland flooding was observed at 5028 Venables Valley Rd and home at location A6 during helicopter overflights. There is evidence of a possible engineered channel on Fan 2045 that was constructed at an unknown date.

Elements in the floodplain of Venables Creek and on Alluvial Fan IDs 2038 and 2039 are assessed in the site applicable to that hazard ID.

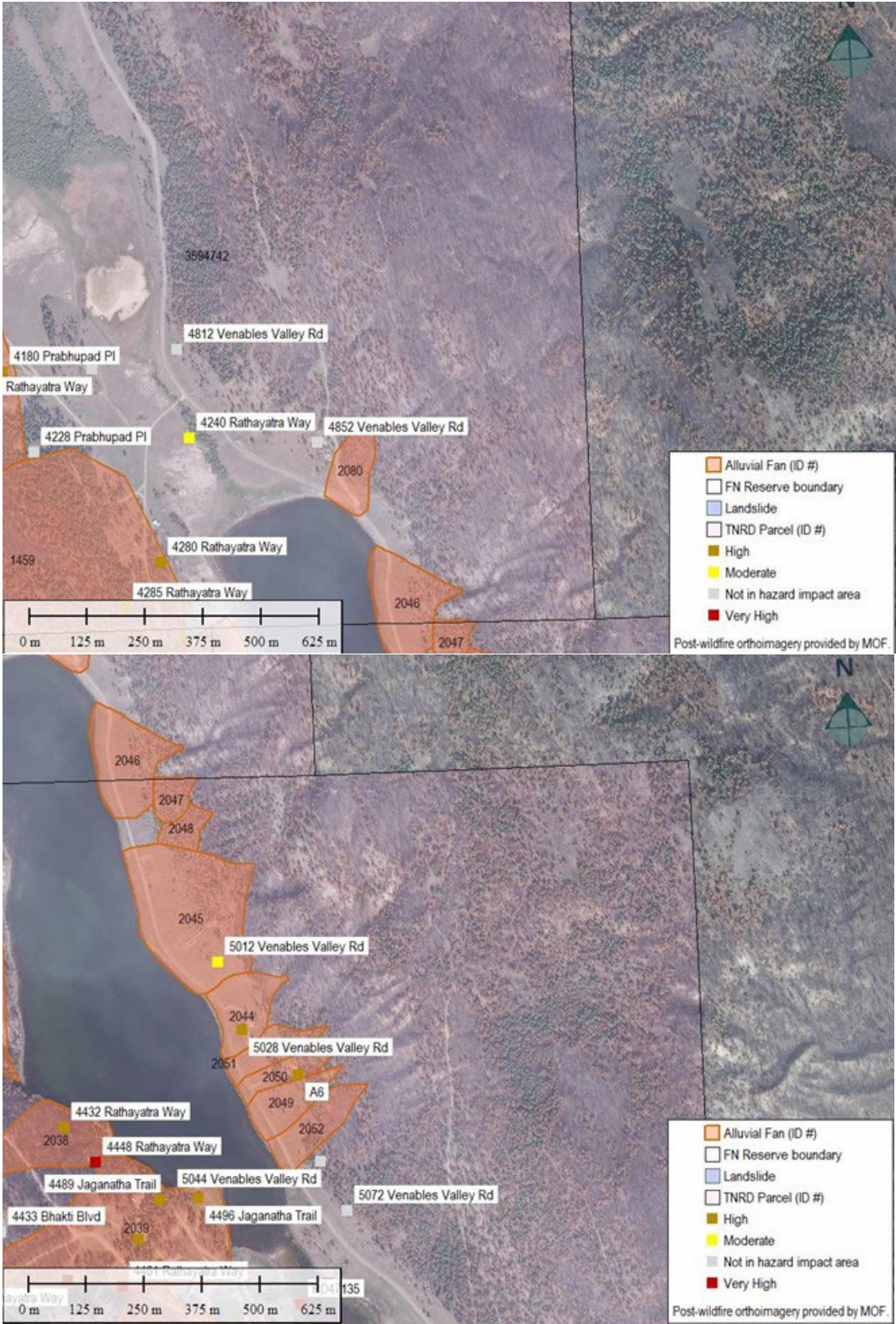
SITE INFORMATION		
Site Name	East side of Venables Lake (page 2 of 2)	

HAZARD ASSESSMENT		
Hazard ID	No mapped hazard	No mapped hazard
Watershed ID	No mapped watershed	No mapped watershed
Stream Name		
Burn Severity - Unburned (%)		
Burn Severity - Low (%)		
Burn Severity - Moderate (%)		
Burn Severity - High (%)		
Process Type		
Estimated Post-wildfire Debris Flow Volume (m³)		
Geohazard Likelihood		

ELEMENTS AT RISK		
Parcel ID	003594726	003594726
Site Identifier	5280 Venables Valley Rd	5320 Venables Valley Rd
Risk Element Type	Building	No apparent element

SPATIAL IMPACT ASSESSMENT		
Presence of incised channel on fan		
Element position in relation to fan apex		
Element position in relation to active channel		
Additional Considerations (+/-)		
Spatial Impact Likelihood	Not in hazard impact area	Not in hazard impact area
Comments		

PARTIAL RISK ASSESSMENT		
Partial Risk Rating	Not in hazard impact area	Not in hazard impact area
Comments		



Note:
Evidence of recent overland flooding was observed at 5028 Venables Valley Rd and home at location A6 during helicopter overflights. There is evidence of a possible engineered channel on Fan 2045 that was constructed at an unknown date.

Elements in the floodplain of Venables Creek and on Alluvial Fan ID 2038 and 2039 are assessed in the site applicable to that hazard ID.

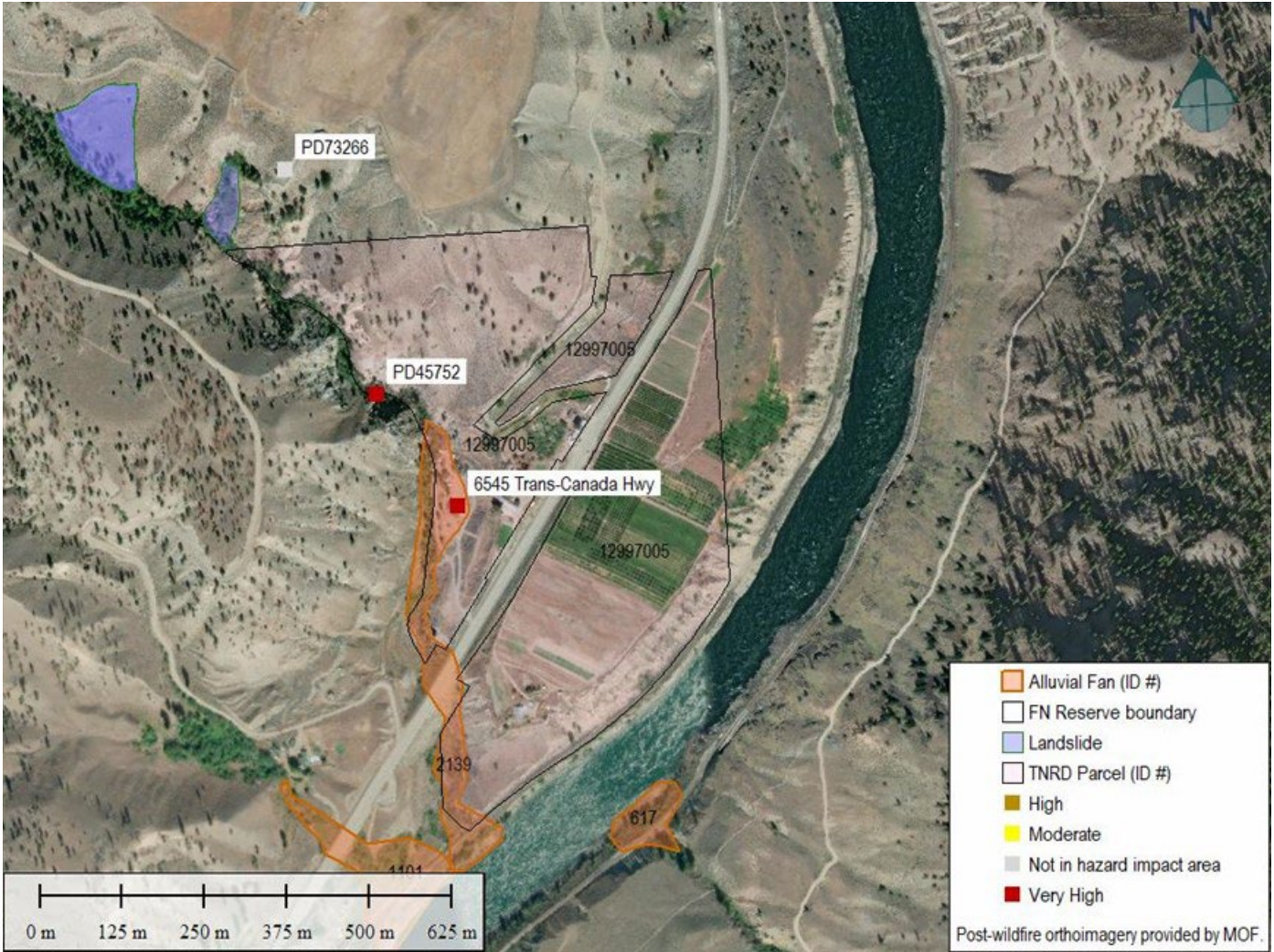
SITE INFORMATION			
Site Name	Hilltop Campground		

HAZARD ASSESSMENT			
Hazard ID	2139	2139	2139
Watershed ID	161	161	161
Stream Name			
Burn Severity - Unburned (%)	15%	15%	15%
Burn Severity - Low (%)	9%	9%	9%
Burn Severity - Moderate (%)	27%	27%	27%
Burn Severity - High (%)	49%	49%	49%
Process Type	Debris Flood	Debris Flood	Debris Flood
Estimated Post-wildfire Debris Flow Volume (m³)	N/A	N/A	N/A
Geohazard Likelihood	High	High	High

ELEMENTS AT RISK			
Parcel ID	012997005	012997005	012997005
Site Identifier	6545 Trans-Canada Highway	PD73266	PD45752
Risk Element Type	Campground	Water license	Water license

SPATIAL IMPACT ASSESSMENT			
Presence of incised channel on fan	Yes		Yes
Element position in relation to fan apex	Proximal (Upper 3rd)		
Element position in relation to active channel	Within 1/3 of active channel		Within 1/3 of active channel
Additional Considerations (+/-)			
Spatial Impact Likelihood	High	Not in hazard impact area	High
Comments	Campground is on low terrace (less than 1 m) and proximal to Twaal Creek channel.		

PARTIAL RISK ASSESSMENT			
Partial Risk Rating	Very High	Not in hazard impact area	Very High
Comments			



Note:
Hilltop Campground is on the low terrace proximal to main channel. The campground has historically flooded during freshet.

SITE INFORMATION									
Site Name	Water licenses along Twaal Creek outside debris flow hazard zones and Spence Creek, as well as PD74780 in a debris flow prone channel.								

HAZARD ASSESSMENT									
Hazard ID	2139	2139	2139	2139	2139	2139	2139	2139	2067
Watershed ID	161	161	161	161	161	161	161	161	119
Stream Name									
Burn Severity - Unburned (%)	15%	15%	15%	15%	15%	15%	15%	15%	0%
Burn Severity - Low (%)	9%	9%	9%	9%	9%	9%	9%	9%	9%
Burn Severity - Moderate (%)	27%	27%	27%	27%	27%	27%	27%	27%	25%
Burn Severity - High (%)	49%	49%	49%	49%	49%	49%	49%	49%	66%
Process Type	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,000-10,000
Geohazard Likelihood	High	High	High	High	High	High	High	High	Very High

ELEMENTS AT RISK									
Parcel ID	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	NICOELTON NO 6	
Site Identifier	PD47025	PD47022	PD47021	PD47019	PD45748	PD45749	PD45750	PD45751	PD74780
Risk Element Type	Water license	Water license	Water license	Water license	Water license	Water license	Water license	Water license	Water license

SPATIAL IMPACT ASSESSMENT									
Presence of incised channel on fan									
Element position in relation to fan apex									
Element position in relation to active channel									
Additional Considerations (+/-)	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is in an active floodplain.	Water intake is within main watershed.
Spatial Impact Likelihood	High	High	High	High	High	High	High	High	High
Comments		Diversion infrastructure includes a ditch.	Diversion infrastructure includes a ditch.				Concrete weir is downstream of resource road crossing.		Earth slide is present in watershed.

PARTIAL RISK ASSESSMENT									
Partial Risk Rating	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Comments									

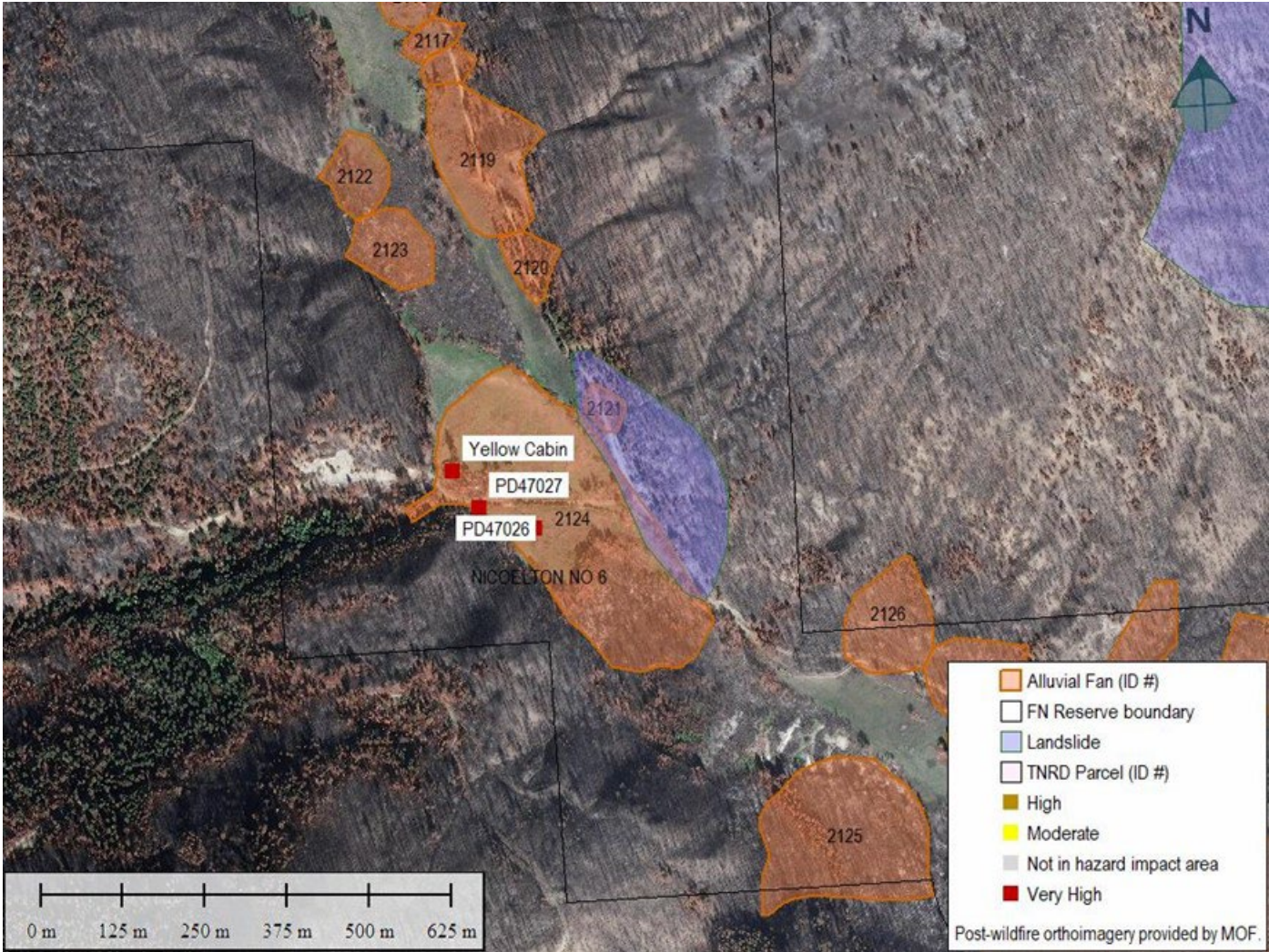
SITE INFORMATION				
Site Name	Yellow Cabin			

HAZARD ASSESSMENT				
Hazard ID				
Watershed ID	55	55	55	55
Stream Name	Spence Creek	Spence Creek	Spence Creek	Spence Creek
Burn Severity - Unburned (%)	18%	18%	18%	18%
Burn Severity - Low (%)	12%	12%	12%	12%
Burn Severity - Moderate (%)	35%	35%	35%	35%
Burn Severity - High (%)	34%	34%	34%	34%
Process Type	Debris Flood	Debris Flood	Debris Flood	Debris Flood
Estimated Post-wildfire Debris Flow Volume (m³)	N/A	N/A	N/A	N/A
Geohazard Likelihood	Very High	Very High	Very High	Very High

ELEMENTS AT RISK				
Parcel ID	Nicoelton No 6	Nicoelton No 6	Nicoelton No 6	Nicoelton No 6
Site Identifier	Cabin	Road	PD47027	PD47026
Risk Element Type	Building	Road	Water license	Water license

SPATIAL IMPACT ASSESSMENT				
Presence of incised channel on fan	Yes	Yes	Yes	Yes
Element position in relation to fan apex	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Medial (Middle 3rd)
Element position in relation to active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel	Within 1/3 of active channel
Additional Considerations (+/-)				Channel previously flowed towards this location
Spatial Impact Likelihood	High	High	High	Moderate
Comments				Spence Creek previously flowed towards this location.

PARTIAL RISK ASSESSMENT				
Partial Risk Rating	Very High	Very High	Very High	Very High
Comments				



SITE INFORMATION																			
Site Name	Access road (Twaal Creek Road) along IR 6 within Twaal Creek valley - section above Yellow Cabin (page 1 of 2)																		

HAZARD ASSESSMENT																			
Hazard ID																			
Watershed ID	61	62	63	64	66	64	70	69	68	71	72	73	74	75	76	77	78	79	80
Stream Name																			
Burn Severity - Unburned (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Burn Severity - Low (%)	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Burn Severity - Moderate (%)	64%	10%	2%	0%	4%	0%	3%	1%	0%	0%	0%	0%	0%	0%	13%	20%	1%	0%	0%
Burn Severity - High (%)	35%	88%	98%	100%	96%	100%	97%	99%	100%	100%	100%	100%	100%	100%	87%	80%	99%	100%	100%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Geohazard Likelihood	High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High

ELEMENTS AT RISK																			
Parcel ID																			
Site Identifier	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road
Risk Element Type	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road

SPATIAL IMPACT ASSESSMENT																			
Presence of incised channel on fan	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Fan Position	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Medial (Middle 3rd)
Channel Position																			
Additional Considerations (+/-)																			
Spatial Impact Likelihood	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	Moderate	High	High	Moderate
Comments					Earthflow in watershed may affect hazard likelihood or magnitude														

PARTIAL RISK ASSESSMENT																			
Partial Risk Rating	Moderate	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	High	High	High	Very High	Very High	Very High	Very High	Very High
Comments																			

SITE INFORMATION															
Site Name	Access road (Twaal Creek Road) along IR 6 within Twaal Creek valley - section below Yellow Cabin (page 2 of 2)														

HAZARD ASSESSMENT															
Hazard ID															
Watershed ID	81		82	87	86	85	83	90	91	92	93	94	95	96	
Stream Name															
Burn Severity - Unburned (%)	0%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Burn Severity - Low (%)	0%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Burn Severity - Moderate (%)	3%		7%	0%	0%	0%	3%	1%	15%	6%	5%	2%	0%	14%	
Burn Severity - High (%)	97%		93%	100%	100%	100%	97%	99%	85%	94%	95%	98%	100%	86%	
Process Type	Debris Flow	Landslide	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Rockfall
Estimated Post-wildfire Debris Flow Volume (m³)	<1000		1,000-10,000	<1000	<1000	<1000	1,000-10,000	<1000	<1000	<1000	<1000	1,000-10,000	<1000	<1000	
Geohazard Likelihood	Very High	High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	High

ELEMENTS AT RISK															
Parcel ID															
Site Identifier	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road
Risk Element Type	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road

SPATIAL IMPACT ASSESSMENT															
Presence of incised channel on fan	No		No	No	No	No	No	No	No	No	No	No	No	No	
Fan Position	Proximal (Upper 3rd)		Medial (Middle 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	Proximal (Upper 3rd)	
Channel Position															
Additional Considerations (+/-)															
Spatial Impact Likelihood	High	High	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	High	High	High	High
Comments															Rockfall deposits observed along road

PARTIAL RISK ASSESSMENT															
Partial Risk Rating	Very High	Very High	Very High	High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Comments															

SITE INFORMATION																	
Site Name	Access road (Twaal Creek Road) along IR 6 within Twaal Creek valley - section below Yellow Cabin																

HAZARD ASSESSMENT																	
Hazard ID																	
Watershed ID	99	100	101	102	103	109	110	111	112	113	114	115	117	127	128	129	130
Stream Name																	
Burn Severity - Unburned (%)	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	4%	20%	68%	90%
Burn Severity - Low (%)	0%	0%	0%	0%	0%	0%	22%	0%	1%	0%	11%	7%	8%	34%	45%	12%	10%
Burn Severity - Moderate (%)	7%	20%	70%	79%	11%	49%	56%	25%	32%	25%	73%	40%	23%	44%	35%	9%	0%
Burn Severity - High (%)	93%	80%	30%	21%	88%	51%	23%	74%	67%	75%	16%	54%	69%	18%	0%	11%	0%
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris Flow
Estimated Post-wildfire Debris Flow Volume (m³)	<1000	<1000	<1000	<1000	1,000-10,000	<1000	<1000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	1,000-10,000	<1000	<1000	N/A
Geohazard Likelihood	Very High	Very High	High	Very High	Very High	Very High	High	Very High	Very High	Very High	Very High	Very High	Very High	High	High	High	Low

ELEMENTS AT RISK																	
Parcel ID																	
Site Identifier	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road
Risk Element Type	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road

SPATIAL IMPACT ASSESSMENT																	
Presence of incised channel on fan	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Element position in relation to fan apex	Distal (Lower 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Medial (Middle 3rd)	Distal (Lower 3rd)	Distal (Lower 3rd)	Proximal (Upper 3rd)
Element position in relation to active channel																	
Additional Considerations (+/-)																	
Spatial Impact Likelihood	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate	Low	Moderate	Moderate	Moderate	Low	Low	High
Comments					An earthflow in the watershed may affect hazard likelihood or magnitude.												

PARTIAL RISK ASSESSMENT																	
Partial Risk Rating	High	High	High	Very High	Very High	Very High	High	High	High	Very High	High	Very High	Very High	High	Moderate	Moderate	Moderate
Comments																	

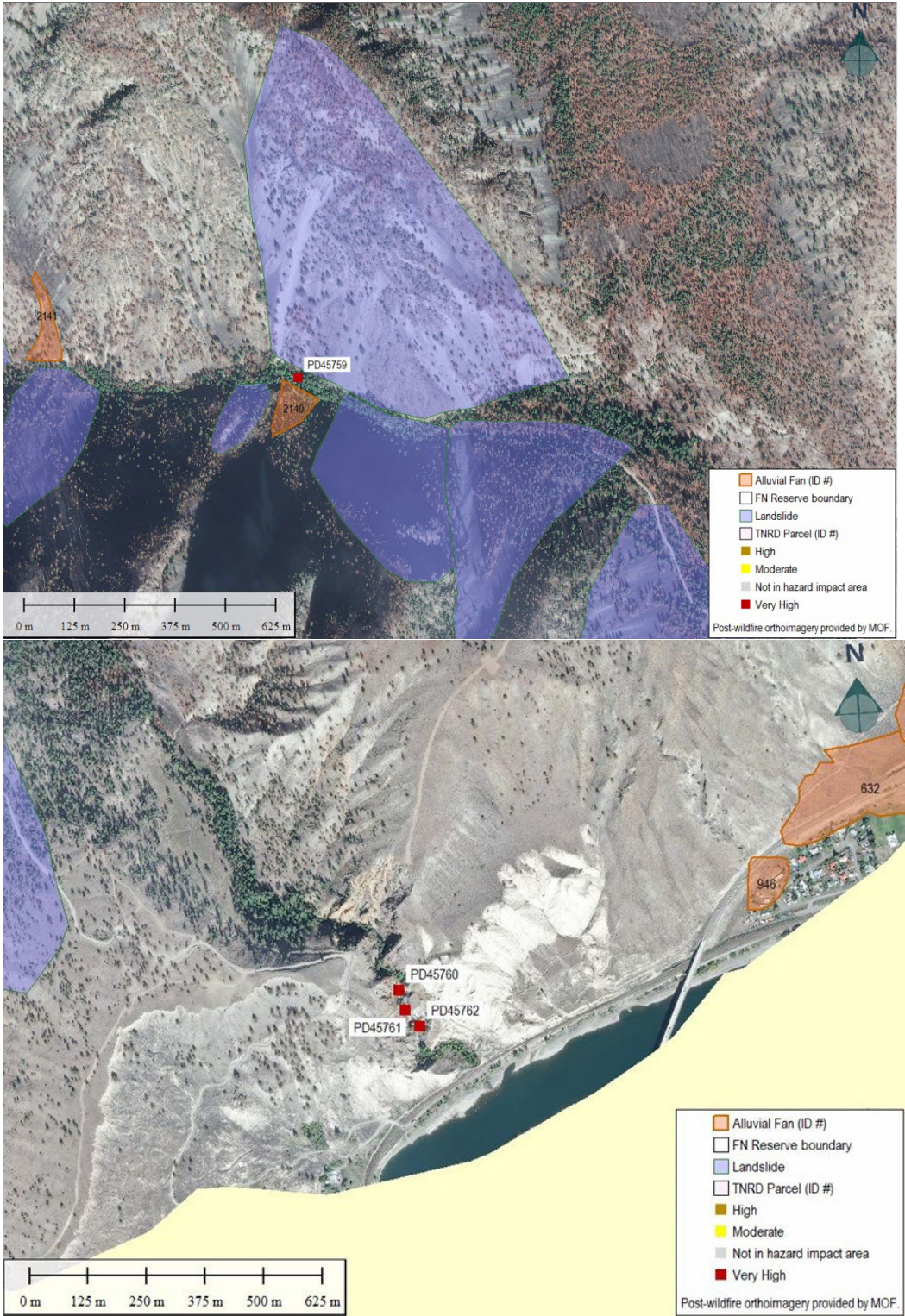
SITE INFORMATION						
Site Name	Water licenses along Murray Creek					

HAZARD ASSESSMENT						
Hazard ID						
Watershed ID	164	163	163	163	152	159
Stream Name	Murray Creek	Murray Creek	Murray Creek	Murray Creek	Shetland Creek	Murray Creek
Burn Severity - Unburned (%)	54%	49%	49%	49%	0%	44%
Burn Severity - Low (%)	12%	13%	13%	13%	8%	13%
Burn Severity - Moderate (%)	20%	22%	22%	22%	29%	24%
Burn Severity - High (%)	14%	16%	16%	16%	63%	19%
Process Type	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris Flow	Debris Flood
Estimated Post-wildfire Debris Flow Volume (m³)	N/A	N/A	N/A	N/A		
Geohazard Likelihood	High	High	High	High	High	High

ELEMENTS AT RISK						
Parcel ID	N/A	N/A	N/A	N/A	N/A	N/A
Site Identifier	PD45759	PD45760	PD45761	PD45762	PD45758	PD47114
Risk Element Type	Water license	Water license	Water license	Water license	Water license	Water license

SPATIAL IMPACT ASSESSMENT						
Presence of incised channel on fan						
Element position in relation to fan apex						
Element position in relation to active channel						
Additional Considerations (+/-)						
Spatial Impact Likelihood	High	High	High	High	High	High
Comments	Water diversion in creek	Water diversion in creek	Water diversion in creek	Water diversion in creek	Water diversion in creek	Water diversion in creek

PARTIAL RISK ASSESSMENT						
Partial Risk Rating	Very High	Very High	Very High	Very High	Very High	Very High
Comments						



Note:
Murray Creek had muddy flows during the last intense rainfall event (July 2023). PD45758 and PD47114 are shown on Drawing 03.

SITE INFORMATION																								
Site Name	Murray Creek FSR - downstream of fireguard																							
HAZARD ASSESSMENT																								
Hazard ID																								
Watershed ID	146	147	148	149		150		154			155		164	164	164	164		148	79					
Stream Name																								
Burn Severity - Unburned (%)	0%	0%	0%	0%		4%		13%			32%		54%	54%	54%	54%		0%	0%					
Burn Severity - Low (%)	9%	20%	20%	20%		21%		43%			49%		12%	12%	12%	12%		20%	0%					
Burn Severity - Moderate (%)	35%	44%	36%	60%		58%		43%			19%		20%	20%	20%	20%		36%	0%					
Burn Severity - High (%)	56%	36%	43%	19%		17%		0%			0%		14%	14%	14%	14%		43%	100%					
Process Type	Debris Flow	Debris Flow	Debris Flow	Debris Flow	Debris fall	Debris Flow	Rockfall	Debris Flow	Rockfall	Rockslide	Debris Flow	Rockfall	Debris Flood	Debris Flood	Debris Flood	Debris Flood	Debris slide	Debris Flow	Debris Flow	Mountain slope deformation	Rockfall	Rockfall	Debris slide	
Estimated Post-wildfire Debris Flow Volume (m³)	1,000-10,000	1,000-10,000	<1000	1,000-10,000		>10,000		1,000-10,000			1,000-10,000		N/A	N/A	N/A	N/A		<1000	<1000					
Geohazard Likelihood	Very High	High	Very High	High	High	Very High	High	High	High	High	High	High	High	High	High	High	High	Very High	Very High	High	High	High	High	
ELEMENTS AT RISK																								
Parcel ID																								
Site Identifier	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Bridge	Road	Bridge	Bridge	Road	Road	Road	Road	Road	Road	Road	
Risk Element Type	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Road	Bridge	Road	Bridge	Bridge	Road	Road	Road	Road	Road	Road	Road	
SPATIAL IMPACT ASSESSMENT																								
Presence of incised channel on fan	No	No	No	No		No		No			No							No	No					
Element position in relation to fan apex	Distal (Lower 3rd)	Medial (Middle 3rd)		Distal (Lower 3rd)		Medial (Middle 3rd)		Medial (Middle 3rd)			Distal (Lower 3rd)							Proximal (Upper 3rd)	Medial (Middle 3rd)					
Element position in relation to active channel																								
Additional Considerations (+/-)													Road is in the active floodplain for approximately 2 km.											
Spatial Impact Likelihood	Low	Moderate	Moderate	Low	High	Moderate	High	Moderate	High	High	Low	High	High	Moderate	High	High	High	High	Moderate	High	High	High	High	
Comments																								
PARTIAL RISK ASSESSMENT																								
Partial Risk Rating	High	High	Very High	Moderate	Very High	Very High	Very High	High	Very High	Very High	Moderate	Very High	Very High	High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	
Comments													There is potential for bank erosion to damage road.								Rapid failure of slope could block channel			

APPENDIX B

POST-WILDFIRE HAZARD AND RISK ASSESSMENT METHODS



B-1 INTRODUCTION

This appendix describes methods used by BGC to identify and characterize post-wildfire geohazard likelihood, estimate the spatial impact likelihood, and rate partial risk for elements at risk within the Shetland Creek Fire study area (Drawing 01). The main report provides an overview of the general approach to the partial risk assessment. This appendix is organized as follows:

- Section B-2 provides key terminology used in this assessment.
- Section B-3 describes the methods used to generate the burn severity map.
- Section B-4 details the methods used to map watershed, alluvial fans, and landslides in the study area.
- Section B-5 outlines the processes used to evaluate the Post-Wildfire Hazard Likelihood Ratings.
- Section B-6 describes the methods used to estimate the volume of post-wildfire debris flows.
- Section B-7 describes the procedures for identifying the elements at risk and their resultant Post-Wildfire Partial Risk rating.

B-2 TERMINOLOGY

This report refers to the following key definitions (Canadian Standards Association, 1997; Engineers and Geoscientists of BC 2018; 2023):

- **Alluvial fan (fan):** Depositional areas of a steep creek consisting of deposited sediment and shaped like an open fan or a segment of a cone. Alluvial fans are typically deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of stream suddenly decreases.
- **Asset:** anything of value, including both anthropogenic and natural assets¹, and items of economic (e.g., businesses) or intangible value (e.g., traditional gathering areas).
- **Bank erosion:** erosion and removal of material along the banks of a stream resulting in either a shift in the river position, or an increase in the river width.
- **Clear-water floods:** riverine and lake flooding resulting from inundation due to an excess of clear-water discharge in a watercourse or body of water such that land outside the natural or artificial banks which is not normally under water is submerged. While called “clear-water floods”, such floods still transport sediment. This term merely serves to differentiate from other flood forms such as debris flows or debris floods.
- **Consequence:** A result or effect on human well-being, property, or the environment due to a post-wildfire geohazard occurring.

¹ Assets of the natural environment: biological assets (produced or wild), land and water areas with their ecosystems, subsoil assets and air (United Nations Statistics Division, 2016).

- **Debris flow:** Very rapid to extremely rapid surging flow of saturated sediment and debris, originating in steep channels. Debris flows entrain material and water from the flow path and deposit material on fans (Hung et al., 2014).
- **Debris flood:** A flood during which the entire bed, possibly barring the very largest clasts, mobilizes for at least a few minutes and over a length scale of at least ten times the channel width, though commonly much farther (Church & Jakob, 2020).
- **Elements at risk:** assets exposed to potential consequences of geohazard events.
- **Geohazard:** geophysical process that is the source of potential harm, or that represents a situation with a potential for causing harm.
- **Landslide:** Mass movement of rock, debris or earth.
- **Risk:** a measure of the probability of a specific geohazard event occurring and the consequence of that event.
- **Partial risk:** a measure of the likelihood of a specific geohazard event occurring and reaching an element at risk (spatial risk). Partial risk does not account for consequence of that event to the element at risk.
- **Spatial impact likelihood:** a measure of the likelihood of a specific geohazard event reaching an element at risk.
- **Steep-creek:** a stream with a gradient exceeding 3° (5% gradient) where debris flows and debris floods are possible. The term 'steep creek processes' is used in this report as a collective term for debris flows and debris floods.
- **Waterbody:** ponds, lakes and reservoirs.
- **Watercourse:** creeks, streams and rivers.

B-3 BURN SEVERITY MAPPING

The most common index used in estimating burn severity uses multispectral satellite imagery and relies on the normalized burn ratio (NBR), which is a normalized difference of the reflectance measured in the near-infrared and short-wave-infrared wavelengths. The difference in NBR (dNBR) between pre-fire imagery and post-fire imagery may be compared to identify burned areas and measure burn severity. MOF provided BGC with an interim dNBR map for the wildfire perimeter, using pre-wildfire satellite imagery from July 7, 2024, and post-wildfire imagery from September 6, 2024. Figure B-1 summarizes the dNBR values in the Shetland Creek Fire perimeter, which shows an average value of 0.53 (which corresponds to "Moderate" burn severity).

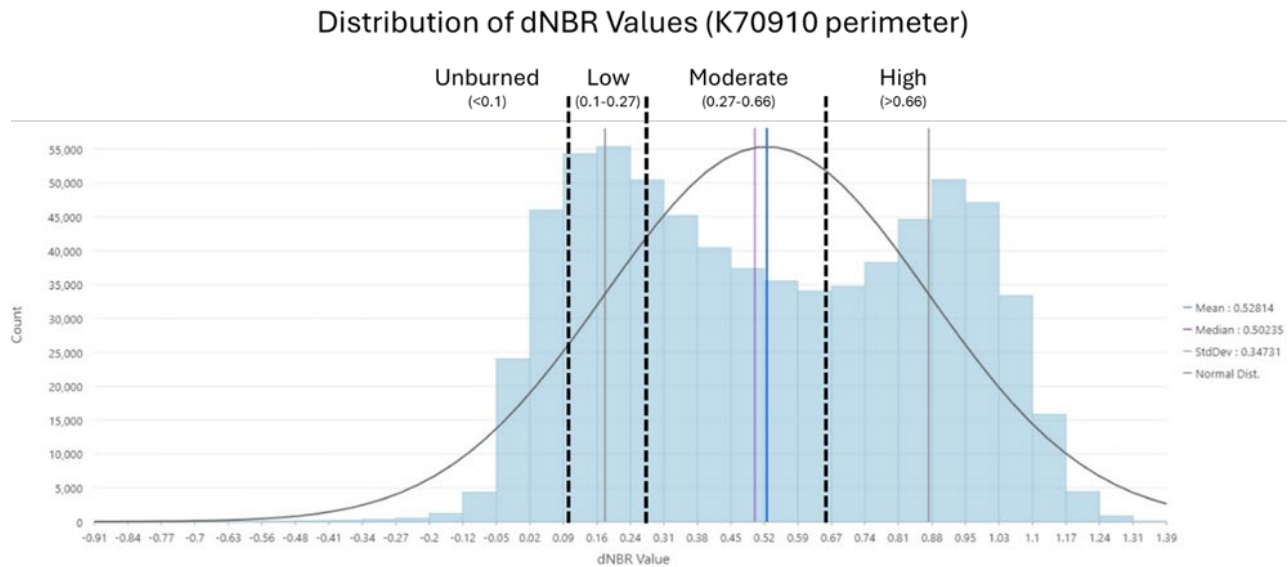


Figure B-1 Distribution of dNBR values within the Shetland Creek fire perimeter. Standard dNBR burn severity classes are annotated on the histogram.

Soil burn severity field checks were completed following procedures outlined in the Land Management Handbook 69 (Hope et al., 2015). BGC completed 15 soil burn severity checks within and adjacent to the burned perimeter. The soil burn severity field checks were primarily conducted upslope of elements at risk, or along roadways that provided access to different vegetation burn severity classes classified by the MOF. Note that between burn severity check sites BS-3 and BS-6, BGC completed a transect to evaluate the range of burn severity observations over a short distance.

The results of the soil burn severity field checks are summarized in the main report. Representative photographs from each site are provided in Appendix D. General observation of the burn severity field checks include:

- The satellite-derived vegetation burn severity generally matched the observed soil burn severity
- Soil burn severity varied over short distances, with low soil burn severity encountered within 10 m of high soil burn severity
- In high soil burn severity areas, observed hydrophobicity was low to moderate (per descriptions in Parsons et al., 2010)
- Rilling, assumed to be generated during the September 25, 2024 rainstorm, was observed in high soil burn severity areas
- Unburned rootlets were typically found within a few centimeters of the soil surface, even in high soil burn severity areas.

B-4 GEOMORPHIC MAPPING

B-4.1 Mapping

Burned watersheds were digitized using GIS analysis with the medium resolution (approximately 30 m resolution) digital elevation model (DEM) (Government of Canada, 2024). The extents were verified and adjusted as necessary to conform to observations of channels and alluvial fans in aerial photographs, a digital stream network derived from the DEM (using a minimum contributing area threshold of 0.1 km²), previously mapped alluvial fans (BGC, April 16, 2020), potential debris flow and/or debris flood hazard areas, and field observations.

The following criteria were used when deciding where to delineate watersheds:

- The watershed intersects or is adjacent to the fire perimeter.
- The watershed is located proximal to an element at risk within the study area.
- The outlet was located at or near a mapped fan, or the mouth of a drainage outlet or gully that was previously shown to be a potential source for downstream debris flow or debris flood inundation based on the runout susceptibility modeling (BGC, March 31, 2019).

In some cases, a watershed was located upstream of another, larger-scale watershed outlet (i.e., a sub-watershed within a larger watershed, which both may pose a hazard to developed areas near their respective outlets). In such cases, both the larger watershed and the sub-watershed were delineated for assessment.

Alluvial fan extents were manually delineated in an ESRI ArcGIS Online web map based on a review of previous mapping (e.g., BGC, March 31, 2019; BGC, July 26, 2023; BC Data Catalogue, October 17, 2024), and from hillshade images built from the available lidar DEMs. At sites where lidar DEMs were not available, the 30 m DEM, aerial photographs, and orthoimagery provided by MOF were used for terrain interpretation. A total of 140 fans were mapped within the study area.

The accuracy of each fan's boundary and hazard rating depends, in part, on the resolution of the available terrain data. Lidar DEMs, where available, provide 1 m or better resolution. Mapped fan boundaries, even where lidar coverage is available, are approximate, but are less certain where lidar coverage was not available. For areas without lidar coverage, the minimum fan size that can be mapped at regional scale with the available information is about 2 ha. Local variations in terrain conditions over areas of 1 to 3 ha, or over distances of less than about 200 m, may not be visible. Future site investigations could alter the locations of the fan boundaries mapped by BGC. Based on the lack of available lidar data, the alluvial fan extents should be considered approximate and should not be used for planning purposes.

Landslides were manually delineated in an ESRI ArcGIS Online web map based on a review of previous mapping (e.g., BGC, July 26, 2023; BC Data Catalogue, October 17, 2024), and from hillshade images built from the available lidar DEM. At sites where lidar DEMs were not available, the 30 m DEM, aerial photographs, and orthoimagery provided by MOF were used for

terrain interpretation. Based on the lack of available lidar data, the landslide extents should be considered approximate and should not be used for planning purposes.

B-4.2 Post-Wildfire Geohazard Process Type

Geohazards are a natural process that involve a mixture of water, debris, and sediment and span a continuum of processes from clearwater floods (flood) to rockfalls flows (Figure B-1). Each of these processes has different runout characteristics that could pose credible threats to people and infrastructure. These hazards typically occur in mountainous areas, and in small to medium sized watersheds (usually less than 100 km²). BGC interpreted post-wildfire geohazard process type from morphometric characteristics, terrain interpretation, and field evidence. The following paragraphs outline these methods.

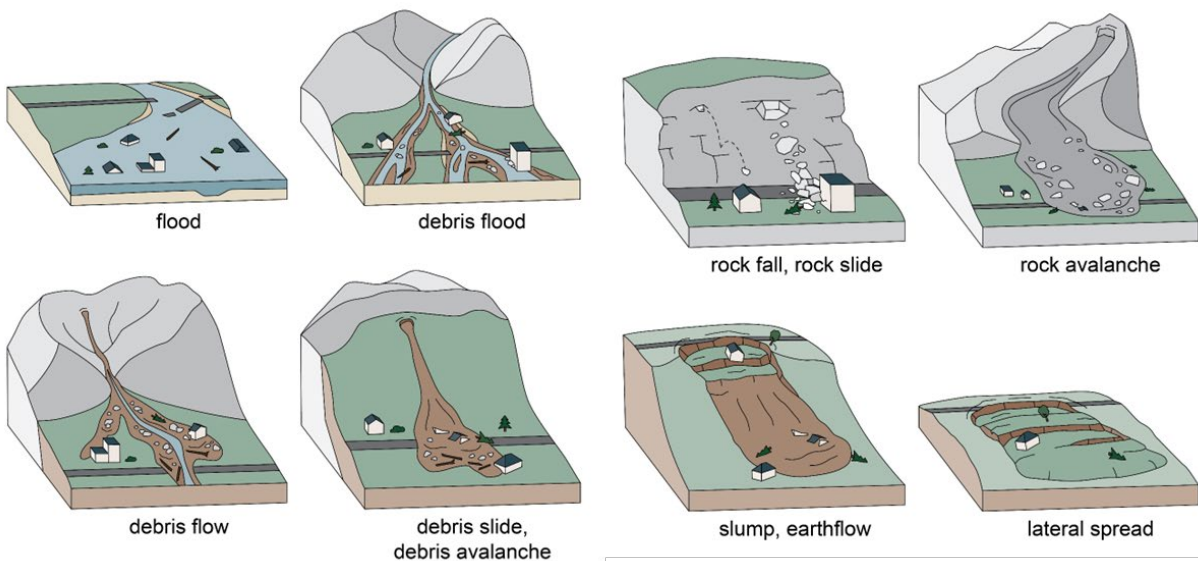


Figure B-2 Types of potential post-wildfire geohazards.

Landslides were assigned one of the following geomorphic process types, following guidance and definitions from Howes and Kenk (1997) and Hungr et al. (2014):

- Earthflow
- Rockfall
- Rock slide
- Rock slope deformation
- Earth slide.

BGC applied a morphometric approach to predict steep creek process type (debris flow, debris flood, flood) for burned watersheds in the study area:

1. Calculate Melton Ratio² and watershed length³ for each burned watershed. These terrain factors are a good screening-level indicator of the propensity of a creek to dominantly produce floods, debris floods or debris flow (Coe et al., 2003; Wilford et al., 2004; Godt & Coe, 2007; Holm et al., 2016; Church & Jakob, 2020).
2. Identify dominant geomorphic process types for all watersheds, based on previously defined class boundaries (Holm et al., 2016).

Melton Ratio and watershed length values for the delineated watersheds in the study area are plotted on Figure B-3⁴. Although there is overlap, creeks with the highest Melton ratio and shortest watershed stream length are mostly prone to debris flows, and those with the lowest Melton ratio and longest watershed stream lengths are mostly prone to clear-water floods. Debris floods fall between these types. The geomorphic process type zone that each watershed fell into was used to estimate the likelihood of post-wildfire debris flows, debris floods, and floods (Section B-5).

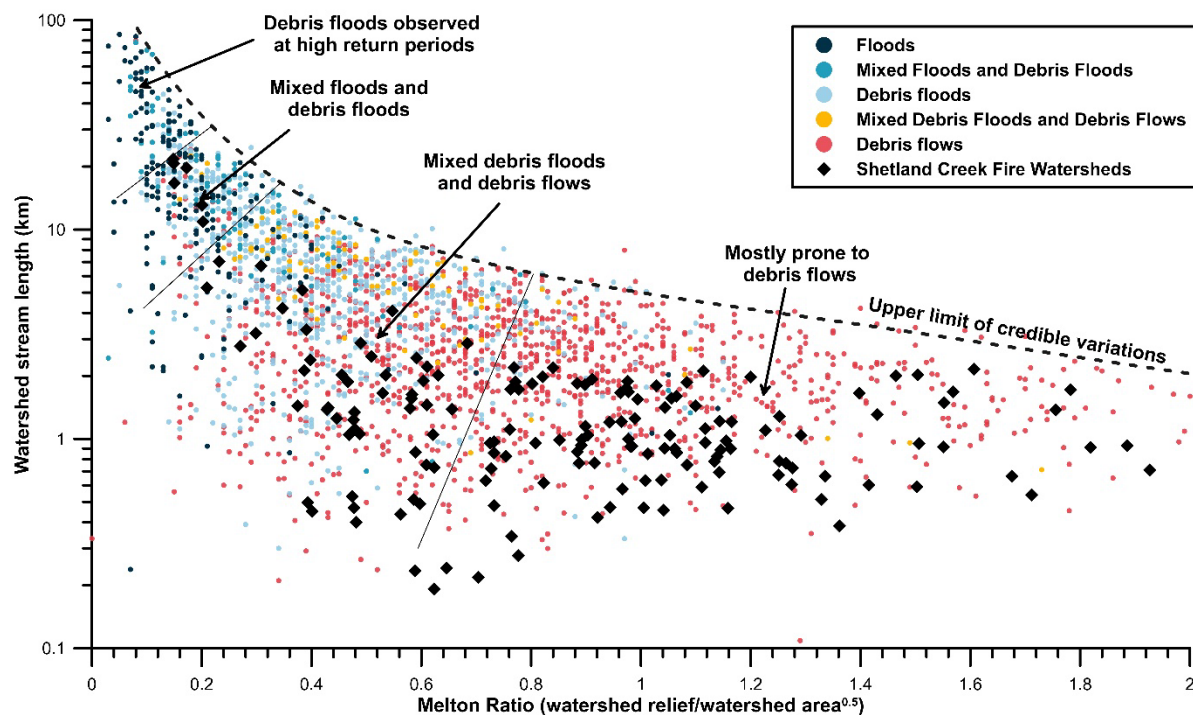


Figure B-3 Classification of hydromorphic process types by watershed stream length and Melton Ratio.

BGC verified or modified the remotely derived post-wildfire geohazard process types, following published guidance (Wilford et al., 2014; de Haas et al., 2024) and the following information sources:

² Melton ratio is watershed relief divided by the square root of watershed area (Melton, 1957).

³ Watershed length is the total channel length upstream of a given stream segment to the stream segment farthest from the fan apex.

⁴ The process type shown in the figure represents the process at the location of the fan apex. Many creeks subject to debris-floods are also subject to debris-flows on steeper creeks higher in the basin.

- The geomorphology of fans and their associated watersheds observed in the available airphotos and imagery
- Field observations of past geohazard deposits and their interpreted geohazard process type
- Records of previous events.

In some cases, remotely sensed (lidar and air photo) or field observations indicated that the stream may be subject to mixed processes (e.g., Venables Creek above its alluvial fan is subject to debris flow and debris flood processes). In this case, the watershed was assigned the more conservative classification (i.e., debris flow is a more conservative rating than debris flood and flood and debris flood is the more conservative rating than flood.).

B-5 POST-WILDFIRE HAZARD LIKELIHOOD RATING

Post-wildfire Hazard Likelihood (Table B-1) for each geohazard were estimated for the three different geohazard types in the study area:

- Debris flows – described in Section B-5.1
- Landslides – described in Section B-5.2
- Debris Floods and Floods – described in Section B-5.3.

Table B-1 Post-wildfire Hazard Likelihood categories and estimated likelihood, adapted from Land Management Handbook 56 (Wise et al., 2004) and Engineers and Geoscientists of BC Landslide Assessment Guidelines (March 1, 2023).

Hazard Likelihood (P(H))	Description ¹	MOF Hazard Criteria	Annual Likelihood Range (Return Frequency)	Five Year Cumulative Likelihood (% / 5 yrs)
Very High	An event is imminent or expected to occur over a 5-year period.	- Most of the catchment has burned with a significant proportion burned at moderate and/or high severity. - Evidence of pre-fire terrain instability within stream channels, on fans or face units. - Post-fire instability observed on similar terrain nearby.	Greater than 20% (Greater than 1.5)	Greater than 67%
High	An event is probable under adverse conditions.	- Most of the catchment has burned with a significant proportion (i.e., >50%) of terrain conducive to post-wildfire natural hazard initiation burned at moderate and/or high severity. - Indicators of pre-fire terrain instability within stream channels, on fans or face units.	1 to 20% (1:100 to 1:5)	5 to 67%

Hazard Likelihood (P(H))	Description ¹	MOF Hazard Criteria	Annual Likelihood Range (Return Frequency)	Five Year Cumulative Likelihood (% / 5 yrs)
Moderate	An event could occur under adverse conditions- it's not probable, but possible over a 5-year period.	- More than 20% of the terrain conducive to post-wildfire natural hazards in the catchment area was burned with moderate and/or high severity. - Historic geomorphic indicators of terrain instability are present.	0.2 to 1% (1:500 to 1:100)	1 to 5%
Low	An event could occur under very adverse conditions - it's considered very unlikely to occur over a 5-year period.	- Limited proportion of the catchment was burned during the fire. - No signs of pre-fire instability are evident within stream channels, on fans, or face units.	0.04 to 0.2% (1:2,500 to 1:500)	0.2 to 1%
Very Low	An event will not occur; or is conceivable though considered exceptionally unlikely to occur over a 5-year period.	- A limited proportion/none of the catchment was burned during the fire. -No terrain instability indicators are present.	Less than 0.04% (Less than 1:2,500)	<0.2%

B-5.1 Post-Wildfire Debris-Flow Likelihood Rating

Following major wildfires in BC, there have been observations of post-wildfire debris flows (e.g., Jordan and Covert, 2009; Jordan, 2016). Although the occurrence of such hazards is well-known, BC does not have a consistent method to evaluate the likelihood of post-wildfire geohazards.

In estimating the likelihood of post-wildfire debris flows, BGC used two methods to estimate the likelihood of post-wildfire debris flows:

- A matrix-based model developed by BGC, based on observations of other wildfires in BC, which has shown reasonable success in nearby wildfire scars
- A statistical model developed for wildfires in the United States (Staley et al., 2015), which has been developed across a variety of physiographies, some of which are similar to the Shetland Creek Fire area.

The combination of these two approaches allowed BGC to systematically generate a semi-quantitative Post-Wildfire Debris-Flow Likelihood Rating for this study area that incorporates a range of methodologies. While this approach is semi-quantitative and assigns P(H) based on the estimated annual probability ranges described in Table B-1, BGC found that observations also generally aligned with the qualitative criteria described by MOF in Table B-1, and is

consistent with observations from nearby wildfire scars that have observed post-wildfire debris flows (2017 Elephant Hill Fire and 2021 Lytton Creek Fire).

In general, the following criteria was used to assign a Hazard Likelihood Rating for each watershed:

- If the watershed was unburned, a rating of “Very Low” was applied.
- If the watershed was less than 20% burned, and the proportion of the watershed burned did not display terrain characteristics typical of debris flows or debris floods, a “Low” rating was applied.
- If the watershed was between 20 to 30% burned, and the BGC and Staley et al. (2015) models provided different results, the less conservative rating was selected. For example, if one method resulted in a “High” rating, and the other a “Moderate” rating, the “Moderate” rating was applied to that watershed.
- If the BGC and Staley et al. (2016) models provided different results, the more conservative rating was selected. For example, if one method resulted in a “High” rating, and the other a “Very High” rating, the “Very High” rating was applied to that watershed.
- For cases where the BGC and Staley et al. (2016) model results differed by two or more classes, an average was taken between the two results (e.g., “Very High” and “Moderate” ratings resulted in a final rating of “High”).

The two debris flow likelihood methods are described further below.

BGC Post-Wildfire Likelihood Model

For each of the burned watersheds, BGC characterized likelihood of post-wildfire debris flow or debris flood based on a “Burn Severity Index” and a “Hydrogeomorphic Process Index”.

- The Burn Severity Index reflects the increase in likelihood of debris flow or debris flood occurrence at increasing burn severity and extent in each watershed.
- The Hydrogeomorphic Process Index characterizes the expected dominant process type (debris flow, debris flood, or clearwater flood) and is independent from occurrence or severity of a wildfire (Section B-4.2). The premise is that the geometry of a watershed gives an indication of what flood processes have formed it and are active currently.

Post-wildfire hazard likelihood ratings were assigned to each watershed by combining the Burn Severity Index with the Hydrogeomorphic Process Index using a matrix (Table B-2).

Table B-2 Post-wildfire hazard likelihood rating for steep creek hazards based on burn severity and coverage and watershed susceptibility to hydrogeomorphic processes.

Post-wildfire Hazard Likelihood		Hydrogeomorphic Process Index (Figure B-3)			
		Susceptible to Debris Floods only in rare storms	Somewhat susceptible to Debris Flows and Debris Floods in moderate to intense storms	Susceptible to Debris Flows and Debris Floods in moderate storms	Very susceptible to Debris Flows and Debris Floods in mild to moderate storms
Burn Severity Index		Process I	Process II	Process III	Process IV
Very High	≥ 40	High	High	Very High	Very High
High	30 to 40	Moderate	High	High	Very High
Moderate	20 to 30	Low	Moderate	High	High
Low	10 to 20	Low	Low	Moderate	High
Very Low	< 10	Very Low	Low	Low	Moderate

The Burn Severity Index is calculated as the sum of watershed areas burned at each severity class (unburned, low, moderate, and high) (Table B-2) multiplied by a weighting factor for each burn severity class (0.7 for high severity, 0.2 for moderate severity, 0.1 for low severity, and 0 for unburned terrain). Mathematically this can be expressed as:

$$I_{BS} = \sum_{i=1}^n W_{BS,i} A_{B,i} \quad [\text{Eq. 1}]$$

where I_{BS} is the Burn Severity Index, calculated as the summation of the product of the area burned at the i th burn severity class ($A_{B,i}$), and the burn severity weight for the i^{th} class ($W_{BS,i}$). There are four burn severity classes (from $i = 1$ to $i = 4$) where $i = 1$ is unburned, $i = 2$ is low burn severity, $i = 3$ is moderate burn severity, and $i = 4$ is high burn severity (in this case, $n = 4$). The weighting factors used in this study were selected by BGC during prior post-wildfire debris-flow hazard assessment work in BC, in which BGC observed varying responses of watersheds to rainfall events depending on the severity of burn. BGC has observed areas of moderate and high burn severity to have the greatest effect on changing the hydrological response relative to baseline conditions. The weighting factors are therefore based on expert judgement and have been qualitatively validated through observation of subsequent post-wildfire debris-flow events in BC.

The Hydrogeomorphic Process Index characterizes the expected dominant process type in each watershed (ranging from flooding to debris flows) and is independent from occurrence or severity of a wildfire. As described in Section B-4.2, BGC plotted the watershed length and the Melton Ratio (watershed relief divided by square-root of watershed area) of a watershed and compared against a database of known process types to identify the potential hydrogeomorphic process of the assessed watershed (Figure B-3). BGC assigned the following classes to each watershed:

- Process Type 1 – Flood-prone

- Process Type 2 – Flood and debris flood prone
- Process Type 3 – Debris flood and debris flow prone
- Process Type 4 – Debris flow prone.

BGC's method has been applied to other wildfires in BC and has performed well in evaluating the likelihood of post-wildfire geohazards. Table B-3 demonstrates that the successful application of this method for 281 watersheds in the Lytton Creek Fire, where 79% of the recorded debris flows were rated as high or very high likelihood by the method described above.

Table B-3 Summary of observations of post-wildfire debris flows in relation to the post-wildfire likelihood rating at the Lytton Creek Fire, BC (data from BGC, MMM DD, 2022; BGC, August 8, 2023; Lau et al., 2023, and Brideau et al., 2025).

Post-Wildfire Likelihood Rating	Number of Watersheds	Number of Watersheds with Observed Post-Wildfire Debris Flows and Debris Floods	Percentage of Watersheds with Observed Post-Wildfire Debris Flows and Debris Floods (%)	Recorded Debris-Flow or Debris-Flood Events with Selected Watershed Rating (%)
Very High	72	57	79	46
High	101	41	41	33
Moderate	78	24	31	19
Low	18	3	17	Less than 1
Very Low	0	0	0	0
Unburned	12	0	0	0
Total	281	125	44	N/A

Staley et al. (2016) Post-Wildfire Likelihood Model

The United States Geological Survey (USGS) estimates the probability of post-wildfire debris flow hazards using empirical models. The current post-wildfire likelihood model (Staley et al., 2016) uses observations from past wildfires across the US to predict future debris flows.

Mathematically, the probability is expressed as:

$$P = \frac{e^X}{1 + e^X} \quad [\text{Eq. 2}]$$

Where:

- P is the probability of a debris flow, given as a value between 0 and 1
- e is a mathematical constant
- X is derived through Equation 3:

$$X = -3.63 + (0.41 * HM23 * i_{15}) + \left(0.67 * \frac{dNBR}{1000} * i_{15}\right) + (0.17 * KF * i_{15}) \quad [\text{Eq. 3}]$$

Where:

- $HM23$ is the proportion of the watershed steeper than 23° and burned at high and moderate intensity
- i_{15} is the rainfall intensity during the most intense 15-minutes of a selected rainfall event
- $dNBR$ is the average differenced normalized burn ratio (Section B-3)
- KF is a soil erodibility factor.

Table B-4 summarizes the input data used to estimate the probability of post-wildfire debris flows using Equation 3. Input data for each watershed is provided in Appendix C. To estimate the annual likelihood of a post-wildfire debris flow ($P(H)$), P was multiplied by annual likelihood of the rainfall event (50%). The selected i_{15} value (12 mm/hr) was justified through observations of post-wildfire debris flows being triggered by these intensities on the nearby 2017 Elephant Hill Fire and 2021 Lytton Creek Fire scars (BGC, June 11, 2024), as well as other wildfire scars in Washington State (Graber, 2023) and Colorado (Cannon et al., 2008). The $P(H)$ values were translated to the qualitative likelihood values used in the five rating categories (Table B-5).

Table B-4 Summary of values used in Equation 3 to estimate post-wildfire debris flow likelihood

Parameter	Value	Data Source
$HM23$	0 to 100% (value assigned per watershed)	Estimated in a geographic information system (GIS) from the burn severity mapping (Section B-3), the watershed perimeters (Section B-4), and the Canadian medium resolution DEM
i_{15}	12 mm/hr	Available climate data in the study area (Section 3.3 in the main body of the report). BGC used the 2-year return period rainfall (annual likelihood of 50%).
$dNBR$	0 to 1.1 (per watershed)	Estimated in a geographic information system (GIS) from the burn severity mapping (Section B-3), the watershed perimeters (Section B-4)
KF	0.045 (Venables and Twaal Creek watersheds) 0.035 (Murray Creek watershed)	BC Soil Information Finder Tool (Government of BC, 2021) and provincial guidance manuals (BC Ministry of Transportation and Infrastructure, n.d.).

Table B-5: Staley et al. (2016) probability values used to assign Post-Wildfire Likelihood Rating.

Staley et al. (2016) Probability	Annual probability of rainfall	Estimated P(H)	Post-Wildfire Debris-Flow Likelihood Rating
Greater than 40%	50%	Greater than 20%	Very High
2 to 40%	50%	1 to 20%	High
0.4 to 2%	50%	0.2 to 1%	Moderate
0.08 to 0.4%	50%	0.04 to 0.2%	Low
Less than 0.08%	50%	Less than 0.04%	Very Low

B-5.2 Post-Wildfire Landslide Likelihood Rating

The Shetland Creek Fire has burned source areas (i.e., steep slopes where landslides may initiate) and runout zones (i.e., where landslides may move after initiation). Within the study area, there are earthflow, rockfall, rockslide, rock slope deformation, and earth slide landslide hazards. Landslides may be more likely to occur and may be able to travel further after a fire due to a loss of vegetation, fire-induced hydrophobicity of the soil, and thermal damage to the source zone. BGC has defined hazard for this report as the likelihood of a geohazard event impacting an asset at risk in the post-wildfire environment.

No empirical models are available to estimate the likelihood of landslides occurring after a wildfire. Therefore, BGC used professional judgement about the wildfire characteristics and terrain interpretation to inform estimates of post-wildfire hazard likelihood (Table B-6). Given the limited information about pre-wildfire frequency, BGC evaluated relatively conservative criteria for landslides.

Table B-6 Criteria used for landslide Post-Wildfire Likelihood Rating.

Spatial Likelihood of Impact Category	Landslide Hazard Criteria
Very Low	Unused
Low	Unused
Moderate	Source area is burned at low burn severity and there is no terrain morphology, based on aerial photographs and the 30 m DEM, of past landslide activity.
High	Source area is less than 50% burned at moderate and high burn severity, and there is terrain morphology, based on aerial photographs and the 30 m DEM of past landslide activity.
Very High	Source area is more than 50% burned at moderate and high burn severity, and there is terrain morphology, based on aerial photographs and the 30 m DEM of past landslide activity.

B-5.3 Post-Wildfire Flood and Debris Flood Likelihood Rating

Few studies have been conducted in BC and worldwide to assess the impact of wildfires on flood hazards than debris flows. In evaluating the likelihood, inundation, and potential consequences of post-wildfire debris flood and flood hazards in the Shetland Creek Fire, BGC relied upon observations of other wildfires in published studies (Eaton, Moore, & Giles, 2010; Stantec, December 20, 2023; Hancock and Wlodarczyk, 2024) and professional judgement based on BGC's experience in many other burned areas in BC and the western United States.

BGC has observed sediment inputs from upstream post-wildfire debris flows have led to large height fluctuations in flood-prone rivers during convective and frontal storms. Additionally, sediment deposited into flood-prone rivers can cause channel shifts (avulsions) for two to ten years following the wildfire.

Burned areas adjacent to rivers are more susceptible to bank erosion and avulsion, as the bank material may have a loss of cohesion due to decaying tree trunks and rootlets. Burned areas within the watershed could also contribute more wood to the channel, which may lead to elevated erosive force along the channel banks as debris interacts with bank material. A study of Fishtrap Creek near Barriere, BC following the 2003 wildfire in the watershed (Eaton, Moore, & Giles, 2010) found that bank instability caused by loss root strength was a driver of lateral channel change.

BGC evaluated the likelihood of post-wildfire flood hazards using consistent methods to the steep creek processes (Section B-5.1), wherein the extent and severity of the wildfire form an important role in evaluating the likelihood of a debris flood or flood event.

B-6 POST-WILDFIRE DEBRIS FLOW MAGNITUDE

In general, larger post-wildfire debris-flow volumes can result in greater economic damage and life-safety risk (Table B-6). Potential damages also depend on the location of buildings and infrastructure on the fan, with structures higher on the fan or closer to the main channel generally being subject to higher risk of damage. Individual watersheds may produce debris flows larger than the volume ranges assessed in this study, due to geotechnical instability in the watersheds that is outside of the scope of the present study.

Table B-7 Debris-flow volume classes, photographs of representative events, and description of potential damages

Estimated Volume (m ³)	Representative Photograph	Potential Damages
Less than 1,000 m ³	 Approximately 500 m³ post-wildfire debris flows/debris floods at Monte Lake, BC from the White Rock Lake Fire (June 3 and 28, 2022). Photo posted to Facebook by Natalie Walsh (June 3, 2023).	Economic damages to permanent buildings and temporary structures (e.g., recreational vehicles) associated with sedimentation and inundation.
1,000 to 10,000 m ³	 Approximately 1,000 m³ post-wildfire debris flow in Nicola River Valley, BC (July 17, 2022). Photo by Jennifer Clarke.	Economic damages to permanent buildings and temporary structures (e.g., recreational vehicles). Depending on debris-flow characteristics, potential to destroy buildings and result in risk to human life.

Estimated Volume (m ³)	Representative Photograph	Potential Damages
More than 10,000 m ³	 Approximately 25,000 m³ post-wildfire debris flow at Kuskonook Creek, BC (June 8, 2004). Photo by Peter Jordan (Jordan & Covert, 2009).	Potential to destroy buildings and result in threats to human life.

BGC did not estimate sediment volumes for debris floods or clearwater floods, due to limited availability of observed post-wildfire volumes for these process types. In general, post-wildfire debris floods and flood magnitudes are expected to be larger than similar hazards in non-wildfire conditions and may have more rapid onset (i.e., floods are expected to be “flashier”).

Post-wildfire debris-flow volumes can be predicted using empirical models (e.g., Cannon et al., 2010; Gartner et al., 2014) and have been used to assess post-wildfire debris flows. The Gartner et al. (2014) model was developed for use in southern California and is used by the USGS for emergency assessments of post-wildfire debris-flow hazards throughout the United States. The model is most applicable for up to two years following a wildfire, after which plant re-growth and/or source area sediment depletion render it less reliable. The inputs for the model include:

- The watershed area burned at moderate and high severity
- The watershed relief
- The storm rainfall intensity measured over a 15-minute duration (selected as a 2-year return period).

In comparison with observed post-wildfire debris flow outside of southern California, BGC and others (e.g., Wall et al., 2021) have found that the Gartner et al. (2014) model generally overpredicts the post-wildfire debris-flow volumes, and as such, the model requires adjustment to account for regional differences. When compared to observed BC post-wildfire debris flow volumes, the Gartner et al. (2014) model has generally overpredicted volumes by a factor of up to 6.4, with a few volumes underpredicting by up to a factor of 0.6 (BGC, August 8, 2023).

Figure B-4 shows the volume estimates for the Shetland Creek Fire compared to observed post-wildfire debris flow volumes in BC. In general, the distribution of the raw Shetland Creek estimates for the 2-year rainfall return period scenario fits within the upper end ranges of observed volumes from other BC wildfires. In comparison, if the predicted volume is halved, the predicted ranges fit within the distribution of observed post-wildfire debris flows in BC. Given this information, BGC applied a 0.5 reduction factor to the predicted volumes in the Shetland Creek Fire.

Estimated volumes were binned into three volume classes:

- Less than 1,000 m³
- Between 1,000 and 10,000 m³
- Greater than 10,000 m³.

Professional judgement was applied to results of the volume assessment, wherein the following rules were also applied:

- A watershed must be at least 0.1 km² to produce a volume greater than 1,000 m³
- A watershed must be at least 1 km² to produce a volume greater than 10,000 m³.

Results of the volume assessment, given a 5-year return period rainfall are provided in Appendix C and were used to evaluate the Spatial Likelihood of Impact rating (Section B-7.2) and the recommended risk reduction measures in the main body of the report.

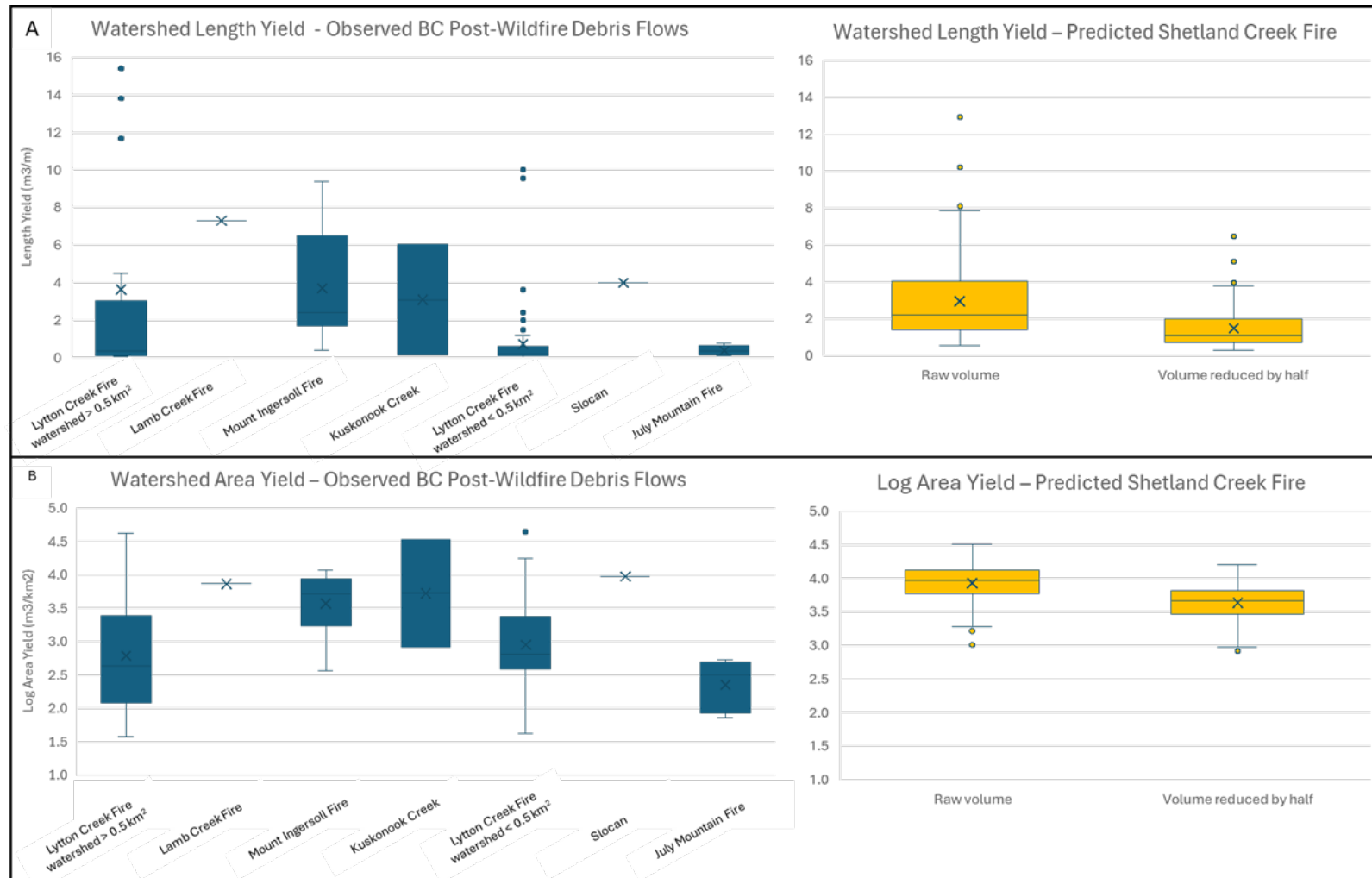


Figure B-4 Observed (left) versus predicted (right) post-wildfire debris flow volumes when normalized as A. Watershed length yield. B. Watershed area yield. Data sources: Lytton Creek Fire (BGC, August 8, 2023), Lamb Creek Fire (Jordan and Covert, 2009), Mount Ingersoll Fire (Jordan and Covert, 2009), Kuskonook Creek (Jordan and Covert, 2009), Slocan (Jordan and Covert, 2009), July Mountain Fire (Hancock and Włodarczyk, 2024).

B-7 POST-WILDFIRE PARTIAL RISK ASSESSMENT

BGC estimated Partial Risk Ratings based on the Post-Wildfire Hazard Likelihood Rating (Section B-5) and Spatial Impact Likelihood (described in Section B-7.2 below). The results of the partial assessment are presented in Appendix A and summarized in main report.

B-7.1 Elements at Risk

BGC assessed a total of:

- 60 buildings (houses, school, agricultural buildings, RV)
- One campground
- 39 water licenses and one water source with no water license
- 25 addresses with no visible elements at risk
- Two resource roads (Twaal Creek Road and Murray Creek Road).

BGC notes that this inventory may not be inclusive of all risk elements within the study area, and may have missed sites of cultural, archeological, or personal significance, visually obscured buildings or building footprints, or areas of agricultural or economic value. Risks were assessed for existing conditions (e.g., locations of buildings and infrastructure) and did not include future development scenarios.

B-7.2 Spatial Impact Likelihood

A Spatial Impact Likelihood Rating was assigned to each element at risk that may be impacted by a post-wildfire geohazard event (Table B-7). For each geohazard type, spatial impact likelihood was estimated based on guidance from published sources and professional judgement. The sections below describe these criteria.

Table B-8 Description for Spatial Impact Likelihood Ratings and associated likelihood ranges for each rating, adapted from Land Management Handbook 56 (Wise et al., 2004).

Spatial Impact Likelihood Rating	Description	Likelihood Range
High	It is probable that the element at risk will be impacted by the hazard.	> 0.5
Moderate	It is possible that the element at risk will be impacted by the hazard.	0.5 - 0.1
Low	It is unlikely that the element at risk will be impacted by the hazard.	<0.1

Debris Flow Spatial Impact

Table B-8 summarizes the guidance for debris-flow hazards on alluvial fans, based on guidance in Zubrycky et al. (2021). The criteria are based on the alluvial fan channel type (channelized or unchannelized flows), the position of the element of risk on a fan, its position relative to the channel (if present). Where appropriate, BGC considered the estimated magnitude of post-

wildfire debris flows (Section B-6), and the influence of roads or other geomorphic features that may increase or decrease the likelihood of spatial impact.

Table B-9 Spatial Impact Likelihood matrix for debris flows

Spatial Impact Likelihood P(S:H)			
	Unchannelized Alluvial Fan	Channelized Alluvial Fan	
Element at risk position relative to channel	N/A	Within 1/3rd of active channel	Beyond 1/3rd of active channel
Upstream of fan apex	High	High	N/A
Proximal (Upper 3rd)	High	High	Moderate
Medial (Middle 3rd)	Moderate	High	Low
Distal (Lower 3rd)	Low	Moderate	Low
Beyond fan boundary	Low	Low	Low

Landslide Spatial Impact

Table B-9 describes the criteria used by BGC to evaluate the Spatial Likelihood of Impact ratings for landslide hazards. The criteria are based on terrain evidence of landslide runout at the element at risk, and the wildfire characteristics in the runout area.

Table B-10 Spatial Impact Likelihood matrix for landslides.

Spatial Likelihood of Impact Category	Flood Hazard Criteria
High	Historical evidence of geohazard deposition near element at risk (e.g., rockfall deposits) OR No evidence of geohazard deposition near element at risk but is within mapped geohazard area, and wildfire has burned vegetation that would typically reduce runout into the area with the element at risk.
Moderate	No evidence of geohazard deposition near element at risk but is within mapped geohazard area.
Low	Element at risk is within 200 m of mapped hazard area.

Flood and Debris Flood Spatial Impact

Table B-10 summarizes the criteria used by BGC to evaluate the Spatial Likelihood of Impact ratings for flood and debris flood hazards. The criteria are based on terrain evidence of flood and debris flood hazards at the element at risk. Where appropriate, BGC considered the potential for avulsions and/or erosion that may increase the likelihood of spatial impact.

Table B-11 Spatial Impact Likelihood matrix for debris floods and floods.

Spatial Likelihood of Impact Category	Flood Hazard Criteria
High	Element at risk is within the active channel observed in the orthoimagery
Moderate	Element at risk is outside of the active channel but within the floodplain, as interpreted from terrain interpretation or available geohazard mapping (BGC, March 31, 2019)
Low	Element at risk is outside of the floodplain

B-7.3 Post-Wildfire Debris-Flow Partial Risk Rating

For each element at risk, the Post-Wildfire Partial Risk Rating (Table B-12) was estimated based on the Post-Wildfire Hazard Likelihood Rating (Section B-5) and the Spatial Impact Likelihood of that hazard relative to the element at risk (Section B-7.2).

Table B-12 Post-Wildfire Debris-Flow Partial Risk Rating based on Combined Post-Wildfire Hazard Rating and Spatial Risk Rating.

Hazard Likelihood P(HA) (Table B-1)	Spatial Impact Likelihood (P(S:H)) (Table B-8)		
	High	Moderate	Low
Very High	Very High	Very High	High
High	Very High	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Very Low
Very Low	Low	Very Low	Very Low

Although MOF does not require a quantitative risk evaluation of life safety, BGC used the MOF criteria and estimated the order-of-magnitude risk of life loss for persons who live full time in buildings using Equation 4.

$$R = H \times S \times T \times V \quad [\text{Eq. 4}]$$

Where:

- **R** is risk, estimated as an annual likelihood of life loss.
- **P(H)** is the annual likelihood of a post-wildfire geohazard occurring (Section B-5).
- **P(S:H)** is the likelihood of spatial impact (Section B-7.2).
- **T** is the conditional likelihood that a person occupies a building during the geohazard (temporal likelihood of building occupation). BGC assumed that buildings in the study area are occupied 70% of the time on average. This may be an overestimate for seasonally occupied buildings.
- **V** is the conditional likelihood of a fatality at a building given impact by the geohazard. For post-wildfire debris flows, vulnerability is related to flow depth, flow velocity, density,

and resultant impact pressures (Jakob et al., 2011; Pollock and Wartman, 2020). Vulnerability can range from 0.01 (for flows less than 1 m and slower than 2 m/s) to 0.9 (typically for flows greater than 1 m and faster than 2 m/s) (Pollock and Wartman, 2020). Based on observations of flow velocity and depths from comparable BC post-wildfire debris flow case studies (e.g., Table B-7), these deeper and faster flows are expected to occur when volumes are larger than 1,000 m³. For the purposes of this assessment, BGC assumed that all buildings are wood-framed.

These calculations were used to estimate life-loss risk at an order-of-magnitude level. Given that this calculation was an order-of-magnitude level, the details of the semi-quantitative risk calculations have not been provided in this report but are on file with BGC. The risk estimation did not account for group risk, or the potential for more than one fatality in a single debris flow. Vegetation recovery during the post-wildfire period may influence the likelihood of hazards originating in the watershed and warrant reanalysis of the partial risk assessment.

The risk estimates informed BGC's recommendations for risk reduction measures that provide proportionate response to the risk. For example, long-term evacuation of properties would only be recommended for properties with high or very high partial risk because these sites are likely to have intolerable risk per life loss risk thresholds established in other Canadian jurisdictions⁵.

⁵ In other jurisdictions in Canada, an annual life loss risk of 1:10,000 or less from natural hazards is considered tolerable for existing development (District of North Vancouver, 2009a; 2009b, District of Squamish, 2018, and Town of Canmore, 2016).

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APPENDIX C

WATERSHED HAZARD ASSESSMENT



Table C-1 Summary of post-wildfire geohazard ratings for the watersheds in the study area.

Watershed		Geomorphic Mapping							Burn Severity						Geohazard Likelihood and Debris Flow Volume Estimate				
ID	Name	Watershed Area (km²)	Watershed Length (m)	Relief (m)	Melton Ratio	Geomorphic Index	Assigned Geomorphic Process Type	KF-Factor	High (%)	Moderate (%)	Low (%)	Unburned (%)	Average dNBR	Burn Severity Index	BGC Post-wildfire Likelihood Rating	Staley et al. (2016) Probability value	Staley, et al. (2016) Post-wildfire Likelihood Rating	Assigned Geohazard Likelihood Rating	Volume Class (m³)
1		1.20	1657	580	0.53	III	Debris Flow	0.045	34%	30%	33%	2%	0.48	High	High	10%	High	High	1,000-10,000
2		0.51	1234	339	0.48	III	Debris Flow	0.045	18%	53%	26%	3%	0.43	Moderate	High	7%	High	High	<1,000
3		0.51	1410	307	0.43	III	Debris Flow	0.045	31%	53%	10%	6%	0.51	Moderate	High	7%	High	High	<1,000
4		2.11	2210	886	0.61	III	Debris Flow	0.045	37%	36%	26%	0%	0.52	Very High	Very High	16%	High	Very High	1,000-10,000
5		0.68	1873	635	0.77	IV	Debris Flow	0.045	56%	31%	11%	1%	0.67	Very High	Very High	17%	High	Very High	1,000-10,000
6		0.06	400	115	0.48	III	Debris Flow	0.045	0%	19%	67%	14%	0.18	Very Low	Low	5%	High	Moderate	<1,000
7		2.72	2474	840	0.51	III	Debris Flow	0.045	33%	47%	19%	1%	0.54	Very High	Very High	12%	High	Very High	1,000-10,000
8		0.25	1208	585	1.17	IV	Debris Flow	0.045	28%	56%	16%	0%	0.51	Moderate	High	46%	Very High	Very High	1,000-10,000
9		2.38	2021	702	0.46	III	Debris Flow	0.045	51%	27%	12%	10%	0.60	Very High	Very High	13%	High	Very High	1,000-10,000
10		0.18	1041	543	1.29	IV	Debris Flow	0.045	100%	0%	0%	0%	0.91	Very High	Very High	62%	Very High	Very High	1,000-10,000
11		0.22	1279	582	1.25	IV	Debris Flow	0.045	87%	13%	1%	0%	0.87	Very High	Very High	57%	Very High	Very High	1,000-10,000
12		0.71	1832	674	0.80	IV	Debris Flow	0.045	67%	21%	11%	1%	0.73	Very High	Very High	32%	High	Very High	1,000-10,000
13		0.19	1041	463	1.05	IV	Debris Flow	0.045	96%	4%	0%	0%	0.87	Very High	Very High	38%	High	Very High	1,000-10,000
14		1.44	2440	710	0.59	III	Debris Flow	0.045	89%	10%	1%	0%	0.90	Very High	Very High	14%	High	Very High	1,000-10,000
15		0.50	1724	542	0.76	IV	Debris Flow	0.045	75%	21%	4%	0%	0.81	Very High	Very High	8%	High	Very High	1,000-10,000
16		0.09	497	118	0.39	III	Debris Flow	0.045	90%	10%	0%	0%	0.87	Very High	Very High	4%	High	Very High	<1,000
17		0.24	1597	520	1.06	IV	Debris Flow	0.045	74%	17%	8%	1%	0.81	Very High	Very High	8%	High	Very High	1,000-10,000
18		0.05	633	168	0.72	IV	Debris Flow	0.045	81%	3%	14%	2%	0.76	Very High	Very High	4%	High	Very High	<1,000
19		0.04	886	239	1.15	IV	Debris Flow	0.045	67%	29%	0%	3%	0.73	Very High	Very High	4%	High	Very High	<1,000
20		0.56	1253	332	0.45	III	Debris Flow	0.045	2%	63%	33%	2%	0.36	Low	Moderate	8%	High	High	<1,000
21		0.13	721	258	0.73	IV	Debris Flow	0.045	1%	54%	44%	1%	0.35	Very Low	Moderate	10%	High	High	<1,000
22		0.40	1055	310	0.49	III	Debris Flow	0.045	11%	61%	26%	2%	0.41	Low	Moderate	5%	High	High	<1,000
23		0.18	968	311	0.73	IV	Debris Flow	0.045	23%	67%	6%	4%	0.51	Low	High	13%	High	High	<1,000
24		0.20	751	274	0.61	III	Debris Flow	0.045	47%	48%	2%	3%	0.62	High	High	26%	High	High	<1,000
25		0.12	825	258	0.75	IV	Debris Flow	0.045	16%	33%	48%	3%	0.37	Low	High	10%	High	High	<1,000
26		0.49	1664	671	0.96	IV	Debris Flow	0.045	69%	21%	9%	1%	0.76	Very High	Very High	39%	High	Very High	1,000-10,000
27		0.15	824	437	1.14	IV	Debris Flow	0.045	10%	61%	29%	0%	0.39	Low	High	53%	Very High	Very High	<1,000
28		0.41	1415	672	1.04	IV	Debris Flow	0.045	58%	37%	5%	0%	0.67	Very High	Very High	40%	Very High	Very High	1,000-10,000
29		1.43	2017	753	0.63	III	Debris Flow	0.045	77%	19%	3%	0%	0.82	Very High	Very High	21%	High	Very High	1,000-10,000
31		0.70	1722	652	0.78	IV	Debris Flow	0.045	61%	17%	20%	2%	0.68	Very High	Very High	11%	High	Very High	1,000-10,000
32		0.28	1860	572	1.08	IV	Debris Flow	0.045	71%	27%	1%	1%	0.78	Very High	Very High	7%	High	Very High	1,000-10,000
33		0.45	1798	693	1.03	IV	Debris Flow	0.045	75%	10%	12%	3%	0.76	Very High	Very High	34%	High	Very High	1,000-10,000
34		0.16	1677	631	1.57	IV	Debris Flow	0.045	61%	13%	27%	0%	0.64	Very High	Very High	12%	High	Very High	1,000-10,000
35		0.42	1253	642	0.99	IV	Debris Flow	0.045	43%	53%	3%	0%	0.61	High	Very High	53%	Very High	Very High	1,000-10,000

Watershed		Geomorphic Mapping							Burn Severity						Geohazard Likelihood and Debris Flow Volume Estimate				
ID	Name	Watershed Area (km²)	Watershed Length (m)	Relief (m)	Melton Ratio	Geomorphic Index	Assigned Geomorphic Process Type	KF-Factor	High (%)	Moderate (%)	Low (%)	Unburned (%)	Average dNBR	Burn Severity Index	BGC Post-wildfire Likelihood Rating	Staley et al. (2016) Probability value	Staley, et al. (2016) Post-wildfire Likelihood Rating	Assigned Geohazard Likelihood Rating	Volume Class (m³)
36	Venables Creek	0.18	979	489	1.16	IV	Debris Flow	0.045	88%	12%	0%	0%	0.82	Very High	Very High	59%	Very High	Very High	1,000-10,000
37		0.09	616	250	0.82	IV	Debris Flow	0.045	71%	23%	6%	0%	0.73	Very High	Very High	25%	High	Very High	<1,000
38		8.07	3198	849	0.30	III	Debris Flow	0.045	73%	20%	4%	2%	0.81	Very High	Very High	20%	High	Very High	>10,000
39		0.20	1376	783	1.76	IV	Debris Flow	0.045	72%	28%	0%	0%	0.75	Very High	Very High	64%	Very High	Very High	1,000-10,000
40		0.08	664	480	1.68	IV	Debris Flow	0.045	80%	20%	0%	0%	0.81	Very High	Very High	78%	Very High	Very High	<1000
41	Twaal Creek	0.12	1008	707	2.04	IV	Debris Flow	0.045	86%	11%	3%	0%	0.78	Very High	Very High	79%	Very High	Very High	1,000-10,000
42		0.12	912	643	1.82	IV	Debris Flow	0.045	85%	13%	2%	0%	0.82	Very High	Very High	83%	Very High	Very High	1,000-10,000
43		0.14	949	562	1.51	IV	Debris Flow	0.045	87%	13%	0%	0%	0.82	Very High	Very High	75%	Very High	Very High	1,000-10,000
44		22.32	5275	990	0.21	III	Debris Flood	0.045	45%	27%	9%	18%	0.56	Very High	Very High	17%	High	Very High	N/A
45		0.08	469	136	0.48	III	Debris Flow	0.045	10%	90%	0%	0%	0.53	Very Low	Low	4%	High	Moderate	<1,000
46	Spence Creek	0.01	242	79	0.65	IV	Debris Flow	0.045	37%	63%	0%	0%	0.60	Moderate	High	4%	High	High	<1,000
47		0.04	488	125	0.60	III	Debris Flow	0.045	4%	86%	10%	0%	0.52	Very Low	Low	4%	High	Moderate	<1,000
48		0.07	531	124	0.47	III	Debris Flow	0.045	23%	64%	13%	0%	0.51	Low	Moderate	4%	High	High	<1,000
49		0.07	450	106	0.40	III	Debris Flow	0.045	30%	60%	10%	0%	0.52	Moderate	High	4%	High	High	<1,000
50		0.01	192	65	0.62	IV	Debris Flow	0.045	13%	67%	19%	0%	0.46	Low	High	4%	High	High	<1,000
51		0.01	277	86	0.78	IV	Debris Flow	0.045	20%	55%	25%	0%	0.48	Low	High	4%	High	High	<1,000
52		0.02	234	77	0.59	IV	Debris Flow	0.045	34%	54%	8%	3%	0.57	Moderate	High	4%	High	High	<1,000
53		0.01	218	75	0.70	IV	Debris Flow	0.045	41%	59%	0%	0%	0.59	Moderate	High	7%	High	High	<1,000
54		2.97	4089	944	0.55	III	Debris Flow	0.035	15%	36%	28%	21%	0.35	High	High	4%	High	High	1,000-10,000
55		20.19	7040	1041	0.23	III	Debris Flood	0.045	34%	35%	12%	18%	0.50	Very High	Very High	8%	High	Very High	N/A
56		2.85	1879	788	0.47	III	Debris Flow	0.045	52%	26%	20%	1%	0.65	Very High	Very High	15%	High	Very High	1,000-10,000
57		0.73	1816	770	0.90	IV	Debris Flow	0.045	94%	5%	0%	0%	0.92	Very High	Very High	29%	High	Very High	1,000-10,000
58		0.94	1340	463	0.48	III	Debris Flow	0.045	98%	2%	0%	0%	1.02	Very High	Very High	25%	High	Very High	1,000-10,000
59		1.78	2389	531	0.40	III	Debris Flow	0.045	51%	40%	5%	4%	0.65	Very High	Very High	11%	High	Very High	1,000-10,000
60		1.44	1437	450	0.38	III	Debris Flow	0.045	63%	34%	3%	0%	0.75	Very High	Very High	15%	High	Very High	1,000-10,000
61		0.21	953	333	0.73	IV	Debris Flow	0.045	35%	64%	0%	0%	0.63	Moderate	High	9%	High	High	<1,000
62		0.21	990	389	0.85	IV	Debris Flow	0.045	88%	10%	2%	0%	1.00	Very High	Very High	21%	High	Very High	<1,000
63		0.12	765	313	0.89	IV	Debris Flow	0.045	98%	2%	0%	0%	1.02	Very High	Very High	52%	Very High	Very High	<1,000
64		0.11	900	379	1.16	IV	Debris Flow	0.045	100%	0%	0%	0%	1.00	Very High	Very High	58%	Very High	Very High	<1,000
65		0.15	902	408	1.04	IV	Debris Flow	0.045	100%	0%	0%	0%	1.00	Very High	Very High	42%	Very High	Very High	<1,000
66		0.17	934	365	0.89	IV	Debris Flow	0.045	96%	4%	0%	0%	1.01	Very High	Very High	28%	High	Very High	<1,000
67		0.26	859	372	0.73	IV	Debris Flow	0.045	96%	4%	0%	0%	0.97	Very High	Very High	48%	Very High	Very High	<1,000
68		0.06	421	228	0.92	IV	Debris Flow	0.045	100%	0%	0%	0%	0.86	Very High	Very High	62%	Very High	Very High	<1,000
69		0.07	918	399	1.55	IV	Debris Flow	0.045	99%	1%	0%	0%	1.02	Very High	Very High	59%	Very High	Very High	<1,000
70		0.12	960	392	1.12	IV	Debris Flow	0.045	97%	3%	0%	0%	1.06	Very High	Very High	31%	High	Very High	<1,000

Watershed		Geomorphic Mapping							Burn Severity						Geohazard Likelihood and Debris Flow Volume Estimate				
ID	Name	Watershed Area (km²)	Watershed Length (m)	Relief (m)	Melton Ratio	Geomorphic Index	Assigned Geomorphic Process Type	KF-Factor	High (%)	Moderate (%)	Low (%)	Unburned (%)	Average dNBR	Burn Severity Index	BGC Post-wildfire Likelihood Rating	Staley et al. (2016) Probability value	Staley, et al. (2016) Post-wildfire Likelihood Rating	Assigned Geohazard Likelihood Rating	Volume Class (m³)
71		0.10	782	392	1.25	IV	Debris Flow	0.045	100%	0%	0%	0%	0.92	Very High	Very High	56%	Very High	Very High	<1,000
72		0.08	607	367	1.27	IV	Debris Flow	0.045	100%	0%	0%	0%	0.81	Very High	Very High	82%	Very High	Very High	<1,000
73		0.03	541	309	1.71	IV	Debris Flow	0.045	100%	0%	0%	0%	0.84	Very High	Very High	81%	Very High	Very High	<1,000
74		0.16	849	407	1.01	IV	Debris Flow	0.045	100%	0%	0%	0%	0.89	Very High	Very High	50%	Very High	Very High	<1,000
75		0.04	514	280	1.33	IV	Debris Flow	0.045	100%	0%	0%	0%	0.89	Very High	Very High	74%	Very High	Very High	<1,000
76		0.05	603	319	1.41	IV	Debris Flow	0.045	87%	13%	0%	0%	0.82	Very High	Very High	57%	Very High	Very High	<1,000
77		0.06	664	320	1.34	IV	Debris Flow	0.045	80%	20%	0%	0%	0.79	Very High	Very High	57%	Very High	Very High	<1,000
78		0.03	592	260	1.50	IV	Debris Flow	0.045	99%	1%	0%	0%	0.87	Very High	Very High	24%	High	Very High	<1,000
79		0.06	726	309	1.28	IV	Debris Flow	0.045	100%	0%	0%	0%	0.87	Very High	Very High	34%	High	Very High	<1,000
80		0.03	470	171	0.94	IV	Debris Flow	0.045	100%	0%	0%	0%	0.91	Very High	Very High	14%	High	Very High	<1,000
81		0.09	731	185	0.62	III	Debris Flow	0.045	97%	3%	0%	0%	0.93	Very High	Very High	4%	High	Very High	<1,000
82	Nicoelton Creek	3.97	2773	539	0.27	III	Debris Flow	0.045	93%	7%	0%	0%	0.94	Very High	Very High	4%	High	Very High	1,000-10,000
83		0.22	1443	511	1.10	IV	Debris Flow	0.045	97%	3%	0%	0%	0.88	Very High	Very High	19%	High	Very High	1,000-10,000
84		3.19	2869	875	0.49	III	Debris Flow	0.045	42%	39%	17%	1%	0.58	Very High	Very High	32%	High	Very High	1,000-10,000
85		0.13	994	325	0.89	IV	Debris Flow	0.045	100%	0%	0%	0%	0.98	Very High	Very High	4%	High	Very High	<1,000
86		0.08	900	292	1.06	IV	Debris Flow	0.045	100%	0%	0%	0%	0.93	Very High	Very High	5%	High	Very High	<1,000
87		0.08	437	161	0.56	III	Debris Flow	0.045	100%	0%	0%	0%	0.93	Very High	Very High	6%	High	Very High	<1,000
88		0.46	1050	318	0.47	III	Debris Flow	0.045	60%	40%	0%	0%	0.72	Very High	Very High	5%	High	Very High	1,000-10,000
89		0.26	865	299	0.59	III	Debris Flow	0.045	82%	18%	0%	0%	0.81	Very High	Very High	5%	High	Very High	<1,000
90		0.07	693	308	1.14	IV	Debris Flow	0.045	99%	1%	0%	0%	0.86	Very High	Very High	68%	Very High	Very High	<1,000
91		0.08	636	300	1.04	IV	Debris Flow	0.045	85%	15%	0%	0%	0.78	Very High	Very High	73%	Very High	Very High	<1,000
92		0.06	589	269	1.11	IV	Debris Flow	0.045	94%	6%	0%	0%	0.84	Very High	Very High	51%	Very High	Very High	<1,000
93		0.03	466	212	1.16	IV	Debris Flow	0.045	95%	5%	0%	0%	0.88	Very High	Very High	48%	Very High	Very High	<1,000
94		0.24	1149	438	0.90	IV	Debris Flow	0.045	98%	2%	0%	0%	0.91	Very High	Very High	7%	High	Very High	1,000-10,000
95		0.16	999	390	0.98	IV	Debris Flow	0.045	100%	0%	0%	0%	0.88	Very High	Very High	9%	High	Very High	<1,000
96		0.06	576	238	0.97	IV	Debris Flow	0.045	86%	14%	0%	0%	0.79	Very High	Very High	14%	High	Very High	<1,000
97		0.05	480	165	0.73	IV	Debris Flow	0.045	99%	1%	0%	0%	0.94	Very High	Very High	15%	High	Very High	<1,000
98		0.08	514	167	0.59	III	Debris Flow	0.045	86%	14%	0%	0%	0.86	Very High	Very High	10%	High	Very High	<1,000
99		0.08	752	298	1.08	IV	Debris Flow	0.045	93%	7%	0%	0%	0.76	Very High	Very High	8%	High	Very High	<1,000
100		0.05	671	291	1.25	IV	Debris Flow	0.045	80%	20%	0%	0%	0.73	Very High	Very High	30%	High	Very High	<1,000
101		0.03	342	138	0.76	IV	Debris Flow	0.045	30%	70%	0%	0%	0.58	Moderate	High	30%	High	High	<1,000
102		0.07	633	266	1.01	IV	Debris Flow	0.045	21%	79%	0%	0%	0.60	Low	High	58%	Very High	Very High	<1,000
103		1.83	1384	579	0.43	III	Debris Flow	0.045	88%	11%	0%	0%	0.85	Very High	Very High	28%	High	Very High	1,000-10,000
104		1.08	1633	606	0.58	III	Debris Flow	0.045	91%	9%	0%	0%	0.88	Very High	Very High	54%	Very High	Very High	1,000-10,000
105		0.55	1747	719	0.97	IV	Debris Flow	0.045	57%	39%	3%	0%	0.69	Very High	Very High	46%	Very High	Very High	1,000-10,000

Watershed		Geomorphic Mapping							Burn Severity						Geohazard Likelihood and Debris Flow Volume Estimate				
ID	Name	Watershed Area (km²)	Watershed Length (m)	Relief (m)	Melton Ratio	Geomorphic Index	Assigned Geomorphic Process Type	KF-Factor	High (%)	Moderate (%)	Low (%)	Unburned (%)	Average dNBR	Burn Severity Index	BGC Post-wildfire Likelihood Rating	Staley et al. (2016) Probability value	Staley, et al. (2016) Post-wildfire Likelihood Rating	Assigned Geohazard Likelihood Rating	Volume Class (m³)
106		0.45	1566	707	1.06	IV	Debris Flow	0.045	59%	35%	7%	0%	0.69	Very High	Very High	51%	Very High	Very High	1,000-10,000
107		0.57	1682	738	0.98	IV	Debris Flow	0.045	50%	46%	4%	0%	0.65	Very High	Very High	48%	Very High	Very High	1,000-10,000
108		0.53	1549	724	0.99	IV	Debris Flow	0.045	51%	35%	13%	1%	0.61	Very High	Very High	50%	Very High	Very High	1,000-10,000
109		0.13	767	325	0.92	IV	Debris Flow	0.045	51%	49%	0%	0%	0.64	High	Very High	31%	High	Very High	<1,000
110		0.05	469	217	1.01	IV	Debris Flow	0.045	23%	56%	22%	0%	0.51	Low	High	28%	High	High	<1,000
111		0.81	1387	590	0.66	III	Debris Flow	0.045	74%	25%	0%	0%	0.73	Very High	Very High	58%	Very High	Very High	1,000-10,000
112		1.06	1556	599	0.58	III	Debris Flow	0.045	67%	32%	1%	1%	0.73	Very High	Very High	54%	Very High	Very High	1,000-10,000
113		0.51	1050	445	0.62	III	Debris Flow	0.045	75%	25%	0%	0%	0.74	Very High	Very High	55%	Very High	Very High	1,000-10,000
114		0.33	955	463	0.81	IV	Debris Flow	0.045	16%	73%	11%	0%	0.49	Low	High	48%	Very High	Very High	1,000-10,000
115		0.79	1401	515	0.58	III	Debris Flow	0.045	54%	40%	7%	0%	0.66	Very High	Very High	31%	High	Very High	1,000-10,000
116		0.16	924	396	0.98	IV	Debris Flow	0.045	24%	60%	15%	1%	0.49	Moderate	High	13%	High	High	<1,000
117		0.17	1100	503	1.23	IV	Debris Flow	0.045	69%	23%	8%	0%	0.69	Very High	Very High	65%	Very High	Very High	1,000-10,000
118		0.34	1107	442	0.76	IV	Debris Flow	0.045	24%	64%	12%	0%	0.49	Moderate	High	21%	High	High	1,000-10,000
119		1.76	2860	906	0.68	III	Debris Flow	0.045	66%	25%	9%	0%	0.70	Very High	Very High	6%	High	Very High	1,000-10,000
120		0.87	2192	784	0.84	IV	Debris Flow	0.045	38%	46%	16%	0%	0.56	High	Very High	6%	High	Very High	1,000-10,000
121		0.13	870	319	0.88	IV	Debris Flow	0.045	23%	29%	38%	9%	0.40	Moderate	High	4%	High	High	<1,000
122		0.61	1842	688	0.88	IV	Debris Flow	0.045	23%	37%	36%	4%	0.41	Moderate	High	8%	High	High	1,000-10,000
123		0.13	1120	405	1.12	IV	Debris Flow	0.045	9%	23%	39%	29%	0.29	Low	High	5%	High	High	<1,000
124		1.02	2016	541	0.53	III	Debris Flow	0.045	2%	27%	39%	32%	0.22	Low	Moderate	5%	High	High	1,000-10,000
125		0.27	1116	249	0.48	III	Debris Flow	0.045	3%	33%	22%	42%	0.21	Very Low	Low	4%	High	Moderate	<1,000
126		6.08	4205	857	0.35	III	Debris Flow	0.045	1%	8%	14%	77%	-0.01	Low	Moderate	4%	High	Moderate	1,000-10,000
127		0.28	1044	476	0.90	IV	Debris Flow	0.045	18%	44%	34%	4%	0.42	Low	High	9%	High	High	1,000-10,000
128		0.16	860	431	1.07	IV	Debris Flow	0.045	0%	35%	45%	20%	0.25	Very Low	Moderate	8%	High	High	<1,000
129		0.13	778	412	1.13	IV	Debris Flow	0.045	11%	9%	12%	68%	0.31	Very Low	Moderate	7%	High	High	<1,000
130		0.39	1211	602	0.96	IV	Debris Flow	0.045	0%	0%	10%	90%	0.01	Very Low	Moderate	4%	High	Low	N/A
131		0.47	2155	1096	1.61	IV	Debris Flow	0.045	8%	37%	24%	30%	0.30	Low	High	24%	High	High	1,000-10,000
132		0.04	457	197	1.04	IV	Debris Flow	0.045	0%	0%	9%	91%	0.03	Very Low	Moderate	4%	High	Low	N/A
133		1.88	2190	1055	0.77	IV	Debris Flow	0.045	14%	28%	36%	22%	0.32	Moderate	High	13%	High	High	1,000-10,000
134		1.25	1926	1018	0.91	IV	Debris Flow	0.045	2%	21%	24%	54%	0.17	Very Low	Moderate	7%	High	High	1,000-10,000
135		0.32	1717	1008	1.78	IV	Debris Flow	0.045	4%	27%	19%	50%	0.23	Very Low	Moderate	14%	High	High	1,000-10,000
136		0.73	1972	1028	1.20	IV	Debris Flow	0.045	10%	37%	27%	25%	0.32	Low	High	23%	High	High	1,000-10,000
137		0.11	1277	684	2.06	IV	Debris Flow	0.045	7%	24%	28%	42%	0.26	Very Low	Moderate	14%	High	High	1,000-10,000
138		0.07	930	483	1.89	IV	Debris Flow	0.045	0%	9%	6%	85%	0.09	Very Low	Moderate	6%	High	Low	N/A
139		0.02	384	187	1.36	IV	Debris Flow	0.045	0%	0%	0%	100%	0.04	Very Low	Moderate	4%	High	Very Low	N/A
140		0.04	711	391	1.93	IV	Debris Flow	0.045	0%	1%	6%	93%	0.07	Very Low	Moderate	4%	High	Low	N/A
141		0.11	767	426	1.26	IV	Debris Flow	0.045	0%	1%	6%	94%	0.06	Very Low	Moderate	4%	High	Low	N/A

Watershed		Geomorphic Mapping							Burn Severity						Geohazard Likelihood and Debris Flow Volume Estimate				
ID	Name	Watershed Area (km²)	Watershed Length (m)	Relief (m)	Melton Ratio	Geomorphic Index	Assigned Geomorphic Process Type	KF-Factor	High (%)	Moderate (%)	Low (%)	Unburned (%)	Average dNBR	Burn Severity Index	BGC Post-wildfire Likelihood Rating	Staley et al. (2016) Probability value	Staley, et al. (2016) Post-wildfire Likelihood Rating	Assigned Geohazard Likelihood Rating	Volume Class (m³)
142		0.38	1657	856	1.40	IV	Debris Flow	0.045	0%	1%	9%	90%	0.03	Very Low	Moderate	4%	High	Low	N/A
143		0.44	2001	974	1.46	IV	Debris Flow	0.045	0%	4%	18%	78%	0.04	Very Low	Moderate	4%	High	Moderate	1,000-10,000
144		0.37	2018	913	1.50	IV	Debris Flow	0.045	0%	7%	9%	84%	0.04	Very Low	Moderate	4%	High	Low	N/A
145		0.60	2114	859	1.11	IV	Debris Flow	0.035	0%	4%	11%	85%	0.02	Very Low	Moderate	4%	High	Low	N/A
146		0.57	1451	462	0.61	III	Debris Flow	0.035	56%	35%	9%	0%	0.65	Very High	Very High	10%	High	Very High	1,000-10,000
147		0.18	1214	490	1.14	IV	Debris Flow	0.035	36%	44%	20%	0%	0.52	Moderate	High	13%	High	High	1,000-10,000
148		0.17	918	400	0.98	IV	Debris Flow	0.035	43%	36%	20%	0%	0.56	High	Very High	18%	High	Very High	<1,000
149		1.01	1894	607	0.60	III	Debris Flow	0.035	19%	60%	20%	0%	0.46	Moderate	High	7%	High	High	1,000-10,000
150		5.39	5131	890	0.38	III	Debris Flow	0.035	17%	58%	21%	4%	0.43	Very High	Very High	6%	High	Very High	>10,000
151		3.24	2121	698	0.39	III	Debris Flow	0.035	26%	28%	22%	24%	0.39	High	High	12%	High	High	1,000-10,000
152		0.17	1308	588	1.43	IV	Debris Flow	0.035	63%	29%	8%	0%	0.70	Very High	Very High	33%	High	Very High	1,000-10,000
153		5.93	3319	951	0.39	III	Debris Flow	0.035	10%	35%	26%	28%	0.30	Very High	Very High	10%	High	Very High	>10,000
154		0.98	1980	813	0.82	IV	Debris Flow	0.035	0%	43%	43%	13%	0.28	Low	High	13%	High	High	1,000-10,000
155		0.51	1202	675	0.94	IV	Debris Flow	0.035	0%	19%	49%	32%	0.18	Very Low	Moderate	6%	High	High	1,000-10,000
156		0.90	1883	926	0.98	IV	Debris Flow	0.035	51%	29%	6%	14%	0.58	Very High	Very High	44%	Very High	Very High	1,000-10,000
157		0.42	1490	1008	1.55	IV	Debris Flow	0.035	10%	22%	23%	45%	0.22	Low	High	13%	High	High	1,000-10,000
158	Teit Creek	14.04	6700	1155	0.31	III	Debris Flood	0.035	45%	38%	15%	2%	0.59	Very High	Very High	25%	High	Very High	N/A
159	East Murray Creek	29.16	10888	1092	0.20	II	Debris Flood	0.035	19%	24%	13%	44%	0.29	Very High	High	5%	High	High	N/A
160	Murray Creek (above East Murray Creek)	73.98	16700	1291	0.15	II	Debris Flood	0.035	10%	12%	7%	71%	0.16*	Very High	High	5%	High	High	N/A
161	Twaal Creek	96.24	19700	1689	0.17	II	Debris Flood	0.045	49%	27%	9%	15%	0.52	Very High	High	13%	High	High	N/A
162	Venables Creek	41.70	13070	1295	0.20	II	Flood	0.045	49%	24%	13%	14%	0.48	Very High	High	11%	High	High	N/A
163	Murray Creek (all)	148.25	21700	1805	0.15	II	Debris Flood	0.035	16%	22%	13%	49%	0.28*	Very High	High	7%	High	High	N/A
164	Murray Creek (above Teit Creek)	128.30	20700	1683	0.15	II	Debris Flood	0.035	14%	20%	12%	54%	0.17*	Very High	High	6%	High	High	N/A

APPENDIX D

PHOTOS



D-1 SELECT FIELD PHOTOS



Photo D-1 Aerial overview photo looking west at Watershed ID 38 and Blue Earth Farms (parcel ID 014598388). Photo taken by BGC on November 18, 2024.



Photo D-2 Historical debris flow or debris flood deposits at mid fan at Blue Earth Farm. Photo taken by BGC on November 17, 2024.



Photo D-3 Aerial overview photo looking northwest towards 4721 Minnabariet Rd block (parcel ID 003594793). Photo taken by BGC on November 18, 2024.



Photo D-4 Aerial overview photo looking west at 4721 Minnabariet Rd. Photo taken by BGC on November 18, 2024.



Photo D-5 Aerial overview photo looking south towards 4788 Minnabariet Rd. Photo taken by BGC on November 18, 2024.



Photo D-6 Aerial photo looking west at Watershed 9 above 4665 Minnabariet Rd. Photo taken by BGC on November 18, 2024.



Photo D-7 Photo of the hillslope near Watershed 9 and above 4665 Minnabariet Rd. Rill and gully erosion are visible on the hillslope. Photo taken by BGC on November 18, 2024.



Photo D-8 Aerial overview photo of 4665 Minnabariet Rd taken by BGC on November 18, 2024.



Photo D-9 Aerial overview photo looking northwest at 4757 Govardan Hill Terr, 4789 Govardan Hill Terr, and 4501 Minnabariet Rd. Photo taken by BGC on November 17, 2024.



Photo D-10 Aerial overview photo looking west towards 4745 Govardan Hill Terr, and elements at risk A5 (no address), and A9 (no address). Photo taken by BGC on November 17, 2024.



Photo D-11 Aerial overview photo looking north towards 4653 Rathayatra Way and 4665 Rathayatra Way. Photo taken by BGC on November 17, 2024.



Photo D-12 Aerial overview photo looking northeast towards elements around the 4600 Rathayatra Way block. Photo taken by BGC on November 17, 2024.



Photo D-13 Aerial overview photo looking north at 4581 Rathayatra Way and 4561 Rathayatra Way. Photo taken by BGC on November 18, 2024.



Photo D-14 Historical debris flow deposits at fan apex on hazard 904 above 4500 block of Rathayatra Way. Photo taken by BGC on November 17, 2024.



Photo D-15 Aerial overview photo looking south towards the 4500 and 4600 blocks of Rathayatra Way. Photo taken by BGC on November 17, 2024.



Photo D-16 Aerial photo looking west towards the watershed above Fan 2036 and Fan 2037. Note 4544 Talavan Cres is visible on the right. Photo taken by BGC on November 18, 2024.



**Photo D-17 Aerial overview photo looking northeast towards the 4400 Rathayatra Way block.
Photo taken by BGC on November 17, 2024.**



Photo D-18 Aerial overview photo looking east at the 4400 Rathayatra Way and 3300 Jaganatha Trail blocks. Photo taken by BGC on November 17, 2024.



Photo D-19 Aerial overview photo looking southeast towards 4544 Talavan Cres and 4469 Rathayatra Way. Photo taken by BGC on November 17, 2024.



Photo D-20 Aerial overview photo looking north towards 4433 Bahki Blvd. Photo taken by BGC on November 17, 2024.



Photo D-21 Aerial overview photo looking west at 4277 Talavan Cres. Photo taken by BGC on November 18, 2024.



Photo D-22 Deposits of historical debris flow or debris flood within 10 m of home at 4277 Talavan Cres. Photo taken by BGC on November 17, 2024.



Photo D-23 Aerial overview photo looking east towards 4277 Talavan Cres and 4286 Rathayatra Way. Photo taken by BGC on November 18, 2024.



Photo D-24 Aerial overview photo looking west at 4180 Prabhupad PI (center-bottom) and towards 4277 Talavan Cres (center-left). Photo taken by BGC on November 17, 2024.



Photo D-25 Aerial overview photo looking west at 4000 Prabhupad PI block (4089 Prabhupad PI center-left). Photo taken by BGC on November 17, 2024.



Photo D-26 Aerial overview photo looking south at Bhumi Farm showing the debris slide hazard (far right-side slope) and the alluvial fan (center). Photo taken by BGC on November 18, 2024.



Photo D-27 Aerial overview photo looking west at Bhumi Farm note the cabin A2 on the left in proximity to both debris slide and debris flow hazards. Photo taken by BGC on November 18, 2024.



Photo D-28 Historical debris flow or debris flood channel near fan apex at Bhumi Farm. Photo taken by BGC on November 16, 2024.



Photo D-29 Aerial overview photo of 5028 Venables Valley Rd (center) and element A6 (right). Note the evidence of overland flow left of 5028 Venables Valley Rd and between 5028 Venables Valley Rd and element A6. Photo taken by BGC on November 18, 2024.



Photo D-30 Aerial overview photo looking north at the Hilltop Farms campground near the fan apex. Note the campground has historically flooding during the freshet. Photo taken by BGC on November 19, 2024.



Photo D-31 Looking downstream (south) along Twaal Creek at the Hilltop Farms Campground. Note the low channel confinement. Photo taken by BGC on November 19, 2024.



Photo D-32 Aerial overview photo of PD45750 water intake structure along Twaal Creek (center-top). Photo taken by BGC on November 18, 2024.



Photo D-33 Aerial overview photo looking west at the Yellow Cabin area in Nicoelton No 6. Note the channel has been re-routed to be parallel and south of the road within the last 10 years. Photo taken by BGC on November 18, 2024.



Photo D-34 Aerial overview photo looking north at a rockfall source area above Twaal Creek Rd and east of the Yellow Cabin. Photo taken by BGC on November 18, 2024.



Photo D-35 Looking north along Twaal Creek Rd and landslide at the road. Photo taken by BGC on November 18, 2024.



Photo D-36 Aerial overview photo of Murray Creek Falls where PD45760, PD45761, and PD45762 are located. Photo taken by BGC on November 19, 2024.



Photo D-37 Aerial photo looking west at the Murray Creek FSR. Note the colluvial slopes on both sides of the road and the road entering an area higher valley confinement.



Photo D-38 Aerial-oblique photo of Murray Creek Rd and one of the three bridge crossings. Note the high relief and high sediment supply above the road.

APPENDIX E

GEOHAZARD INFOGRAPHICS



DEBRIS FLOWS

A fast, flowing landslide comprised of mud, rocks, trees, and water

Debris flows are triggered by heavy bursts of rain or rain-on-snow events



Debris flows are more likely to occur after periods of prolonged rain or snowmelt, or in years following forest fires

Houses at the base of steep slopes with mountain creeks are at greatest risk



Debris flows begin in mountain creeks and grow in size as they travel down slope, usually in surges (pulses)

Debris can bury or destroy houses



Debris can flow faster than the fastest human can run

Debris can suddenly jump out of the channel

Debris can impact houses far from the channel



Debris can sweep away or crush cars



PROTECT YOURSELF FROM

DEBRIS FLOWS

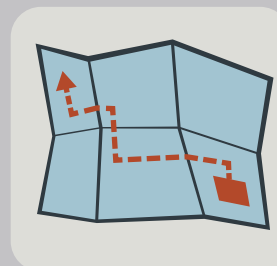
BEFORE

Stay informed



Keep updated with weather advisories, such as heavy rainfall warnings. Consult your local hazard map to learn where the slope hazard zones are located.

Prepare and plan



Prepare an emergency kit for your home, vehicle, and workplace. Plan a safe evacuation route and muster point. Know which rooms are safest if you have to shelter in place.

Know the signs



Look/listen for an abrupt increase or decrease in water flow, unusually muddy water, shaking ground, and a loud roar (sounds like a train or helicopter).

Safe home design



Put high occupancy rooms like bedrooms on the top floor and on the downhill side (away from slopes).

DURING

DECISION: evacuate



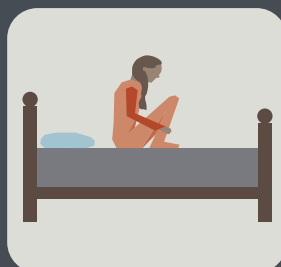
If you believe your life to be in imminent danger and you see a clear path to safety, evacuate. Get away and to higher ground as fast as you can.

DECISION: shelter



If it is unsafe to evacuate, shelter up and away. Climb to the top floor or on the roof. Shelter on the downhill side, away from the slope. Avoid basements.

Climb on top of furniture



Get on top of a bed or counter to avoid being swept away or buried. Do not hide behind or underneath heavy furniture as they can crush or pin you down.

Shelter in a closet



If you cannot escape vertically, small rooms like closets can offer additional protection from collapse if your home is buried.

DO NOT exit out of curiosity



Seek shelter instead of investigating the situation. Only go outside if you have to evacuate.

DO NOT cross flood waters



Moving water as little as 30 cm deep can quickly sweep you away. Do not attempt to drive or walk through water or debris.

AFTER

Assume more will come



Debris flows come in surges (pulses) and can continue for days. Subsequent pulses may be more severe than the previous.

Make noise if buried



Shout or tap on something so search and rescue can locate you faster.

If safe, help neighbours



Help evacuate your neighbours when it's safe to do so, and offer assistance to search and rescue personnel.

Obey closures



Evacuation orders and road closures must be taken seriously. Only return when local authorities declare it safe to do so.

NOTES

BGC Engineering Inc. (BGC) prepared this infographic with artwork by Sophia Zubrycky. This infographic depicts some measures that may help to lower but not eliminate certain kinds of risk associated with debris flows. Simply following the measures shown in this infographic does not make it safe to occupy areas at risk of debris flows. Even if the measures shown in this infographic are taken, debris flows may still cause serious personal injury (including death) or property damage. BGC provides no guarantee or warranty of any kind related to the information in this infographic. Persons and entities using or relying on this infographic do so at their own risk. BGC will not be responsible or liable for any loss or damage including any personal injury, death, or property damage that any person or entity may suffer or sustain as a result of the information in this document, or any use of or reliance on this document.

Information on life loss risk reduction in case of debris flow impact is informed by Pollock, W., and Wartman, J. (2020) Human Vulnerability to Landslides. GeoHealth, 4, e2020GH000287. <https://doi.org/10.1029/2020GH000287>.

Photo references:

[Top right] Wildfire. Photo: Shutterstock.

[Middle left] Debris flow at Cataline Creek, BC. Photo: BGC.

[Middle right] Debris flow at Wilcox Creek, BC. Photo: BGC.

[Bottom left] Debris flow in the Austrian Alps. Photo: Shutterstock.

[Bottom right] Car swept away by debris on the Coquihalla Highway, Hope, BC. Photo: THE CANADIAN PRESS/Jonathan Hayward.

DEBRIS FLOODS

Floods that move large amounts of soil, rocks, and trees

Debris floods can be triggered by heavy rain, rain-on-snow events, and upstream hazards (debris flows, dam breaches)

Debris floods are more likely to occur after periods of prolonged rain or snowmelt, or in years following forest fires

Houses near mountain creeks are at greatest risk

Debris floods can occur over a long period of time (days) and can have several surges (pulses)



Debris floods can burst their banks and flood houses far from the channel

Debris floods can erode banks and undermine building foundations



Debris floods can sweep away or bury cars



Debris floods can destroy roads and bridges

PROTECT YOURSELF FROM DEBRIS FLOODS

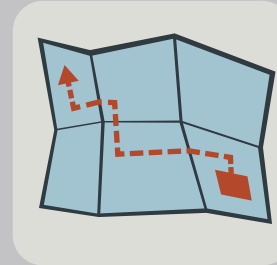
BEFORE

Stay informed



Keep updated with weather advisories, such as heavy rainfall warnings. Consult your local hazard map to learn where the flood hazard zones are located.

Prepare and plan



Prepare an emergency kit for your home, vehicle, and workplace. Know your local flood evacuation routes and emergency shelter locations.

Know the signs



Look/listen for an abrupt increase or decrease in water flow, unusually muddy water, and the sound of cracking trees and rolling boulders.

Protect your property



Store valuables in high places or water-tight containers. Consider flood-proofing measures, such as elevating the first floor, flood walls, erosion protection, sump pumps, etc.

DURING

DECISION: Evacuate



If it is safe to do so, take the flood evacuation route or go to higher ground. If you are able, shut off your gas/electricity and help others evacuate.

DECISION: Shelter



If you are unable or it is unsafe to evacuate, seek shelter on high ground. Avoid basements.

Build sandbag dikes



Sandbag dikes can prevent or lessen damage from overland flooding. Do not attempt to build if you are required to evacuate.

DO NOT go near the bank



Debris floods can quickly erode and undermine banks. If you are near the bank, you put yourself at risk of falling in and being swept away.

DO NOT cross bridges



Debris floods can erode bridge piers and cause bridges to collapse. Bridges affected by debris flooding must be avoided.

DO NOT cross flood waters



Moving water as little as 30 cm deep can quickly sweep you away. Do not attempt to drive or walk through water or debris.

AFTER

Obey road closures



Do not enter areas that are closed-off. There may be emergency repair efforts underway or flooded areas unsafe to the public.

Return only when safe



Do not return home until authorities say it is safe and they have cleared your home of structural, electrical, or other hazards.

Help each other



Floods are stressful and traumatic events. Offer and accept help if you are able. Communities are more resilient when they work together.

Clean up



If your home was flooded, dispose of mouldy items, open doors and windows, and scrub all washable surfaces with a household bleach solution.

NOTES

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Information on flood preparedness is from PreparedBC's Flood Preparedness Guide.

Photo references:

[Top right] Wildfire. Photo: Shutterstock.

[Top left] Debris flood in Canmore, AB. Photo: THE CANADIAN PRESS/Jonathan Hayward.

[Middle right] Flood damaged homes along Cougar Creek in Canmore, AB. Photo: THE CANADIAN PRESS/Jeff McIntosh.

[Bottom left] Car swept away by debris on the Coquihalla Highway, Hope, BC. Photo: THE CANADIAN PRESS/Jonathan Hayward.

[Bottom right] Bridge damages from debris flood on Hwy. 1, Lytton, BC. Photo: TranBC.

LANDSLIDES

Movements of earth, rocks, trees, and debris down a slope

Landslides can be triggered by rain, snowmelt, or earthquakes

Landslides can be triggered by human-made land changes, such as roads, fill placement, or excavations

Landslides can occur with little warning

Landslides are more likely to occur after periods of prolonged rain and snowmelt, or in years following forest fires

Landslides can bury or destroy houses

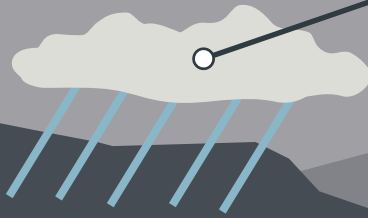
Houses on or near hillsides are at greatest risk

Landslides can reach speeds faster than cars

Landslides can sweep away or crush cars



Landslides can impact areas far from their source



PROTECT YOURSELF FROM

LAND- SLIDES

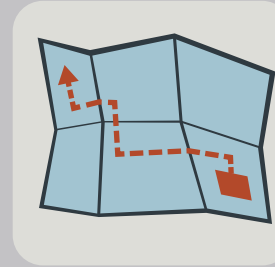
BEFORE

Stay informed



Keep updated with evacuation alerts, road closures, and weather advisories, such as heavy rainfall warnings.

Prepare and plan



Prepare an emergency kit for your home, vehicle, and workplace. Plan a safe evacuation route and muster point. Know which rooms are safest if you have to shelter in place.

Know the signs



Look/listen for fallen debris, moving and cracking trees, shaking ground, and a loud roar (sounds like a train or helicopter).

Safe home design



Put high occupancy rooms like bedrooms on the top floor and on the downhill side (away from slopes).

DURING

DECISION: evacuate



If you believe your life to be in imminent danger and you see a clear path to safety, evacuate. Get away and to higher ground as fast as you can.

DECISION: shelter



If it is unsafe to evacuate, shelter up and away. Climb to the top floor or on the roof. Shelter on the downhill side, away from the slope. Avoid basements.

Shelter in a closet



If you cannot escape vertically, small rooms like closets can offer additional protection from collapse if your home is buried.

Shelter in your vehicle



If you cannot drive away safely, shelter in your vehicle. Your vehicle may provide some protection from a landslide impact.

DO NOT exit out of curiosity



Seek shelter instead of investigating the situation. Only go outside if you have to evacuate.

DO NOT cross debris



Crossing fallen debris is very dangerous since more debris could come down. Take a route away from the slope and debris.

AFTER

Assume more will come



Debris may continue to slide since the slopes are unstable. Subsequent landslides may be more severe than the previous.

Make noise if buried



Shout or tap on something so search and rescue can locate you faster.

If safe, help neighbours



Help evacuate your neighbours when it's safe to do so, and offer assistance to search and rescue personnel.

Obey closures



Evacuation orders and road closures must be taken seriously. Only return when local authorities declare it safe to do so.

NOTES

BGC Engineering Inc. (BGC) prepared this infographic with artwork by Sophia Zubrycky. This infographic depicts some measures that may help to lower but not eliminate certain kinds of risk associated with landslides. Simply following the measures shown in this infographic does not make it safe to occupy areas at risk of landslides. Even if the measures shown in this infographic are taken, landslides may still cause serious personal injury (including death) or property damage. BGC provides no guarantee or warranty of any kind related to the information in this infographic. Persons and entities using or relying on this infographic do so at their own risk. BGC will not be responsible or liable for any loss or damage including any personal injury, death, or property damage that any person or entity may suffer or sustain as a result of the information in this document, or any use of or reliance on this document.

Information on life loss risk reduction in case of landslide impact is informed by Pollock, W., and Wartman, J. (2020) Human Vulnerability to Landslides. GeoHealth, 4, e2020GH000287. <https://doi.org/10.1029/2020GH000287>.

Photo references:
[Top right] Wildfire. Photo: Shutterstock.
[Middle right] House buried by Johnsons Landing landslide, BC. Photo: CBC. Available from: <https://www.cbc.ca/news/canada/british-columbia/johnsons-landing-evacuation-order-lifted-2-years-after-fatal-landslide-1.2723388>
[Bottom left] Landsliding in Petropolis, Brazil. Photo: AP Photo/Silvia Izquierdo.
[Bottom right] Car swept away by debris on the Coquihalla Highway, Hope, BC. Photo: THE CANADIAN PRESS/Jonathan Hayward.

ROCKFALLS & ROCKSLIDES

Pieces of rock falling, bouncing, or rolling down a slope

Large masses of rock detaching, sliding, and breaking apart down a slope



Rocks can easily break through walls and roofs



Rockslides can easily destroy roads, railways, and buildings

Smaller rockfalls often precede larger rockfalls and rockslides

Rocks can reach speeds faster than cars



Rocks can be larger than a truck



Rocks can bounce and roll long distances

Events occur mostly during heavy rain, freeze/thaw cycles, or earthquakes

Houses at the base of steep slopes are at greatest risk

Boulders might be evidence of past rock-falls and rockslides



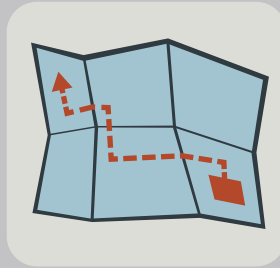
BEFORE

Stay informed



Keep updated with weather advisories, such as heavy rainfall warnings and repeated cycles of freeze/thaw.

Prepare and plan



Prepare an emergency kit for your home, vehicle, and workplace. Plan a safe evacuation route and muster point. Know which rooms are safest if you have to shelter in place.

Know the signs



Look/listen for loud cracking, clouds of dust, and shaking ground (like an earthquake). Smaller rockfalls often come before larger ones.

Know the hazard zones



Consult your local hazard map to learn where the slope hazard zones are located.

Limit exposure



Limit time spent in the slope hazard zones. Do not park beneath steep slopes or rock cuts.

Safe home design



Put high occupancy rooms like bedrooms on the top floor and on the downhill side (away from slopes).

DURING

DECISION: evacuate



If you believe your life to be in imminent danger and you see a clear path to safety, evacuate. Get away from the slope as fast as you can.

DECISION: shelter



If it is unsafe to evacuate, shelter in a room on the downhill side of your house, preferably on the top floor.

DO NOT cross rock path



Crossing fallen debris is very dangerous since more rocks will likely fall here. Take a route away from the slope and debris.

DO NOT stay to watch



Rocks can bounce irregularly and roll long distances. Get away from the slope instead of watching or filming them.

PROTECT YOURSELF FROM

ROCKFALLS & ROCKSLIDES

AFTER

Assume more will fall



Rocks may continue to come down because the slope is unstable.

Notify authorities



Report any rockfalls and rockslides (big or small) to local authorities.

If safe, help neighbours



Help evacuate your neighbours when it's safe to do so, and offer assistance to search and rescue personnel.

Obey closures



Evacuation orders and road closures must be taken seriously. Only return when local authorities declare it safe to do so.

NOTES

BGC Engineering Inc. (BGC) prepared this infographic with artwork by Sophia Zubrycky. This infographic depicts some measures that may help to lower but not eliminate certain kinds of risk associated with rockfalls and rockslides. Simply following the measures shown in this infographic does not make it safe to occupy areas at risk of rockfalls and rockslides. Even if the measures shown in this infographic are taken, rockfalls and rockslides may still cause serious personal injury (including death) or property damage. BGC provides no guarantee or warranty of any kind related to the information in this infographic. Persons and entities using or relying on this infographic do so at their own risk. BGC will not be responsible or liable for any loss or damage including any personal injury, death, or property damage that any person or entity may suffer or sustain as a result of the information in this document, or any use of or reliance on this document.

Photo references:
 [Top left] Rockfall damage from Christchurch, New Zealand earthquake. Photo: Julian Thomson.
 [Top right] Rockslide blocking Sea-to-Sky highway near Porteau Cove, BC. Photo: THE CANADIAN PRESS/Jonathan Hayward.
 [Bottom left] Site of rockfall tragedy in Rockville, Utah. Photo: Daily Mail U.K. Available from: <https://www.dailymail.co.uk/news/article-2523067/Boulder-size-elephant-crushes-entire-house-instantly-kills-inhabitants-Utah-landslide.html>
 [Bottom right] Semi-truck smashed by boulder east of Spences Bridge, BC. Photo: Matt Ruscheinski. Available from: <https://www.cbc.ca/news/canada/british-columbia/trans-cana-da-highway-rock-slide-semi-boulder-1.4502567>