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BC Ministry of Forests

POST-WILDFIRE NATURAL HAZARDS RISK ANALYSIS PONDEROSA FSR FIRE (N51069)

December 18, 2024

Report Number: 24.510.01.03.01.04
Distribution:
MoF – 1 copy
SNT Geotechnical Ltd. – 1 copy

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1. Introduction and Objectives

The Ponderosa FSR wildfire (N51069) was discovered on July 18, 2024 and burned 1,859 hectares on the east side of the Slocan River between Lemon Creek and the village of Slocan in southeastern B.C. (Figure 1). The Ponderosa FSR Fire (the Fire) started near the Ponderosa Forest Service Road (FSR) and burned south to Lemon Creek and north to southern edge of the Springer Creek valley (Photos 1 and 2). The west side of the Fire was contained with a fire guard along the mid-slope and the east side of the Fire had a modified (limited) response as it was burning away from inhabited areas.

The Fire includes or is adjacent to several populated areas along the east side of Slocan River above the village of Slocan and was considered by the Ministry of Forests (MoF) to be a high priority for a Post-Wildfire Natural Hazards Risk Analysis (PWNHRA). SNT Geotechnical Ltd. (SNTG) was retained by BC Wildfire Service (BCWS) to complete this work. The Fire is entirely within the Regional District of Central Kootenay (RDCK).

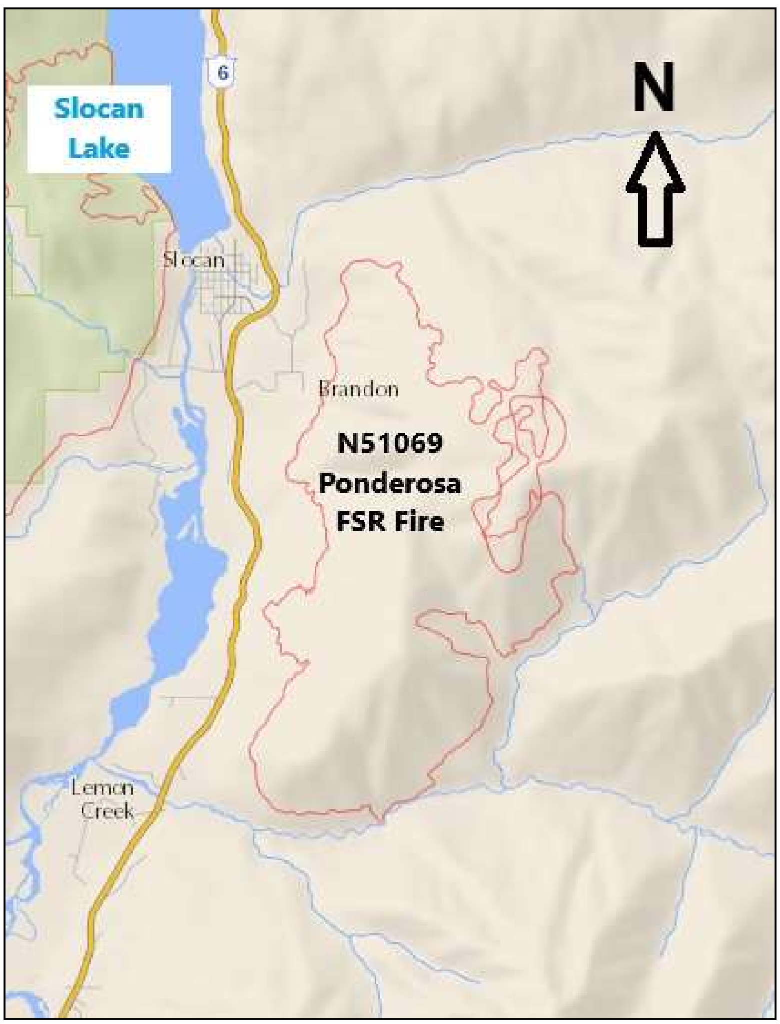

Figure 1: Location of the Fire (outlined in red) above the village of Slocan. The Fire overlaps a small fire (N51229) along the eastern edge.

Photo 1: Sentinel-2 L2A Satellite imagery from August 1; the Fire is burning south of O'Shea Creek and has spotted to the ridge top. Smoke from the Mulvey Creek Fire (N51117) can be seen west of Slocan.

Photo 2: Sentinel-2 L2A Satellite imagery from August 31; the Fire appears to have reached its full extent and is out.

1.1. Reconnaissance Assessment

A Reconnaissance PWNHRA (Level 2) was completed by the MoF (Crookshanks, 2024[1]; attached in Appendix B). This analysis included a review of the preliminary burn severity map and a summary of post-wildfire natural hazards and risks (floods, debris flows or rockfall) to residences and roads (primarily Highway 6 (the Highway), Austyn, Martens and Springer Roads). A comprehensive assessment of the domestic water systems within or affected by the fire was not completed. Table 1 summarizes the MoF assessment which determined the following preliminary partial risks to possible elements at risk within and adjacent to the wildfire.

Table 1: Summary of the MoF Reconnaissance PWNHRA report.

Location	Hazard	Partial Risk	Elements at Risk
Ringrose Creek	Debris flow or flood	Moderate	Private residences
Ringrose Creek	Debris flow or flood	High	Highway 6
O'Shea Creek	Debris flow or flood	Low	Private residences or Highway 6
Erhard (Popoff) Creek[2]	Debris flow or flood	Low	Private residences or Highway 6
Shook Creek	Debris flow or flood	Low	Private residences or Highway 6
Grant Creek	Debris flow or flood	Low	Private residences or Highway 6
Vincent Creek	Debris flow or flood	Low	Private residences or Highway 6

[1] Crookshanks, S. 2024. *Ponderosa FSR – Level 2 Reconnaissance Report*. Prepared for the Ministry of Forests. Dated September 11, 2024.

[2] Erhard Creek was a name provided to SNTG by MoF and refers to the watershed within the Fire; Popoff Creek appears in the water well records and seems to be a downslope extension of the creek across the lower bench. For the purposes of this report, Popoff Creek is considered to be the same as Erhard Creek.

1.2. Detailed Assessment

The scope of the Detailed PWNHRA (Level 3), as defined by the MoF, is to:

- Identify any elements at risk from potential post-wildfire hazards. These are defined as:
  - residences or occupied buildings on private property or occupied public or private buildings;
  - public highways and arterial roads, public infrastructure, utilities, and industrial infrastructure (i.e., railways, pipelines, tele-communication infrastructure and industrial access roads);
  - registered active points-of-diversion for domestic, irrigation, and community water supplies, including reservoirs and related infrastructure;
  - recreational sites as determined by MoF or local authorities; and
  - discrete cultural sites as designated by MoF specialists.
- Identify potential post-wildfire natural slope hazards which might affect the elements at risk. These hazards include landslides, debris avalanches, rockfall, debris flows, debris floods, clearwater flooding or water quality effects;
- Conduct a partial risk analysis for each hazard and for each individual element at risk; this will include the background (i.e., pre-wildfire) likelihood of that specific hazard and the incremental increase in hazard likelihood due to the wildfire[3]. Clearly indicate hazard or likelihood of occurrence of a specific natural hazard (i.e., P(H)), spatial probability or likelihood of a spatial effect if a specific hazardous event occurs (i.e., P(S:H)), and the resulting partial risk (i.e., P(HA)) for each hazard and element at risk; and
- Provide conceptual risk mitigation options or strategies for elements at risk with partial risk ratings moderate or higher.

We understand that the intended use of the detailed risk analysis is to communicate the general post-wildfire risk to potential stakeholders so that they can undertake specific risk assessments to mitigate the risk, if deemed unacceptable to them.

The detailed risk analysis was completed in general conformance with the guidance provided in:

- Land Management Handbook 56 (LMH56) – *Landslide risk case studies in forestry development planning and operations* (2004), BC Ministry of Forests[4]
- Land Management Handbook 69 (LMH69) – *Post-wildfire Natural Hazards Risk Analysis in British Columbia* (2015), BC Ministry of Forests, Lands, and Natural Resource Operations[5], and
- Risk Analyses Tables A1, A2 and A3 provided by MoF (shown as Tables 2 through 4 in Section 3.5).

[3] The pre-wildfire likelihood of specific hazards and the incremental increase in the hazard likelihood due to the wildfire is not included as this would require extensive review and investigation which is simply not possible due to the urgency and short timelines of the project.
[4] Wise, M.P., G.D. Moore, and D.F. VanDine (editors). 2004. *Landslide risk case studies in forest development planning and operations*. B.C. Ministry of Forests, Land Management Handbook 56. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/LMH56.htm.
[5] Hope, G., P. Jordan, R. Winkler, T. Giles, M. Curran, K. Soneff, and B. Chapman. 2015. *Post-wildfire natural hazards risk analysis in British Columbia*. B.C. Ministry of Forests, Lands and Natural Resource Operations, Land Management Handbook 69. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/LMH69.htm

- Table A1. Qualitative descriptions of post-wildfire hazard likelihood, hazard criteria, and related quantitative probabilities,
- Table A2. Qualitative descriptions of the likelihood of spatial interaction and related quantitative probabilities, and
- Table A3. Matrix of post-wildfire natural hazard partial risk.

2. Potential Hazards as a Result of the Fire

2.1. Ground Effects

Wildfires can impact the initiation of potential slope hazards in several ways. Depending on the burn severity, wildfire-induced water repellency (i.e., hydrophobicity), which can reduce infiltration rates, may develop within the upper soil layers. This, combined with the loss of vegetative ground cover, results in a significant increase in the potential for runoff to develop during rainfall events, thereby creating a much faster hydrologic response (i.e., a "flashier" runoff regime). The loss of tree canopy also leads to increases in snow accumulation and snowmelt rates, especially during sunny day (radiant) snowmelt events. The effect of these conditions typically lessens as the vegetative ground cover re-establishes and the water repellency breaks down, returning to the pre-wildfire levels; this generally occurs within 2 to 5 years following a wildfire.

Water repellency is often observed in areas of moderate and high soil burn severity, and although not a necessary condition, water repellency makes it more likely that overland flow will be generated during high-intensity summer or early fall rains (generally following dry spells when water repellency is greatest). High soil burn severity also causes reduced infiltration capacity, even without water repellency, and therefore can increase susceptibility to overland flows even in areas where water repellency was not observed. In areas of moderate vegetation burn severity, needle fall from the dead trees can create an effective mulch, which tends to slow down surface runoff and promote infiltration. The partial or total loss of forest litter and duff layer in moderate and high soil burn severity areas results in a reduction in water storage capacity and increased surface run-off flow velocity.

Soil erosion can be a significant process in high soil burn severity areas due to exposed bare soil and lack of protective litter and duff layers. Increased sediment load during flood events can contribute to flood damage, by blocking culverts and ditches. It can also contribute to the likelihood of debris flows in steep watersheds. Erosion from burned areas may result in adverse impacts to water quality in the creeks affected by the fire. In addition, peak flow in some extensively burned watersheds could result in additional sediment entrainment from bank erosion or through tributary debris deposition. In the first few rainstorms and snowmelt events after the fire, ash and soot can be washed downstream and enter water intakes. In addition to ash and sediment entrainment there have been documented increases of other types of water contamination including an increase in heavy metal concentrations post-wildfire (Silins et al., 2016[6], Bladon et al., 2014[7])

[6] Silins, U., Anderson, A., Bladon, K., Emelko, M., Stone, M., Spencer, S., Williams, C., Wagner, M., Martens, A. and Hawthorn, K. 2016. *Southern Rockies Watershed Project*. The Forestry Chronicle, v92-1.
[7] Bladon, K., Emelko, M., Silins, U. and Stone, M. 2014. *Wildfire and the Future of Water Supply.* Environ. Sci. Technol. 2014, 48, 8936−8943.

Snow avalanche hazard is increased for 15-20 years post-wildfire (Germain et al., 2005[8]). The hazard is increased due to a combination of the reduced number of trees anchoring the snow mass to the slope and increased accumulation of snow due to the loss of snow interception provided by living timber (LMH69). In addition, blackened trees tend to absorb an increased amount of solar radiation during the spring, heating the snowpack adjacent to the trunk and creating weak points within the snowpack which can also lead to increased snow avalanche frequency. Increased magnitude and/or frequency of snow avalanche events may transport an increased amount of debris (primarily trees or woody debris) to streams.

2.2. Natural Hazards

On slopes burned to a moderate and/or high severity, there is often substantial ash, sediment and woody debris available to be mobilized by runoff generated from short-duration/high-intensity rainfall. When these are mobilized by runoff, the flow becomes "bulked up" (i.e., more viscous) and erosional scour can occur on the open slope surface or within gullies or draws. When this occurs on face unit slopes, the resulting hazard is generally referred to as a sediment-laden flow. When the "bulked up" runoff becomes channelized in gullies and draws, debris flows, debris floods or floods can be triggered. These events can travel farther than sediment-laden flows, extending across fan surfaces at the outlets of watersheds. Research[9] suggests that once these events have been triggered from slopes burned by a wildfire, the likelihood of them occurring a second time from the same slopes is significantly reduced.

These post-wildfire debris flows, debris floods, sediment-laden flows and floods (collectively referred to as hydrogeomorphic processes) which can occur as a result of high-intensity rainfall on severely burned and/or water-repellent soils, are typically triggered in mid to late summer within the first two years following a wildfire (Cannon and Gartner 2005)[10]. Examples in B.C. include the 2004 Kuskonook Creek and Jansen Creek debris flows near Creston, debris floods and flows following the 2017 Elephant Hill Fire (91 events, one causing a fatality on Highway 99) and debris floods in Kelowna and near Falkland, which followed the 2003 wildfires. Cannon and Gartner (2005) note that the rainfall conditions required to trigger a post-wildfire debris flow can be at least an order of magnitude smaller than those required for debris flow generation in an unburned setting.

Debris flows and floods can also occur during spring runoff as a result of rapid snowmelt in burned areas. Examples include several debris flows that followed the 2007 Springer Creek Fire[11] near Slocan (one causing a fatality) and debris flows that followed a 2009 fire at Kelly Lake. They can also occur, although less commonly, during fall (2005 Mt. Ingersoll Fire with 15 channel failures and seven hillslope landslides) or early winter rain-on-snow events. The springtime hazards are due to increased snow accumulation, more rapid snowmelt, and higher groundwater levels in burned areas, and can persist for several years or decades until revegetation occurs.

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[8] Germain, D, Filion, L, Hétu, B. 2005. *Snow avalanche activity after fire and logging disturbances, northern Gaspé Peninsula, Quebec, Canada.* Canadian Journal of Earth Sciences, v42: 2103- 2116

[9] Rengers, F.K., McGuire, L.A., Oakley, N.S., Kean, J.W., Staley, D.M. and Tang, H. 2020. *Landslides after wildfire: initiation, magnitude, and mobility*. Landslides, DOI 10.1007/s10346-020-01506-3

[10] Cannon, S.H. and Gartner, J.E. 2005. *Wildfire-related debris flow from a hazards perspective*. In: Debris-flow Hazards and Related Phenomena. https://doi.org/10.1007/3-540-27129-5_15

[11] Nicol, D, Jordan, P. and Curran, M. 2009. *Assessment of the Middle Van Tuyl Landslide Event of May 2008*. Prepared for the BC Ministry of Forests and Range.

In August 2018, in the area burned by the 2017 Elephant Hill Fire near Cache Creek, there were several unusually intense, short-duration rainstorms which caused severe flooding and erosion in many small, steep creeks (SNTG, 2018[12]). Overland flow and flood damage occurred even in watersheds which drained moderate and low burn severity areas, including grassland. Some flooding also occurred in unburned watersheds, but it was much more extensive and severe in burned areas. These rainstorms were estimated to have a return period of 100 years or more in the most severely affected areas (that is, in any given year, the probability of occurrence is 0.01, based on historical data). Extreme rainstorm events are likely to cause widespread flooding and possibly landslides in all areas, burned or unburned; however, the Cache Creek events illustrate that burned areas are more susceptible to damaging events. In the post-wildfire risk analysis procedure, the hazard ratings are generally assumed to apply to flood or erosion events that may occur as a result of rainfall or snowmelt events that are likely in the two-to-five-year period after a fire. Although the risk analysis focuses on a two-to-five-year time horizon, lingering hazards can extend for decades until forest regeneration occurs.

In the Ponderosa FSR Fire area, potential debris flow, debris flood, sediment-laden flows and flood hazards are possible due to short-duration, high-intensity rainfall events, rain-on-snow events, or rapid snowmelt runoff events. These hazards are described in more detail below:

2.2.1. Debris Flows

Debris flows are very rapid to extremely rapid, surging flow of saturated non-plastic and sometimes organic debris in a steep channel; they commonly have the consistency of wet concrete and are very destructive. Debris flows initiate in the steep headwaters of a drainage and transport material along the channel (Hungr et al., 2014[13]). They can consist of bouldery fronts of up to 70% sediment by volume, followed by lower sediment concentration slurries. Flow velocities of up to 20 m/s can be attained and they may have instantaneous peak discharges up to 50 times greater than floods. Debris flows require a channel gradient in excess of 27% for prolonged transport (Takahashi 1991[14]). Transport continues at lower gradients (under 20%) but tends to lose momentum and begin deposition. Although much less common, long run-out debris flow events have been documented extending considerable distances through fan gradients as low as 6%, particularly when the local surficial material is fine grained[15]. In burned watersheds, the runoff process of progressive sediment bulking (Cannon 2001[16]), where overland flow concentrates rapidly into channels, readily eroding the bed, is common.

2.2.2. Debris Floods

Debris floods are a very rapid, sediment-charged flow of water in a steep channel with abundant fines in suspension and gravels, cobbles and boulders transported as bedload. Debris floods may have

[12] SNTG. 2018. *Post-Wildfire Natural Hazards Risk Analysis, Elephant Hill Fire (K20637, 2017)*. Report prepared for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Dated December 20, 2017.
[13] Hungr, O., Leroueil, S. and Picarelli, L. 2014. *The Varnes classification of landslide types, an update*. Landslides 11: 167-194.
[14] Takahashi, T. 1991. *Debris flow*. Monograph of IAHR, Balkema, Rotterdam: 1–165.
[15] Jordan, P., Nicol, D., and Turner, K. 2011. *Debris flow hazards in the southern interior of British Columbia: the problem of events with unusually long runout.* GeoHazPaper124. Proceedings of the 5th Canadian Conference on Geotechnique and Natural Hazards; Kelowna, May 15 to 17, 2011.
[16] Cannon, S.H. 2001. *Debris-flow generation from recently burned watersheds*. Environmental and Engineering Geoscience 7 (4):321-341.

instantaneous peak discharges up to 5 times that of a clearwater flood (Hungr et al., 2001[17]). Debris floods have increased sediment volumes but continue to be propelled by the tractive forces of water; objects impacted by debris floods are generally buried or surrounded by debris but are often undamaged or only slightly damaged.

2.2.3. Sediment-laden flows

Sediment-laden flows are hydrologic processes that are common on open slopes (also known as face units) following wildfire. They are a smaller-scale runoff process that transports ash, soil and woody debris downslope, but can transition into debris floods or debris flows in channelized settings.

2.2.4. Floods

Floods occur on rivers and lakes when there is inundation due to an excess of clearwater 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 sometimes called “clearwater floods,” such floods still transport sediment.

3. Methods

The methodology adopted for the analysis included the following:

3.1. Review of existing information

Review of available background information, including previous post-wildfire reports, other geological and geotechnical reports, geology and geomorphology maps, biogeoclimatic data and natural disturbance types, aerial photographs and satellite imagery, LiDAR imagery, hydrometric data, local weather patterns, historic wildfire information and burn severity mapping.

3.2. Watershed Morphometrics

Assessing the watershed morphometrics to determine the potential hydrogeomorphic hazards that could be triggered within them. An analysis of the longitudinal profile of the mainstem creeks within the watersheds was also completed to identify reaches that may be prone to initiation, transport and deposition.

3.3. Fieldwork

Fieldwork was completed to:

- compare the preliminary satellite-derived Vegetation Burn Severity (VBS) with on the ground observations of the Soil Burn Severity (SBS) and describe the relationship between the VBS and the SBS observed at plot sites within the fire perimeter;
- observe terrain conditions, sediments or indicators of slope stability and review the runout from historic landslides (i.e., open slope failures, rockfall or talus cones) or channel instability (i.e., evidence of previous debris flows, debris floods or floods);

[17] Hungr, O., Evans, S.G., Bovis, M. and Hutchinson, J.N. 2001. *Review of the classification of landslides of the flow type*. Environmental and Engineering Geoscience 7 (3): 221-238.

- observe the condition of the mainstem channels and riparian zones, including a review of the channel and floodplain characteristics and the extent of the riparian areas that burned;
- review the fluvial or alluvial fans at the base of the slopes to determine their genesis, potential for post-wildfire events and expected runout distances of any such events;
- review the hazard estimates developed from modelling;
- identify and make observations of the elements that could be at risk should an event occur; and
- identify any roads or fireguards that could increase the potential of post-wildfire slope hazards occurring.

A helicopter reconnaissance flight to review the general slope conditions within the fire perimeter and to identify existing landslides within the Fire was completed on August 23, 2024 by Sarah Crookshanks, P.Geo. (MoF), Doug Nicol, P.Eng. (SNTG), Ryan Williams, P.Geo. (SNTG) and Tim Giles, P.Geo. (SNTG).

Fieldwork was completed by Jacqueline Cormier, P.Eng. (SNTG) and Tim Giles between September 24 and September 26, 2024. Upslope fieldwork was focused on the creeks, channels and fans of Ringrose, O'Shea, Erhard, Shook, Grant and Vincent watersheds as these were thought to have the highest risk (the combination of steep slopes with significant burned areas and downslope values). Foot traverses were completed to review low, moderate and high VBS areas and determine the relationship between the VBS and the SBS. Assessment of SBS was completed by examination of the burned surface and shallow excavation to view the soil profile and complete water repellency testing. Field observation sites are plotted on Maps 1 and 2 in Appendix A.

Information on the surficial sediments, slopes, soil drainage characteristics and geomorphological processes was obtained from site observations; no subsurface investigation (i.e., test pits, trenching or drilling) or laboratory testing was completed. Slope gradients were measured using a handheld clinometer, and relevant observations were recorded as waypoints using an iPhone equipped with an in-built GPS, which typically has a horizontal accuracy of ±5 m.

3.4. HEC-RAS Flow Modelling

The 2-dimensional variant of HEC-RAS[18] (v6.2) was used to model flow paths on select watersheds where SNTG identified elements at risk close to the creek channels or where there was possibility of channel avulsion. The channel roughness was estimated to be equivalent to a Manning's n value of 0.07. Debris flow parameters were selected based on the author's experience with modelling of other local channels. The model results appear credible based on field observations. **The results of the flow modelling are preliminary in nature and were intended to confirm the field observations and should not be used for design purposes.**

The model geometry was developed using the LiDAR base data; Vincent and Ringrose Creeks were modelled. Vincent was identified as having residences close to the channel on the fan and field observations suggest that debris flows could reach the upper fan. Ringrose Creek has a steep and confined

[18] HEC-RAS is the US Army Corps of Engineers, Hydrologic Engineering Center, River Analysis System. The software allows 1-dimensional steady flow and 1 and 2-dimensional unsteady flow calculations and sediment transport/mobile bed computations.

draw leading onto a moderately sloped fan with residences on the fan surface and the Highway close to the fan apex.

A representative model output from a creek within the Komonko Creek Fire, located 15 km north of Slocan, is shown in Figure 2. The Aylwin Creek model illustrates the dispersion plume of water and sediment. The debris crosses most of the fan in a well-confined channel and spreads out as the gradient drops near the Highway. At the Highway, the debris overflows in both directions along the road, with the majority of the flow across the Red Mountain Road junction and the southbound pullout further north. Below the road, the flow finds several old channels but would likely return to the main channel relatively quickly. It is noted that debris flow events of greater volumes, or that behave differently than assumed (based on model input parameters), may runout further or into different areas. Similarly, channel blockages due to logs or sedimentary debris during a debris flow event may result in runout to differing portions of the fan than is indicated by the model. Modelling was primarily a check of field observations.

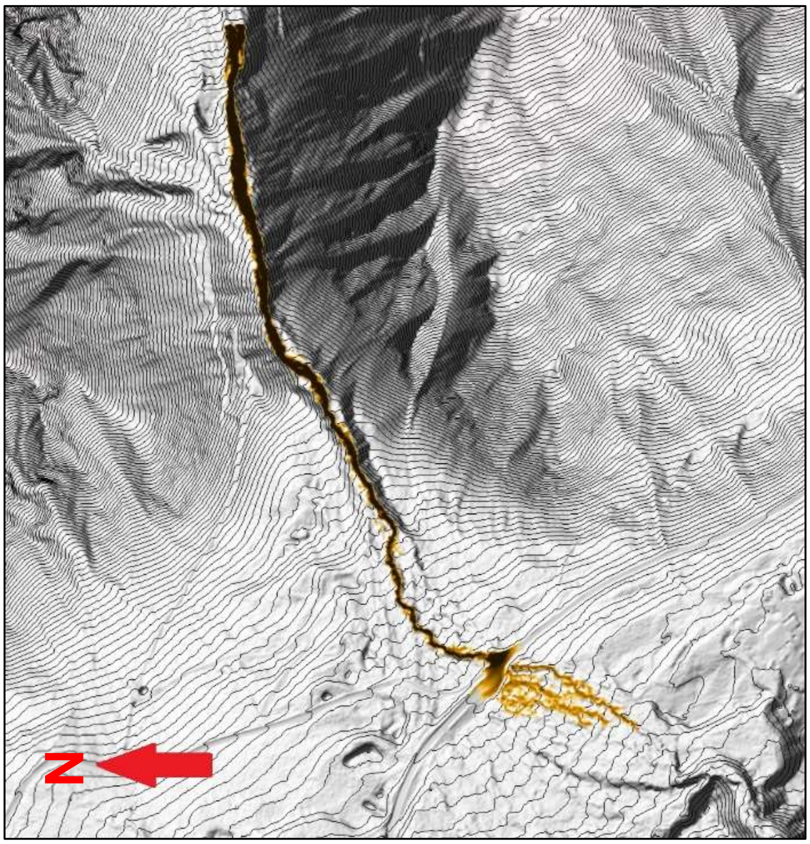

Figure 2: Modelled flows on Aylwin Creek above the Highway. North is to the left of image.

3.5. Analysis and Partial Risk Estimation

Mapping of potential post-wildfire hazards and the analysis of risks followed the general methodology outlined in LMH69. In the simplest terms, risk is the product of hazard and consequence.

Partial risk is defined as the probability (or likelihood) of a specific hazardous event affecting an element at risk and can be expressed as:

$$P(H:A) = P(H) \times P(S:H) \times P(T:S)$$

where:

- P(H:A) is the partial risk.
- P(H) is the likelihood of a hazardous event occurring.
- P(S:H) is the spatial likelihood that the hazardous event will reach the element at risk.
- P(T:S) is the temporal likelihood that the element at risk will be at the site if the hazardous event occurs.

For fixed structures, such as buildings and roads, the temporal probability is numerically 1. The partial risk then reduces to:

$$P(H:A) = P(H) \times P(S:H)$$

Effectively, the partial risk rating is an "encounter probability" and it does not include an assessment of the degree of damage (vulnerability) to the element at risk.

Qualitative ratings, i.e., low, moderate, and high, are used to describe the hazard levels and spatial likelihood levels in this assessment, although the qualitative descriptions can be associated with quantitative ranges as described in Tables 2 and 3. The hazard and spatial likelihood ratings are then combined in a matrix (Table 4) to estimate the partial risk.

Table 2. Qualitative descriptions of post-wildfire hazard likelihood, hazard criteria, and related quantitative probabilities as defined by the Ministry of Forests.

Hazard Likelihood P(H)	Description	Hazard Criteria	Annual Probability Range	Five Year Cumulative Probability
Very High	An event is 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.	>0.2 (> 1:5)	>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.	0.01 - 0.2 (1:100 to 1:5)	5 - 67%
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.	0.002 – 0.01 (1:500 to 1:100)	1 - 5%

Hazard Likelihood P(H)	Description	Hazard Criteria	Annual Probability Range	Five Year Cumulative Probability
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.	0.0004 – 0.002 (1:2,500 to 1:500)	0.2 - 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.	< 0.0004 (< 1:2,500)	<0.2%

Table 3. Qualitative descriptions of the likelihood of spatial interaction and related quantitative probabilities as defined by the Ministry of Forests.

Likelihood of spatial impact	Description	Criteria	Probability Range
High Likelihood	The element at risk will be impacted by the hazard.	▪ The element at risk is within or immediately adjacent to a stream channel, at the apex of a fan, or at the foot of a face unit slope, and there are no natural or artificial barriers preventing the hazardous event from impacting the element.	>0.5
Moderate Likelihood	It is possible that the element at risk will be impacted by the hazard.	▪ The element at risk is located outside the zone of direct impact, but within a zone of potential impact based on the geomorphic processes associated with the specific hazard. ▪ There are no natural or artificial barriers preventing the hazardous event from impacting the element.	0.5 - 0.1
Low Likelihood	It is unlikely that the element at risk will be impacted by the hazard.	▪ The element at risk at the distal end of a runout zone for the specific hazard. Natural or artificial barriers exist that are anticipated to prevent the hazardous event from impacting the element.	< 0.1

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

Hazard Likelihood P(HA) Table 2	Spatial Impact Likelihood P(S:H) (Table 3)		
	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

For the purpose of post-wildfire risk analysis level 3 reports, only partial risk is considered; this is the probability that a hazardous event (e.g., a debris flow) will occur and that it will reach or affect the site of the element at risk (e.g., a house or highway) with consideration to the spatial and temporal probability but not the value or vulnerability of the elements at risk. More detailed specific risk analysis generally involves ground inspections of high value elements exposed to considerable hazards.

The partial risk was considered in an incremental context and not as an absolute risk which would also consider pre-existing natural hazards. For example, an element at risk may have been considered to be at high partial risk pre-fire, but if there is no significant increase in the assessed risk at the location of the element considered, the post wildfire risk would be assessed as low or non-existent.

The background information review, modelling results and field observations were then compiled and analyzed. Based on this analysis, the partial risk was estimated for the identified elements at risk.

3.6. Report

The results of this work were then detailed in this report, addressing the scope and providing conceptual recommendations to reduce the post-wildfire natural hazard risk where appropriate.

4. Background Information

The following information was used in the Analysis:

- Aerial photographs covering the fire in various years were reviewed to understand the recent changes to the landscape and occurrence of landslides in the general area.
- Google Earth ProfessionalTM imagery dated 1985, 2004, 2009, 2011, 2014, 2018, 2020 and 2023 including relevant applications provided by DataBC Public Web Map Service (i.e., TRIM elevation contours and Freshwater Atlas).
- An undated orthoimage from Bing Maps (estimated age 2022) was also reviewed to understand the recent changes to slopes in the general area.
- Hoy, T., Church, B., Legun, A., Glover, K., Gibson, G., Grant, B., Wheeler, J., Dunne, K., Cunningham, J. and Desjardins P. 1994. *The geology of the Kootenay Mineral Assessment Region*, British Columbia Geological Survey Open File 1994-08.
- Bedrock Geology spatial data obtained from the BC Data Catalog. Accessed from: https://catalogue.data.gov.bc.ca/dataset/ef8476ed-b02d-4f5c-b778-0d44c9126144.
- SNT Geotechnical Ltd. and Sitkum Consulting Ltd. 2022. *Post-wildfire Natural Hazards Risk Analysis – Trozzo Fire (N5170).* Prepared for the BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development. Date February 4, 2022.
- LiDAR – data was acquired from the RDCK.
- Historic climate data obtained from the Pacific Climate Impacts Consortium online data portal. Accessed from: https://pacificclimate.org/data.

- Climate analysis using the 1971-2000 dataset from the ClimateBC website. Accessed from: http://www.climatebc.ca/.

4.1. Aerial Photograph Review

Aerial photography covering some or all of the Fire area is available for 15 different years (Table 5). Flight lines from four years were selected to be reviewed to determine the state of the forest, including previous wildfire scars, natural landslide occurrences and the history of land development, including forestry and agricultural development.

The photographs selected were from:

- 1965 and 1966; these are earliest comprehensive images of the entire Fire;
- 1982; these show the early years of development on the upper slopes;
- 1997; these show the early years of development on the upper slopes; and
- 2005; these are most recent photographs with complete coverage of the Fire.

Table 5: Aerial Photographs covering the Fire

Flight Line	Photograph Numbers	Year
BC4315	22-25, 72-75	1965
BC4377	141-144, 194-196	1966
BC5356	86-90	1969
BC5725	137-140	1976
BC77103	238-246	1977
BC78023	25-31	1978
BC80138	15-16, 49-50	1980
BCB82035	22-23, 46-47	1982
BCB90132	191-192, 227-228, 244-245	1990
BCB90142	18-20	1990
BCB95064	162-164	1995
BCB97059	16-19, 109-113, 204-208, 299-301	1997
BCB00030	73-74	2000
BCB00035	15-17	2000
BCC04014	32-33	2004
BCC04042	14-15	2004
BCC05004	76-78, 162-165, 171-173	2005
BCC06135	184-185	2006

The following is a summary of the relevant observations from the aerial photograph imagery.

4.1.1. 1965-1966 Aerial Photographs

Development

In this imagery, the Highway is a gravel road running along the base of the slope. The alignment is in approximately the same location as the present alignment from Lemon Creek to Martens Road. From Martens Road north, the Highway follows what is now identified as the Slocan South Road and continues north along the edge of Slocan Lake instead of rising up on the north side of Springer Creek.

Springer Road and several other trails lead upslope onto the forested slopes and selective harvesting is common across the lower slope face units from O'Shea to Springer Creek. A single trail extends off the Springer Road on the north side of North Vincent Creek and accesses the top of the slope via numerous switchbacks. Several small agricultural holdings are present along the Highway corridor, with one larger development on the south side of the Springer Road.

The fire lookout tower is present at the top of Ringrose Creek and the trail up is likely through Ringrose watershed but is not distinct enough to identify clearly.

Fire Scars and Landslides

There is a large fire from 1930 mapped[19] across the ridgeline from O'Shea Creek south to Lemon Creek but on these images the fire scar is not clearly visible.

Three landslides were observed along the south edge of the Fire. The most westerly landslide occurs in a defined creek (Lemon Gully 1, see Maps 1 and 2 in Appendix A) and appears to be a debris flow which originates on the upper slope and travels all the way down into Lemon Creek. The easterly landslides also start on the upper slope but appear to follow less well-defined creeks and come to rest on the mid-slope; the easternmost landslide occurs in Lemon Gully 2.

The headwaters of O'Shea Creek have numerous open landslide tracks; these appear to be over-steepened gullies which are predominantly infilled with rubbly talus derived from local bedrock.

4.1.2. 1982 Aerial Photographs

Development

The Highway has been upgraded and now follows the present alignment from Lemon Creek to north of Slocan. Private land timber harvesting has continued on the lower slopes across the lower edge of the Fire between Ringrose and Springer Creek. Most of the harvesting is selective with numerous skid trails and there are no clearcuts. On the south edge of the Fire, the Lemon Creek road system provides access to the southeast portion of the Fire. Agricultural development can be seen on both sides of the Highway.

Fire Scars and Landslides

There are no visible fire scars within the Fire perimeter.

No new landslides have occurred naturally or as a result of forest or agricultural development. The older landslides on the south end of the Fire are revegetating. The O'Shea landslides appear somewhat active with fresh landslide deposits occurring within the existing landslide tracks.

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[19] iMapBC, https://maps.gov.bc.ca/ess/hm/imap4m/

4.1.3. 1990 Aerial Photographs

Development

The Ponderosa FSR has been constructed and accesses timber on the south end of the Fire. The trail to the fire tower is now clearly visible rising up through the Ringrose Creek watershed. On the north end of the Fire, the Springer Road has reached the gentler plateau surface west of Dayton Creek and several clearcuts have been harvested on the plateau leading south into the Cameronian Creek watershed. The Lemon Creek road system accesses the south end of the Fire but is limited to the lower slopes along Chapleau Creek. Agricultural development is infilling along the base of the slope.

Fire Scars and Landslides

There are no visible fire scars within the Fire perimeter.

No new landslides have occurred naturally or as a result of forest or agricultural development. The O'Shea watershed shows continued landslide activity within the existing landslide tracks.

4.1.4. 2005 Aerial Photographs

Development

Timber harvesting has continued on the plateau off the Springer Road. The Lemon Creek road system has reached the plateau and several cutblocks have been harvested within the Cameronian Creek watershed. The Springer and Lemon Creek road systems do not join on the plateau.

Small private land parcels have been harvested along the lower slope across the fans of Vincent, Grant, Shook, and Erhard Creeks.

The private land mine site on the north edge of the Fire has been clearcut.

Fire Scars and Landslides

There are no visible fire scars within the Fire perimeter.

No new landslides have occurred naturally or as a result of forest or agricultural development. Landslides in the headwaters of O'Shea Creek remain active.

4.2. Google Earth and Bing Satellite Imagery

4.2.1. 2014 Google Earth Imagery

These orthoimages show the extensive forestry development on the plateau surface east of the Slocan Valley. No timber harvesting has occurred since 2005 within the fire perimeter. Private land parcels on the O'Shea Creek fan have been harvested.

There are no new fire scars within the perimeter of the Fire.

Landslides in the upper O'Shea watershed show continued signs of activity.

4.2.2. 2022 Bing Maps and 2023 Google Earth Imagery

Private land logging has removed timber in a narrow cutblock from the Highway to mid-slope on the north side of Ringrose Creek. A second parcel of land has been clearcut on the mine site at the north edge of the Fire. No other timber harvesting has occurred since 2014 within the fire perimeter, but a trail has been built and deactivated from the Springer road system to the fire tower at the top of Ringrose Creek.

There are no new fire scars within the perimeter of the Fire.

The upper O'Shea watershed shows continued sediment movement within the existing landslide tracks.

4.3. LiDAR[20]

LiDAR was obtained from the RDCK for the area surrounding the Fire. Review of the LiDAR imagery provides better identification of critical features, including creeks, alluvial fans, rock outcrops and allows better definition of watershed boundaries.

4.4. Debris Flood and Debris Flow Susceptibility Maps

Debris flood and debris flow susceptibility maps (Figures 3 and 4) from the Cambio Community web application[21] were reviewed. These maps were commissioned by the RDCK to assist with the identification and prioritization of hazardous areas within their jurisdictional area (BGC Engineering Ltd., 2019[22]). The maps were created using a combination of digital elevation model metrics (20 m contour intervals) to identify potential debris source zones within creek channels/gullies and flow propagation modelling to plot potential downslope flow paths; in most cases the maps are not field verified.

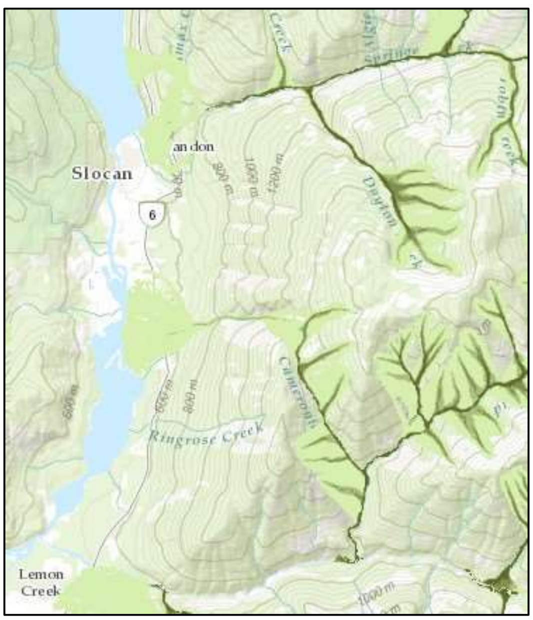


Figure 3: Excerpt from the Debris Flood Susceptibility Mapping (Source RDCK Cambio Communities Map). The darker the green coloration the higher the likelihood of debris flood occurrence.

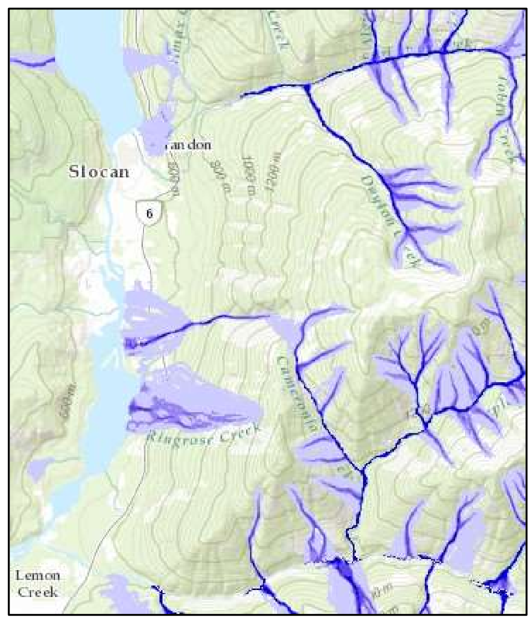


Figure 4: Excerpt from the Debris Flow Susceptibility Mapping (Source RDCK Cambio Communities Map). The darker the blue coloration the higher the likelihood of debris flow occurrence.

[20] Lidar (*Light Detection and Ranging)* is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth. These light pulses generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

[21] https://communities.bgcengineering.ca/Index.aspx

[22] BGC Engineering, 2019 RDCK Floodplain and Steep Creek Geohazards Risk Prioritization

Debris floods and debris flows are quite similar hydrogeomorphic[23] processes and these maps tend to be quite similar in their output. The susceptibility maps indicate that moderate to high debris flood susceptibility is limited to O'Shea, Cameronian, Chapleau, Dayton and Springer creeks within the Fire. On the debris flow susceptibility map, Ringrose, O'Shea, Cameronian, Chapleau, Dayton, Springer and some of the Lemon Creek tributaries are indicated to be susceptible to debris flows.

The authors of the debris flow and debris flood susceptibility report and maps caution that the maps are not suitable for undertaking site-specific hazard assessments (Sturzenegger et al., 2021[24]). While the maps are not intended to be used for detailed, site-specific hazard assessments, they do provide an indication, and initial office-based screening method, for where debris flow or debris flood hazards may be of concern. The hazard ratings do not have a physical meaning and the methodology does not compute or provide debris flow or debris flood volumes, mass depths, velocities, peak discharges, or impact forces. They are intended to be used for a regional comparison between sites to determine areas with higher hazard potential.

Given the limitations of the hazard susceptibility mapping, the site-specific observations and hazard assessments contained in this report take precedence over the hazard susceptibility maps.

5. Terrain and Watershed Conditions

The Fire is situated in the Kokanee Range of the Selkirk Mountains, part of the Columbia Mountains within southeastern British Columbia. The general physiography of the fire area consists of rounded peaks and ridge crests with steep valley sides. Summit levels lie between 1700 m and 2100 m, and relief is roughly 1600 m, ranging from 540 m along Slocan Lake to the unnamed peak summit at 2120 m on the east side of the fire.

Along the shoreline of Slocan Lake to between 900 m and 1100 m elevation, depending on aspect (higher on south facing slopes), the biogeoclimatic mapping has identified the West Kootenay variant of the Dry Warm subzone of the Interior Cedar – Hemlock zone (ICH dw1). Upslope of the ICH dw1 the mapping indicates that this zone transitions into the Slocan variant of the Moist Warm subzone of the Interior Cedar – Hemlock zone (ICH mw2) which extends to between 1500 m and 1600 m. Along the upper slopes and covering the lower peaks are thin bands of the Columbia variant of the Wet Hot Engelmann Spruce – Subalpine Fir zone (ESSF wh1) and the Selkirk variant of the Wet Cold Engelmann Spruce – Subalpine Fir zone (ESSF wc4). The uppermost biogeoclimatic zones are the Wet Cold Woodland Engelmann Spruce – Subalpine Fir zone (ESSF wcw) and Wet Cold Parkland Engelmann Spruce – Subalpine Fir zone (ESSF wcp).

Based on the precipitation modeling available from ClimateBC Map, the mean annual precipitation (MAP) within the burn area ranges from approximately 725 mm at the Highway 6 crossing of Lemon Creek to 1325 mm on the ridgetop along the east side of the Fire at 2000 m elevation. On the lower slopes above the Slocan River (at elevations between 540 m and 800 m), where most of the agricultural and

[23] Hydrogeomorphic processes such as floods, debris floods or debris flows move sediment, water and organic debris from the hillslopes of a watershed through channels to the depositional areas.

[24] Sturzenegger, M., Holm, K., Lau, C-A., Jakob, M. 2021. Debris-Flow and Debris-Flood Susceptibility Mapping for Geohazard Risk Priorization. Environmental and Engineering Geoscience, 27(2), 179-194. https://doi.org/10.2113/EEG-D-20-00006

residential development has occurred, the MAP rises upslope from 725 mm to 850 mm; an increase in precipitation is noted moving northwards. The mid-slopes (between 800 m and 1200 m) have steadily rising precipitation levels between 850 mm and 1000 mm MAP. On the upper slope and onto the gently sloped ridgeline (between 1200 m and 2000 m) the MAP is 1000 mm to 1300 mm. This is generally consistent with reference data available from weather stations throughout the region.

The regional geology mapping as viewed in iMapBC[25] indicates the Fire area is underlain entirely by the Middle Jurassic Nelson intrusive batholith. These consist of massive porphyritic granite, granodiorite and a metamorphic equivalent gneiss.

Terrain stability mapping covers much of the Fire area, but the mapped polygons lack terrain classification identifiers and only provide the terrain stability class rating (I to V where I is mapped as stable and II, III, IV and V are increasingly unstable; or Stable, Potentially Unstable or Unstable). Some of the steeper open slopes and gullied terrain are classified as Potentially Unstable; Ringrose and Vincent are both mapped this way. O'Shea Creek and the steep rock slopes along the south end of the fire above Lemon Creek are mapped as Unstable. Gentler slopes and plateau areas are generally mapped as stable.

6. Watershed Hazards

Watershed morphology is analyzed to confirm the expected hydrogeomorphic hazards within a watershed (i.e., floods, debris floods or debris flows) that could potentially affect downstream areas. Watershed boundaries in the area were delineated using LiDAR-derived 5 m contours for small drainages, and TRIM based 20 m contours for the large watersheds where LiDAR was unavailable. Watersheds were subdivided into smaller units to delineate drainage basins above alluvial fans. Many streams are not named on published maps, so some names used for watershed identification in this report may be arbitrary. Key characteristics of the watersheds are provided in Table 6.

Table 6. Characteristics of watersheds in the Fire. The Melton ratios are plotted versus watershed length on Figure 5 and channel length on Figure 6; coloration in the table reflects the zone in which they plot on Figure 6. The numbers in the left column refer to labels in Figure 6.

#	Watershed	Area (km^2)	Min elev (m)	Max elev (m)	Watershed Length (km)	Melton Ratio	Channel Length (km)	Channel Gradient (%)
5	Cameronian	4.66	905	1975	3.90	0.50	3.91	22.4
3	Chapleau	24.83	708	2200	7.85	0.30	10.97	14.5
4	Dayton	6.51	935	2125	4.61	0.47	4.55	21.2
11	Erhard	0.93	750	1890	2.66	1.18	1.28	52.3
12	Grant	0.90	721	1890	2.78	1.23	1.84	44.6
1	Lemon	202.85	566	2600	22.22	0.14	27.27	6.7
13	Lemon Gully 1	1.07	660	1710	2.20	1.02	1.73	43.5
7	Lemon Gully 2	0.69	680	1725	1.99	1.26	1.61	46.1

[25] iMapBC, https://maps.gov.bc.ca/ess/hm/imap4m/

#	Watershed	Area (km^2)	Min elev (m)	Max elev (m)	Watershed Length (km)	Melton Ratio	Channel Length (km)	Channel Gradient (%)
6	O'Shea	1.31	748	1760	2.43	0.88	1.89	43.0
9	Ringrose	1.02	641	1725	2.17	1.07	2.00	41.0
10	Shook	1.03	706	1890	2.78	1.17	1.60	49.0
2	Springer	49.01	601	2245	11.26	0.23	13.08	11.5
14	Vincent Main	0.68	723	1820	2.48	1.33	1.78	43.7
8	Vincent North	0.84	765	1720	2.35	1.04	1.60	42.2

Watershed areas are as depicted on Maps 1 and 2 in Appendix A. Minimum watershed elevation is the elevation at the fan apex, creek confluence or outlet into Slocan Lake, taken from Maps 1 and 2. Maximum elevations are sourced from iMapBC. Watershed length is measured in a straight line from the location of the minimum elevation of a watershed to the most distant point in a watershed. Stream lengths are the measured distance from the location of the minimum elevation to the end of the stream channel (following the stream channel). The stream gradient is the average gradient of the stream on the dominant stream channel within the Fire.

Differentiation between the hydrogeomorphic processes in a watershed is important from a landslide hazard perspective, as each process has different characteristics and impacts. The combination of the watershed length and Melton ratio[26] has been shown to reasonably predict the dominant hydrogeomorphic hazard that can be expected within a watershed (Figure 5; Wilford et al. 2004[27]):

- Watersheds with a Melton ratio less than 0.3 are susceptible to flood processes,
- Watersheds with a Melton ratio greater than 0.6 and a watershed length of less than 2.7 km are susceptible to debris flows, and
- Those not meeting either of these criteria are susceptible to debris floods. i.e., Melton ratios between 0.3 and 0.6.

[26] Watershed relief divided by the square root of the watershed area.
[27] Wilford, D.J., Sakals, M.E., Innes, J.L., Sidle, R.C., and Bergerud, W.A. 2004. Recognition of debris flow, debris flood and flood hazard through watershed morphometrics. Landslides, 1(1), 61-66. https://doi.org/10.1007/s10346-003-0002-0.

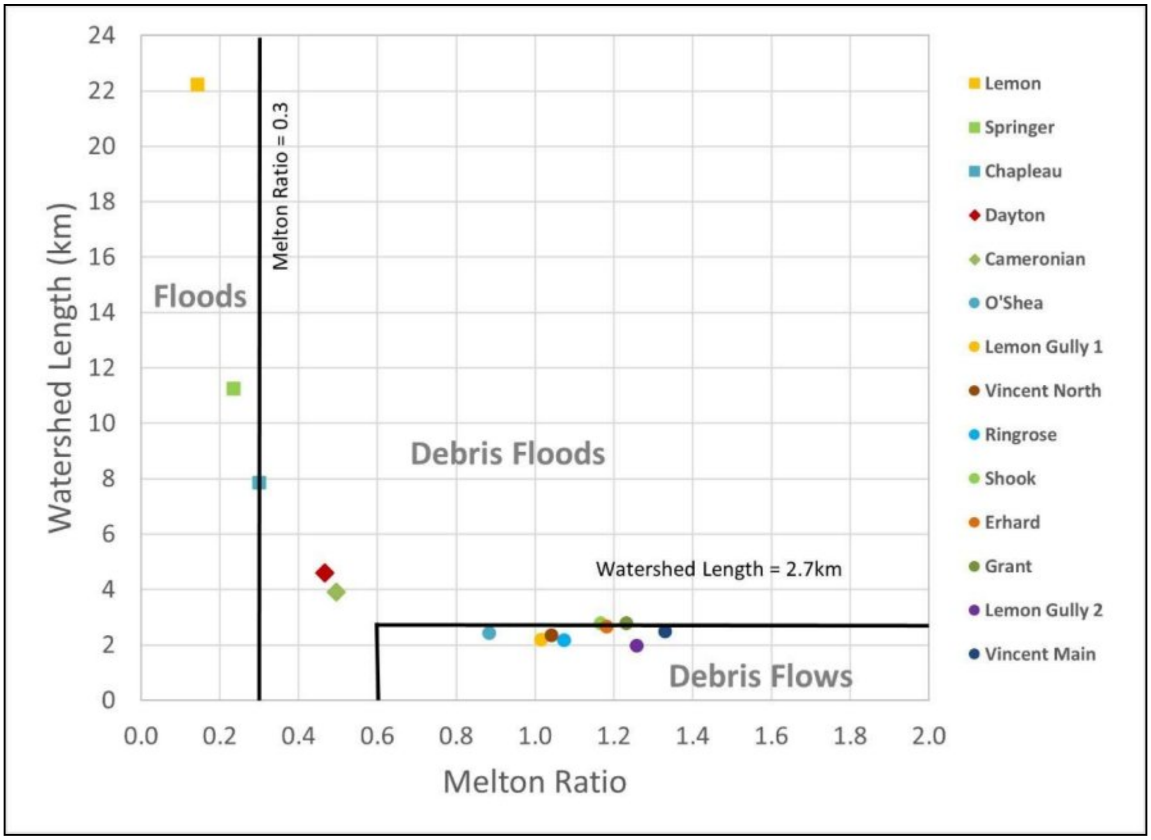


Figure 5: The hydrogeomorphic processes of creeks in the Fire plotted as a function of the Melton ratio and watershed length (Wilford et al. 2004).

Lemon Creek is a very large watershed in which flooding is the expected hydrogeomorphic process; Springer Creek also plots in the flood zone (Figure 5). Chapleau Creek is on the border between flood and debris floods. Dayton and Cameronian Creeks are mid-sized watersheds (6.51 and 4.66 km^2, respectively) that plot within the region where a debris flood is the expected hydrogeomorphic process. The remainder of the watersheds are short and steep and plot within the region where debris flows are the expected hydrogeomorphic process.

Church and Jakob (2020[28]) use a different metric to differentiate between hydrogeomorphic processes; they plotted the Melton ratio versus stream length for a large dataset of watersheds across BC and Alberta (Figure 6). Due to greater relief along shorter streams, the Melton ratios in steep face unit streams have higher Melton ratios; these are shaded in green in Table 6. All of the small face unit streams plot in the "*Mostly prone to debris flows*" zone. The slightly larger to mid-sized watersheds, shaded orange in Table 6, have lower Melton ratios and plot in the "*Mixed floods and debris floods*" or "*Mixed debris floods and debris flows*" zones. Lemon Creek has a long, gentle gradient stream that plots in the "*Mixed floods and debris floods*" and very close to the "*Mostly prone to floods"* zone. None of the creeks in the Fire plot in the "*Mostly prone to floods"* zone as the physiography of the region is typically mountainous with steep slopes.

[28] Church, M., and Jakob, M. 2020. *What is a debris flood?* Water Resources Research, 56, e2020WR027144. https://doi.org/10.1029/2020WR027144.

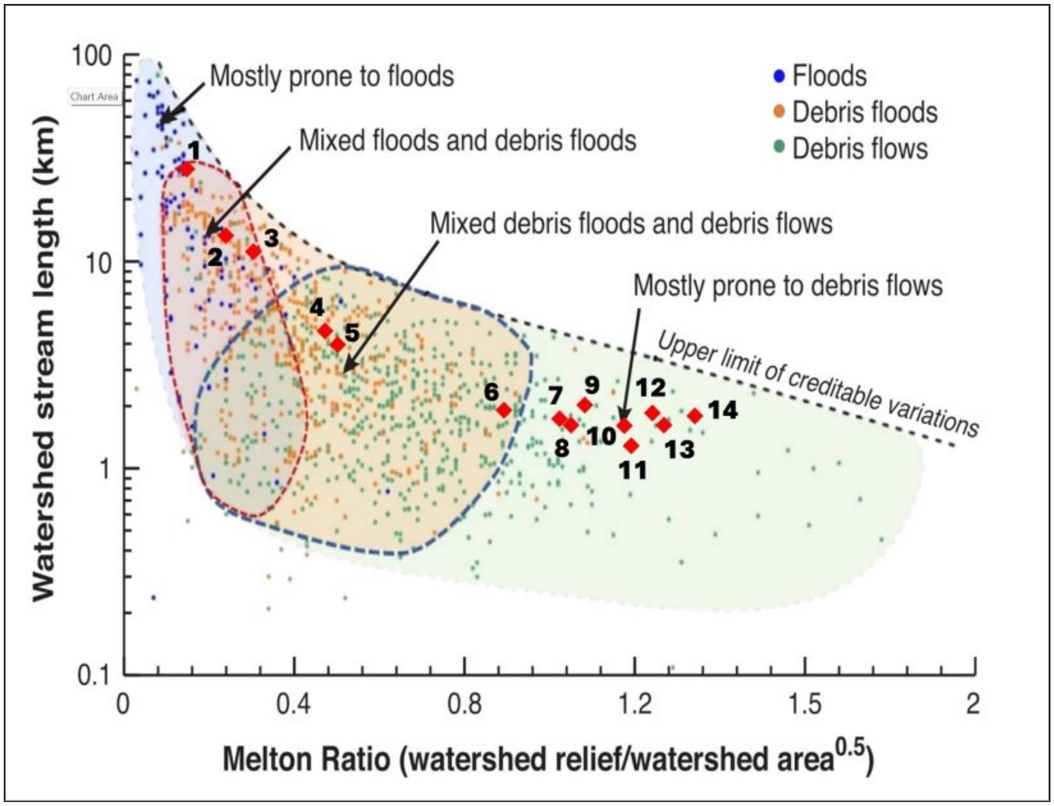


Figure 6: Creeks within the Fire plotted on a figure of the steep creek processes as a function of the Melton ratio and stream length, from Church and Jakob (2020). The numbers refer to the watersheds in Table 6.

The two methods of differentiating the hydrogeomorphic processes illustrate the complexity of classification of events. The Wilford method is inflexible in terms of numerically defined boundaries separating the events whereas the Church and Jakob method allows overlap of the event types and is less definite on the expected event. For instance, the watersheds defined as debris floods by Wilford (Dayton and Cameronian) plot within the "*Mixed debris floods and debris flows*" zone of Church and Jakob. Use of both methodologies is useful in estimation of the expected hydrogeomorphic event.

Note that the predictive methods described above are typically relevant to well-graded watersheds, i.e., watersheds with gradually increasing slope gradients when moving from the bottom to the top of the watershed. Watersheds which feature an upper, gentle plateau area over a steep lower slope are not well-graded and the predictive methods described above may erroneously determine that such watersheds are only prone to flood or debris flood events when in reality debris flow processes are present. As is common with natural systems, on the ground, site-specific field observations take precedence over the empirical, office based predictive methods described above.

7. Burn Severity Mapping

Burn severity is an important factor in determining the potential for post-wildfire natural hazards to occur. Burn severity is derived from:

- The vegetation burn severity mapping which uses satellite images to process reflectance data and estimate the change to the vegetation cover, and
- The soil burn severity, which relies on field tests and observations of the effects of fire on soils to determine loss of ground cover, loss of soil structure and increases in water repellency (Curran et al 2006)[29].

The vegetation burn severity or Burned Area Reflectance Classification (BARC) map was prepared by the MoF based on comparative (pre and post fire) satellite images taken on July 7 and August 11, 2024.

Burn severity maps are used to assess the potential hydrologic effects of the fire in each watershed due to forest cover and soil changes. The definitions of high, moderate, and low vegetation burn severity (VBS) are given in LMH69 and Parsons et al. (2010[30]), as well as the procedure for preparing a burn severity map. Briefly, the vegetation burn severity categories are:

- High – trees dead (black); needles, twigs, and understory consumed
- Moderate – trees dead (orange); scorched needles remain on trees, understory burned
- Low – trees live (green); canopy mostly unburned, understory lightly burned.

Soil burn severity (SBS) is similarly classified as high, moderate, or low, and is based on the extent of consumption of the forest floor and fuels on the ground, and on the extent of exposed bare soil:

- High – forest floor and near-surface roots consumed, mineral soil structure altered
- Moderate – litter consumed, duff partly consumed or charred, mineral soil unaltered
- Low – litter scorched or partly consumed, often with patchy forest floor burn.

Moderate and high burn severities correspond to a higher rate of vegetation consumption (i.e., loss of canopy, groundcover and organic soil layer) during a fire and the presence of typically stronger and more prevalent water repellency conditions. This is important because the hydrologic response (i.e., increased peak flows and runoff volumes) in a watershed following rainfall events can be significantly altered on slopes burned to these severities.

Remotely sensed vegetation burn severity maps are intended to be modified by fieldwork to ascertain soil conditions on the ground and to produce verified soil burn severity mapping[31]. Normalized Burn Ratio (NBR) is sensitive primarily to living chlorophyll and the water content of soils and vegetation, with lesser response to lignin, hydrous minerals, ash and char. Where pre-fire images are available, the post-fire NBR can be subtracted from the pre-fire NBR to give the differenced NBR (dNBR). The dNBR data are separated into four categories of severity (unburned, low, moderate, high), and the resulting map has become the most commonly used remotely sensed illustration of fire severity. The final soil burn severity map is a modification of the preliminary remotely sensed vegetation burn severity map that incorporates the field-verified effects of the fire on the soil.

[29] Curran, M.P., Chapman B., Hope G.D., and Scott D. 2006. *Large-scale Erosion and Flooding after Wildfires: Understanding the Soil Conditions,* BC Ministry of Forests and Range, Technical Report 030.
[30] Parsons, A, Robichaud, P.R, Lewis, S.A, Napper, C, and Clark, J.T. 2010. *Field guide for mapping post-fire soil burn severity.* USDA Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-243.
[31] Safford, H.D. Miller, J., Schmidt, D. Roath, B. and Parsons, A. 2008. *BAER Soil Burn Severity Maps Do Not Measure Fire Effects to Vegetation: A Comment on Odion and Hanson (2006).* Ecosystems 11: 1-11; DOI: 10.1007/s10021-007-9094-z

Vegetation and soil burn severity are usually, but not always, fairly well correlated. For example, a high VBS site most commonly has a high SBS, though may have moderate SBS but is unlikely to have a low SBS. Water repellency is often, but not always, present on high SBS sites. Where SBS is high, the infiltration capacity of the soil and storage capacity of the forest floor is often significantly reduced, and overland flow may be generated during heavy rain. If this occurs over large areas, soil erosion and downstream flooding can occur. If water repellency is present, the amount of overland flow can be considerably greater. Where VBS is moderate, dead needles remain on the trees. These soon fall, often covering the ground with an effective mulch which promotes infiltration and reduces erosion and the likelihood of overland flow. Therefore, fire related flood and debris flow hazards from rainstorms are generally high only where both VBS and SBS are high.

Increased flood hazard during spring snowmelt is due to loss of the forest canopy, which results in both a higher winter snowpack and more rapid snowmelt. The effect is similar to that of clearcutting. However, in the first one or two years, the effect of fire may be greater than clearcutting, due to the black colour of burned tree trunks and the soot and debris which falls on the snow. The reduced water storage and run-off attenuation from the loss of the litter and/or duff may also contribute to increased freshet related flood hazard although this is less of a factor during freshet as the litter/duff storage capacity is typically reduced in the during freshet. Also, because there is no longer transpiration from trees and understory vegetation, the water table and soil moisture may be higher when winter comes. The flood hazard in a watershed is a function of the area burned at high and moderate VBS; low VBS sites (in which many trees and shrubs have survived) generally do not contribute significantly to flood hazard.

Field data on vegetation and soil burn severity were collected at a limited number of ground plots, with more general visual observations made throughout the field assessments. Four unburned, six low and four moderate burn severity plots were completed, but only 1 high burn severity plot was completed due to the paucity of, and poor access to, the more severely burned terrain.

The field observations were used to check the accuracy of the high, moderate, low, and unburned categories on the BARC map and were found to correspond reasonably well to the BARC map categories. In addition, comparison of the vegetation burn severity and soil burn severity was found to be in close agreement; the BARC map is considered to be suitably representative of the vegetation burn severity and soil burn severity for the purpose of this assessment and is shown on Map 1 in Appendix A.

Investigation of unburned terrain to compare with burned sites indicated that, in general, the steeper slopes are well drained and lack thick organic LFH accumulations. Lower gradient slopes had much thicker moss, LFH and organic soils and were generally, due to longer moisture retention, wetter sites. Water repellency is often observed in unburned locations, but on this Fire none was observed at any of the sites tested.

Photos 3 through 6 are overview photos of the Fire. These images were taken on August 23, 2024, while the fire was still active and smoke impeded visibility.

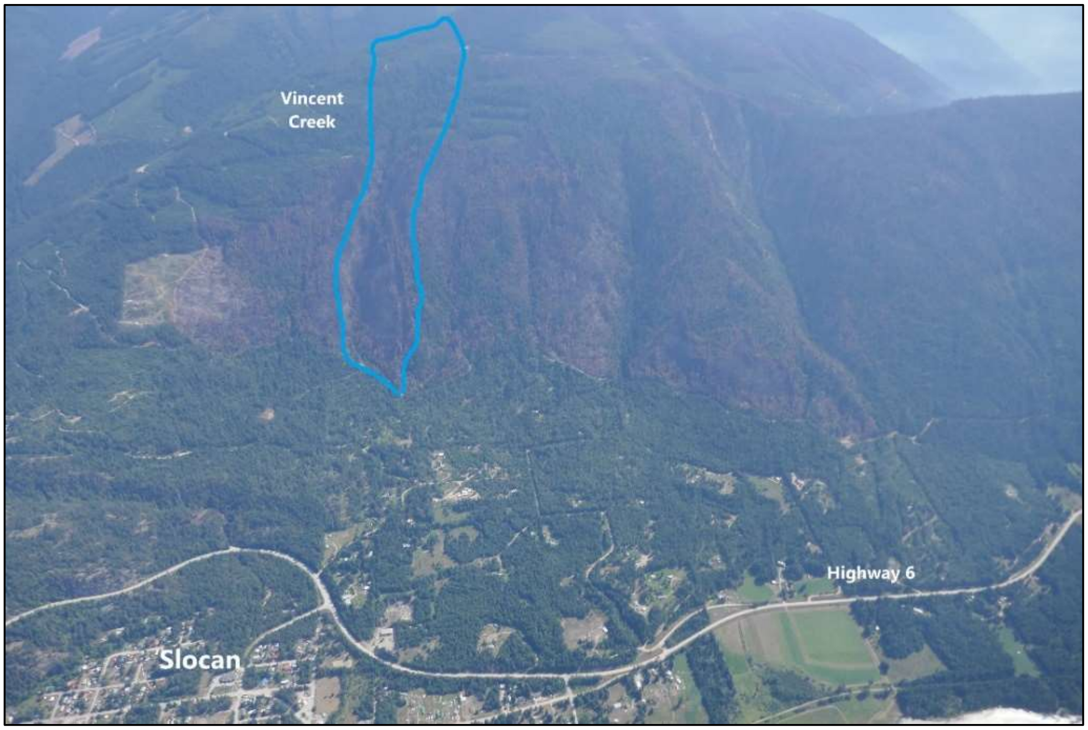


Photo 3: Mixed burn severities on the north end of the Fire. Vincent Creek is outlined; a small patch of high VBS can be seen low in the watershed on the north side of the creek draw.

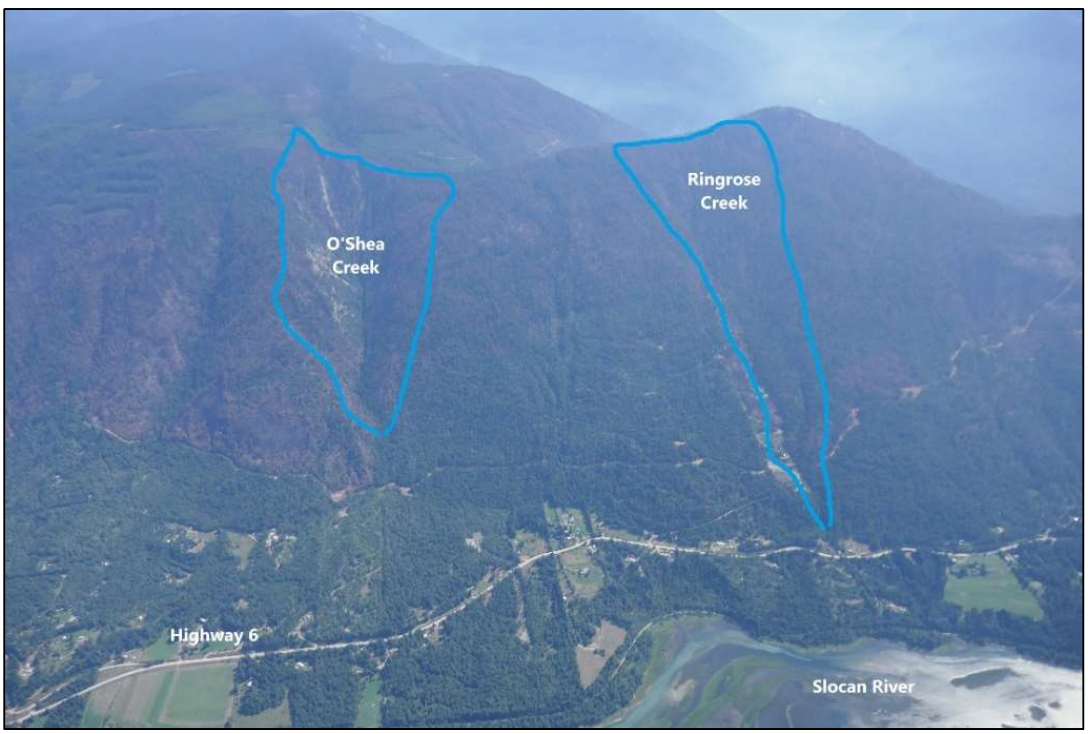


Photo 4: Variable burn severity on the face slopes across O'Shea Creek (outlined) and Ringrose Creek (outlined). Much of the lower slope burned at low VBS while the upper slope was mixed low and moderate VBS.

Photo 5: View of the southern end of the Fire. The Ponderosa FSR ascends the slope from the gravel pit at lower centre and has two branches; one extends east along the slope above Lemon Creek and the second continues upslope to the northeast.

Photo 6: Mixed high, moderate and low VBS on the south end of the Fire. A section of the Ponderosa FSR can be seen in the middle of the image.

In addition to the low, moderate, and high drainage VBS categorization, a weighted burned area classification (referred to as the effective burn severity index (EBSI)) was also used to assess the landslide and flood hazard. The EBSI is calculated as the sum of 100% of the area of the high burn severity (in km^2) plus 50% of the area of moderate burn severity (in km^2) divided by the drainage area (in km^2). Base EBSI values and the qualitative ratings are shown in Table 7. Calculated base EBSI values for each watershed are provided in Table 8.

Table 7. EBSI values and corresponding ratings of potential increase in landslide hazard.

EBSI Value	Potential Increase in Landslide Hazard
0 - 15	Very Low
15 - 30	Low
30 - 50	Moderate
50 - 75	High
> 75	Very High

Table 8. Vegetation Burn Severity and calculated EBSI by watershed. Coloration of the base EBSI values reflect the ratings shown in Table 7.

Watershed	Area (km^2)	Vegetation Burn Severity				EBSI
		Area Unburned within Drainage (%)	Area Low Burn Severity within Drainage (%)	Area Moderate Burn Severity within Drainage (%)	Area High Burn Severity within Drainage (%)	
Cameronian	4.66	54.2	27.1	17.9	0.9	9.8
Chapleau	24.83	85.7	8.7	5.3	0.2	2.9
Dayton	6.51	99.2	0.4	0.4	0.0	0.2
Erhard	0.93	57.2	24.9	17.6	0.3	9.1
Grant	0.90	47.5	24.8	26.8	0.9	14.3
Lemon	202.85	96.7	1.8	1.4	0.1	0.8
Lemon Gully 1	1.07	4.0	39.7	55.3	1.0	28.6
Lemon Gully 2	0.69	16.8	40.2	40.0	3.0	23.0
O'Shea	1.31	44.9	40.4	14.7	0.0	7.3
Ringrose	1.02	32.4	43.4	24.0	0.1	12.1
Shook	1.03	62.7	19.3	18.0	0.0	9.0
Springer	49.01	100.0	0.0	0.0	0.0	0.0
Vincent Main	0.68	55.9	9.2	30.1	4.7	19.8
Vincent North	0.84	53.9	23.8	18.6	3.7	13.0

Calculation of the base EBSI rating for each watershed is straightforward, but there are several judgement factors which individually or in combination with others, can increase the rating depending on the severity of the effect, including:

- presence of an older burn which is still affecting the watershed, this was not the case for this Fire;
- burning of the gentle slopes in a gentle-over-steep watershed configuration,
- burning of the riparian zone, and
- concentration of the high burn severity in one elevation band, particularly in the upper, steeper portions of a watershed where debris flow initiation is elevated due to increased sediment availability and decreased channel stability.

Table 9. The Base EBSI Value Rating is adjusted based on review of the factors noted above. The Adjusted EBSI Ratings are colored if they have been altered from the Base EBSI Value Rating.

Watershed	EBSI	Base EBSI Value Rating	Old Fire Effects	"Gentle-over-steep"	Riparian Zone Burned	Burn Concentration	Adjusted EBSI Rating[32]
Cameronian	9.8	Very Low					Very Low
Chapleau	2.9	Very Low					Very Low
Dayton	0.2	Very Low					Very Low
Erhard	9.1	Very Low		Partially		Mid-slope, steep	Very Low
Grant	14.3	Very Low		Unburned gentle	Minor	Mid-slope, steep	Low
Lemon	0.8	Very Low					Very Low
Lemon Gully 1	28.6	Low					Low
Lemon Gully 2	23.0	Low					Low
O'Shea	7.3	Very Low				Steep	Very Low
Ringrose	12.1	Very Low			Yes	Upper, steep	Low
Shook	9.0	Very Low		Unburned gentle	Minor	Mid-slope, steep	Very Low
Springer	0.0	Very Low					Very Low
Vincent Main	19.8	Low		Unburned gentle	Yes	Lower, steep	Low
Vincent North	13.0	Very Low		Unburned gentle	Minor	Lower, steep	Very Low

The adjusted EBSI rating is considered equivalent to the qualitative "Hazard Likelihood" as described in Table 2 and is therefore used in the calculation of partial risk as shown in Table 10 in Section 9.

[32] The Adjusted EBSI Ratings are considered to be equivalent to the MoF Hazard Descriptions as described in Table 2.

8. Elements at Risk and Partial Risk for Drainages of Interest

Property, infrastructure, and water supplies are often at risk from post-wildfire hazards, such as flooding or landslides. These areas or sites are referred to as "elements at risk" and include the following:

- damage to residential structures and out-buildings;
- damage to, and loss of access on highways and other transportation infrastructure (subsidiary Ministry of Transportation and Transit (MoTT) roads and forest access roads);
- public safety for houses and other occupied structures;
- public safety of users on highways and other transportation infrastructure (subsidiary MoTT roads and forest access roads);
- domestic water supplies ;
- linear infrastructure including hydro transmission lines; and
- campgrounds and parks.

Some general information on potential risks is given here and more specific analyses of risks are described in the following sections and the accompanying tables. If any particular elements are not given any further mention, it is because no moderate or high risks were identified.

Houses and other buildings are shown on maps, based on TRIM data with additional information added from available imagery (Google Earth and RDCK web mapping service). Houses and other structures were considered to be at risk if they are located on alluvial or debris flow fans, near stream channels, or at the base of steep slopes below burned areas. Such sites comprise most of the risk elements in this study.

Water license information was obtained from the BC Government water license query page, and from the POD (points of diversion) shown on iMap BC. There are numerous domestic licenses on many of the creeks. A partial risk assessment was not completed for every water intake or point of diversion. Instead, Table 10 should be referenced to determine the hazard relating to any one water intake.

8.1. Cameronian Creek

Cameronian Creek is a small watershed (4.66 km^2) which has headwaters on the ridgeline and drains south into Chapleau Creek. The creek has a Melton ratio of 0.50, an average channel gradient of 22.4% and a length of 3.90 km; it is considered to be able to initiate and transport post wildfire debris floods. There are no water licenses drawing water from Cameronian Creek.

The fire burned on the upper slopes of the watershed at mostly low and moderate burn severity; a few small patches of high burn severity were mapped. The fire burned 46% of the watershed with 18% moderate and 1% high burn severity; the calculated EBSI is 9.8 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 bridge on Lemon Creek. Cameronian Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.2. Chapleau Creek

Chapleau Creek is a moderately-sized watershed which drains south along the southeast edge of the Fire into Lemon Creek. The watershed is 24.83 km^2 in size, has a Melton ratio of 0.30, an average channel gradient of 14.5%, and a length of 7.85 km. This watershed is considered to be a flood or debris flood watershed. There are no water licenses drawing water from Chapleau Creek.

The fire burned only a small portion along the western edge of the watershed. The fire burned 14% of the watershed with 5% moderate and less than 1% high burn severity; the calculated EBSI is 2.9 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 bridge on Lemon Creek. Chapleau Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.3. Dayton Creek

Dayton Creek is a small, north-facing watershed which flows into Springer Creek. The watershed is 6.51 km^2 with a Melton ratio of 0.47, an average channel gradient of 21.2% and a length of 4.61 km. The creek is considered to be able to initiate and transport post wildfire debris floods into the mainstem channel of Springer Creek. One water license draws water from Dayton Creek, but there is no attribution on iMap.

The fire burned on the upper southwestern edge of the watershed at mostly low and moderate burn severity. The fire burned 1% of the watershed with less than 1% moderate and no high burn severity; the calculated EBSI is 0.2 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 culvert on Springer Creek. Dayton Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.4. Erhard (Popoff) Creek

Erhard Creek is a steep narrow watershed which is 0.93 km^2 in size, has a Melton ratio of 1.18, an average channel gradient of 52.3%, and a length of 2.66 km. A broad, gently to moderately sloped alluvial fan (8 to 16%) has been developed on an elevated glaciofluvial bench where the channel becomes unconfined at the outlet of the upper watershed. This watershed is considered to be able to initiate and transport post wildfire debris flows. The creek was reviewed above the fireguard along the lower boundary of the Fire and as shown in Photo 7, there was no defined or armoured channel in the base of the draw and no streamflow was observed.

Two domestic or irrigation use water licence points of diversion are located on Erhard Creek (PD27851 and PD71392). Five other domestic or irrigation use water license points of diversion (PD27846, PD27847, PD27849, PD75043 and PD206997) are located further downslope on the same creek but are referred to as being on Popoff Creek. For the purposes of this report, water in Popoff Creek is considered to be sourced from the Erhard Creek watershed.

Photo 7: Erhard Creek was a dry creek in a well-defined draw on the lower slopes (Waypoint P25).

The fire burned 43% of the watershed with 18% moderate and less than 1% high burn severity; the calculated EBSI is 9.1 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. A small portion of the gentle slopes in the upper watershed were burned but this area is disconnected from the main channel. The burning that did occur within the watershed was concentrated on the steep, south facing valley slope. The calculated EBSI value is considered satisfactory for this watershed.

The elements at risk are residences located at 8904, 8910 and 8911 Martens Road. These residences are built on the lower slopes of the alluvial fan of Erhard Creek and are situated sufficient distance from the apex of the Erhard Creek fan such that a debris flow occurring on the creek is unlikely to extend to the residences

Erhard Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact to the residences at 8904, 8910 and 8911 Martens Road; the overall partial risk to the residences at 8904, 8910 and 8911 Martens Road is rated as VERY LOW.

8.5. Grant Creek

Grant Creek is a steep narrow watershed which is 0.90 km^2 in size, has a Melton ratio of 1.23, an average channel gradient of 44.6%, and a length of 2.78 km. A wide, gently to moderately sloped alluvial fan (10 to 18%) has formed where the channel becomes unconfined at the outlet of the upper watershed; this fan is coalescent with the Vincent Creek fan to the north. This watershed is considered to be able to initiate and transport post wildfire debris flows. The creek was viewed on the gentle bench below the Fire near Austyn Road and was noted to be a small creek with steady streamflow in a broad swale (Photo 8).

Two domestic or irrigation use water licence points of diversion are located on Grant Creek (PD27878 and PD77878) above Austyn Road. Grant and Vincent Creeks appear to join above Austyn Road; several points of diversion are located below Austyn Road and are named either Grant or Vincent Creek.

The fire burned 53% of the watershed with 27% moderate and 1% high burn severity; the calculated EBSI is 14.3 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The riparian zone along Grant Creek was observed from the air and noted to be moderately burned. The burning that did occur within the watershed was concentrated on the steeper slopes. For these reasons, the EBSI is adjusted to low and the incremental post wildfire hazard is likely to be slightly elevated.

The element at risk is the residence and outbuildings located at 8946 Austyn Road. This residence is built on the alluvial fan of Grant Creek. The residence and outbuildings are located a sufficient distance from the apex of the Grant Creek fan such that a debris flow event occurring on the creek is unlikely to impact the residence or outbuildings.

Grant Creek has been rated as having a LOW incremental post wildfire hazard with a LOW likelihood of spatial impact to the residence at 8946 Austyn Road; the overall partial risk to the residence at 8946 Austyn Road is rated as VERY LOW.

Photo 8: Grant Creek is a small creek in a shallow swale on the open slopes above Austyn Road (Waypoint P28).

8.6. Lemon Creek

Lemon Creek is a large watershed 202.85 km^2 in size, has a Melton ratio of 0.14, an average channel gradient of 6.7%, and a length of 22.22 km and is considered to be a flood watershed. Lemon Creek is a broad gravel bed creek which flows along the southern boundary of the Fire. There are numerous domestic and irrigation use water licence points of diversion on Lemon Creek.

The fire burned less than 3% of the watershed with 1% moderate and less than 1% high burn severity; the calculated EBSI is 0.8 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 bridge. Lemon Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact to the Highway 6 bridge; the overall partial risk to the Highway 6 bridge is rated as VERY LOW.

8.7. Lemon Gully 1

Lemon Gully 1 is a very small watershed 1.07 km^2 in size, has a Melton ratio of 1.02, an average channel gradient of 43.5%, and a length of 2.20 km. This watershed is considered to be able to initiate and transport post wildfire debris flows. There are no water licence points of diversion on Lemon Gully 1.

The fire burned over 96% of the watershed with 55% moderate and 1% high burn severity; the calculated EBSI is 28.6 which is considered to be low and the incremental post wildfire hazard is likely to be slightly elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 bridge on Lemon Creek. Lemon Gully 1 has been rated as having a LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.8. Lemon Gully 2

Lemon Gully 2 is a very small watershed 0.69 km^2 in size, has a Melton ratio of 1.26, an average channel gradient of 46.1%, and a length of 1.99 km. This watershed is considered to be able to initiate and transport post wildfire debris flows. There are no water licence points of diversion on Lemon Gully 2.

The fire burned over 83% of the watershed with 40% moderate and 3% high burn severity; the calculated EBSI is 23.0 which is considered to be low and the incremental post wildfire hazard is likely to be slightly elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 bridge on Lemon Creek. Lemon Gully 2 has been rated as having a LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.9. O'Shea Creek

O'Shea Creek is a very small watershed which leads down to a very large, gently to moderately sloped (10-21%) alluvial fan. The watershed is 1.31 km^2 in size, has a Melton ratio of 0.88, an average channel gradient of 43.0%, and a length of 2.43 km. O'Shea Creek is considered to be a debris flow or debris flood watershed. The steep headwaters have exposed bedrock cliffs and several open rubbly talus cone or debris tracks. The creek was viewed along the upper reaches of the alluvial fan near the lower boundary of the Fire and along the Highway. The creek was noted to have strong continuous streamflow across the fan (Photo 9) and in the ditch along the Highway. Flow was carried in the Highway ditch from P29 to P30 where it is conveyed under the Highway through a 600 mm culvert and runs out across a field in a diversion ditch towards the Slocan River. The culvert appears to be adequately sized for expected increases in flow.

Photo 9: View of O'Shea Creek on the upper reaches of the gently sloped alluvial fan at Waypoint P22.

Seven domestic or irrigation use water licence points of diversion are located on O'Shea Creek (PD27838, PD27839, PD27840, PD27841, PD27842, PD28744 and PD56376) above the Highway.

The fire burned 55% of the watershed with 15% moderate and no high burn severity; the calculated EBSI is 7.3 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The burned areas are dispersed across the watershed and the riparian zone was only slightly affected. The calculated EBSI value is considered satisfactory for this watershed.

The elements at risk are residences and outbuildings at 8558 and 8578 Highway 6. O'Shea Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact to the residences; the overall partial risk to the residences is rated as VERY LOW.

8.10. Ringrose Creek

Ringrose Creek is a very small steep watershed 1.02 km^2 in size, has a Melton ratio of 1.07, an average channel gradient of 41.0%, and a length of 2.17 km. This drainage is considered to be able to initiate and transport post wildfire debris flows. The creek observed within this watershed has steady flow and follows a confined draw onto the moderately sloped alluvial fan about 150 m above the Highway. The average slope gradient from the apex of the alluvial (655 m elevation) to the Highway (610 m elevation) is approximately 30%. This moderate gradient indicates that the fan was primarily formed by debris flow processes.

The fan surface has two potential channels which direct the flow northwest or southwest from the fan apex through two broad shallow draws. Currently a 600 mm steel pipe culvert directs the flow into the northwest draw. The northwest creek flows down to the Highway where it passes through a 500 mm culvert at Waypoint P13 and continues downslope in a northwesterly direction towards the Slocan River.

There is avulsion potential at the apex of the fan where the flow could be diverted to the southwest. The southwest creek is a trickle which reaches the Highway at Waypoint 2; the source of this flow is assumed to be seepage or groundwater flow from the hillslope. The flow passes under the Highway through a culvert buried in the ditch; the culvert is estimated to be 400 mm in diameter, but this was not confirmed. The flow continues downslope to the southwest in a draw which leads to the Slocan River.

Three domestic or irrigation use water licence points of diversion are located on Ringrose Creek above the Highway (PD27823, PD27825 and PD27826).

The fire burned 68% of the watershed with 24% moderate and less than 1% high burn severity; the calculated EBSI is 12.1 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. Much of the mid-slope of the riparian zone of the watershed was observed to have low to moderate burn severity (Photo 10). Most of the burned areas are dispersed across the upper steeper portions of the watershed. For these reasons, the EBSI is adjusted to low and the incremental post wildfire hazard is likely to be slightly elevated.

Photo 10: View looking upslope along the Ringrose Creek draw on the mid-slopes of the watershed (Waypoint P7). The creek is confined in a deep, steep-sided draw with a moderate gradient channel.

Modelling of the flows on the Ringrose Creek watershed shows the channel on the steep upper slopes losing confinement at the top of the alluvial fan and flow spreading out across the fan surface in the two shallow draws.

The elements at risk are the residences at 8246 and 8252 Highway 6 and the Highway. The residence at 8246 Highway 6 is located 25 m south of the southwest creek draw on the mid-slope of the fan and is considered to have a high likelihood of spatial impact from debris flows, debris floods and floods. The residence at 8252 Highway 6 is located between the two creek draws (approximately 40 m north of the southwest creek and 40 m south of the northwest creek) on the mid-slope of the fan and is considered to have a high likelihood of spatial impact from debris flows, debris floods and floods.

Ringrose Creek has been rated as having a LOW incremental post wildfire hazard with a HIGH likelihood of spatial impact to the residences at 8246 and 8252 Highway 6 (this is supported by modelling of debris flow runout through the Ringrose Creek watershed); the overall partial risk to the residences at 8246 and 8252 Highway 6 is rated as MODERATE.

Ringrose Creek has been rated as having a LOW incremental post wildfire hazard with a HIGH likelihood of spatial impact to the Highway; the overall partial risk to the Highway is rated as MODERATE.

8.11. Shook Creek

Shook Creek is a steep narrow watershed 1.03 km^2 in size, has a Melton ratio of 1.17, an average channel gradient of 49.0%, and a length of 2.78 km. A small, moderately sloped alluvial fan (20 to 30%) has been developed above Martens Road where the channel becomes unconfined at the outlet of the upper watershed. This steep drainage is considered to be able to initiate and transport post wildfire debris flows. The creek was viewed on the moderate slopes above Martens Road and was noted to have a trickle of flow in a moderately confined swale.

Six domestic or irrigation use water licence points of diversion are located on Shook Creek (PD27858, PD27860, PD27862, PD27869, PD27870 and PD76339).

The fire burned 37% of the watershed with 18% moderate and no high burn severity; the calculated EBSI is 9.0 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. Much of the mid-slope of the riparian zone of the watershed was observed to have low to moderate burn severity. The burned areas are dispersed across the upper steeper portions of the watershed. The calculated EBSI value is considered satisfactory for this watershed.

The elements at risk are two residences elevated above the creek draw on open slopes above the alluvial fan. Shook Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.12. Springer Creek

Springer Creek is a large watershed 49.01 km^2 in size, has a Melton ratio of 0.23, an average channel gradient of 11.5%, and a length of 11.26 km and is considered to be a flood watershed. Springer Creek is a gravel bed creek which flows along the northern boundary of the Fire. There are numerous domestic and irrigation use water licence points of diversion on Springer Creek.

The fire burned less than 1% of the watershed with less than 1% moderate and less than 1% high burn severity; the calculated EBSI is 0.0 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Highway 6 culvert. Springer Creek has been rated as having a VERY LOW incremental post wildfire hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

8.13. Vincent Creek

Vincent Creek is a steep narrow watershed 0.68 km^2 in size, has a Melton ratio of 1.33, an average channel gradient of 43.7%, and a length of 2.48 km. A broad, gently to moderately sloped alluvial fan (15 to 25%) has formed where the channel becomes unconfined at the outlet of the upper watershed; this fan is coalescent with the Grant Creek fan to the south. This steep drainage is considered to be able to initiate and transport post wildfire debris flows. The creek was observed at and above the fireguard at P32 (Photos 11 and 12, respectively) where there was a steady flow through a deep and well confined draw on the moderate to steeply graded slopes. The creek was also reviewed where it passed under Austyn Road through a 1200 mm culvert (P34).

The fire burned 44% of the watershed with 30% moderate and 5% high burn severity; the calculated EBSI is 19.8 which is considered to be low and the incremental post wildfire hazard will be slightly elevated. The burning that did occur within the watershed was concentrated on the steep, lower slopes and included some of the riparian zone. The location of the burned area lower on the slope limits the potential volume of a debris flow as there is a limited length of channel to entrain debris. The calculated EBSI value is considered satisfactory for this watershed.

Numerous domestic or irrigation use water licence points of diversion are located on Vincent Creek.

The elements at risk are residences at 8990, 9002 and 9006 Springer Creek Road. These residences are built on the gently to moderately sloped alluvial fan at the base of the hillslope adjacent to Vincent Creek. Modelling of the flows on the Vincent Creek watershed shows the channel on the steep upper slopes losing confinement at the top of the alluvial fan and flow spreading out across the fan surface.

Photo 11: View upstream along Vincent Creek (Waypoint P32).

Photo 12: View looking upstream along Vincent Creek (Waypoint P32).

Vincent Creek has been rated as having a LOW incremental post wildfire hazard with a MODERATE likelihood of spatial impact to the residences at 8990 and 9006 Springer Creek Road; the overall partial risk to the residences at 8990 and 9006 Springer Creek Road is rated as LOW. This is supported by modelling of debris flow runout through the Vincent Creek watershed.

Vincent Creek has been rated as having a LOW incremental post wildfire hazard with a HIGH likelihood of spatial impact to the residence at 9002 Springer Creek Road; the overall partial risk to the residence at 9002 Springer Creek Road is rated as MODERATE. This is supported by modelling of debris flow runout through the Vincent Creek watershed.

8.14. Vincent North Creek

Vincent North Creek is a very small drainage which is 0.84 km^2 in size, has a Melton ratio of 1.04, an average channel gradient of 43.2%, and a length of 2.35 km. This watershed is considered to be a debris flow watershed. The creek was observed at and above the fireguard at P33 (Photo 13) where there was a steady flow through a deep and well confined draw on the moderately graded slopes

There are no water licence points of diversion on Vincent North Creek.

The fire burned 46% of the watershed with 19% moderate and 4% high burn severity; the calculated EBSI is 13.0 which is considered to be very low and the incremental post wildfire hazard is unlikely to be elevated. The areas burned are lower in the watershed and poorly connected to the creek channel. The calculated EBSI value is considered satisfactory for this watershed.

The element at risk is the Springer Creek FSR. Vincent North Creek has been rated as having a VERY LOW hazard with a LOW likelihood of spatial impact; the overall partial risk is rated as VERY LOW.

Photo 13: View of Vincent North Creek crossing an old road which was cleared as a fireguard (Waypoint P31).

9. Summary of Watershed Partial Risk

Based on the burn severity observed in each watershed which incrementally increases the likelihood of landslides and flooding hazards, in addition to the watershed characteristics and conditions, the likelihood of a hazardous event occurring has been assigned to all of the watersheds. In Table 10, the Melton Ratio, Base EBSI Value and Expected Hazard is provided, as is the Adjusted EBSI Rating (from Table 9; shown as Hazard Likelihood) and Spatial Likelihood. The Hazard Likelihood and Spatial Likelihood are combined to provide a Partial Risk Rating; the partial risk is determined prior to any mitigation works. The Element at Risk is also identified.

Table 10: Compilation of watershed characteristics and hazards to estimate the likelihood of a hazardous event occurring, the spatial likelihood that the hazardous event will reach the element at risk and the partial risk.

Watershed	Melton Ratio	Base EBSI Value	Expected Hazard	Hazard Likelihood	Spatial Likelihood	Partial Risk	Element at Risk[33]
Cameronian	0.50	9.8	Debris Flood or Flood	Very Low	Low	Very Low	Highway 6 culvert
Chapleau	0.30	2.9	Flood or Debris Flood	Very Low	Low	Very Low	Highway 6 culvert
Dayton	0.47	0.2	Debris Flood or Flood	Very Low	Low	Very Low	Highway 6 culvert
Erhard	1.18	9.1	Debris Flow	Very Low	Low	Very Low	Residences
Grant	1.23	14.3	Debris Flow	Low	Low	Very Low	Residence
Lemon	0.14	0.8	Flood	Very Low	Low	Very Low	Highway 6 bridge
Lemon Gully 1	1.02	28.6	Debris Flow	Low	Low	Very Low	Highway 6 bridge
Lemon Gully 2	1.26	23.0	Debris Flow	Low	Low	Very Low	Highway 6 bridge
O'Shea	0.88	7.3	Debris Flow or Debris Flood	Very Low	Low	Very Low	Residences
Ringrose	1.07	12.1	Debris Flow	Low	High	Moderate	8246 and 8252 Highway 6
Ringrose	1.07	12.1	Debris Flow	Low	High	Moderate	Highway 6
Shook	1.17	9.0	Debris Flow	Very Low	Low	Very Low	Residences
Springer	0.23	0.0	Flood	Very Low	Low	Very Low	Highway 6 culvert
Vincent Main	1.33	19.8	Debris Flow	Low	Moderate	Low	8990 and 9006 Springer Creek Road
Vincent Main	1.33	19.8	Debris Flow	Low	High	Moderate	9002 Springer Creek Road
Vincent North	1.04	13.0	Debris Flow	Very Low	Low	Very Low	Springer Creek FSR

[33] Many of these drainages also have domestic and irrigation water licenses. Individual water license infrastructure was not reviewed.

10. Watershed Management Considerations

Salvage harvesting of burned areas has the potential to increase the associated hazards and risks associated with flooding and landslides. It is recommended that if salvage harvesting is proposed within watersheds with a likelihood of post wildfire landslide or flooding hazards exceeding low that site specific Terrain Stability Assessments (TSAs) be completed. It is the responsibility of the proponents of such development to review the risk assessments contained in the TSA and to determine whether the risk is tolerable or not, and whether to proceed with the development on this basis.

11. Summary of Recommendations

The recommendations are not intended as an evaluation of the acceptability of either the present risk or residual risk given the implementation of a risk reduction strategy. In addition, some risk reduction strategies may result in increased risks for other downslope values so any measures implemented must consider the potential for both positive and negative consequences.

All watersheds with a moderate (or higher) rating for Hazard Likelihood or Spatial Likelihood are further evaluated below.

11.1. General Recommendations: all affected drainages

Residents located adjacent to the creeks and watersheds discussed should be provided an electronic copy of this report. During periods of elevated risk:

- high flows during spring runoff (precipitation or snowmelt driven),
- summer rainstorm events (thunderstorms or convective cells), and
- fall storms with significant precipitation (generally with rain on snow events),

residents should be diligent with regards to work/travel adjacent to the local creeks and be aware of any sudden changes to creek flows (rapid increase or decrease in flows, or flow pulses), colour, or debris (logs, boulders, sediment) transport.

Residents should familiarize themselves with the creeks, their location relative to the creeks, and where damages would be sustained if flooding/debris flows were to occur. If changes are observed, they should be reported promptly to the Ministry of Emergency Management and Climate Readiness (EMCR) at 1 (800) 663-3456.

Residents should be vigilant by monitoring the creeks for turbidity and monitoring weather forecasts and local weather conditions; spatial variability of precipitation rates can be significant in mountainous terrain and should be prepared to evacuate on short notice during times of elevated risk.

Residents should familiarize themselves with the *Landslide and Flooding Risks due to Wildfires* and the *Debris Flow Hazard Awareness in the Kootenay Region* brochures published by the MOF, both of which are attached in Appendix C.

11.2. Water Points of Diversion

There are numerous points of diversion for licensed water use for domestic, irrigation or power usage throughout the Fire; these are shown on Maps 1 and 2 in Appendix A. Consideration should be given to either building protective structures around the licensed water intakes or developing contingency plans to provide an alternate source of water in case of damage to the intake or elevated levels of turbidity which render the water undrinkable.

If flow to residences is cut off for any reason, care should be exercised in resolving the issue. Loss of flow in a creek could be an indication that water is being ponded upslope; when this is released, the resulting flood could be highly charged with sediment and woody debris which might be very destructive. Review of the water intake is recommended to occur initially from a distance outside of the creek channel and after a suitable period of time to avoid being caught in floodwaters or by a debris flow.

Note that research has shown that heavy metal concentrations and biological contamination may increase in streams effected by wildfire. As such, residents obtaining water from wildfire effected creeks should consider testing their drinking water for heavy metal contamination and biological contamination.

11.3. Ringrose Creek

Ringrose Creek has a moderately sloped (30%) alluvial fan at the outlet of a small steep watershed which was moderately burned (EBSI = 12.1; very low adjusted to low incremental post-wildfire hazard). This creek is assessed to be a debris flow prone creek, capable of producing and transporting debris flows to the apex of the alluvial fan which is about 150 m upslope of the Highway.

The residence at 8246 Highway 6 is located 25 m south of the southwest creek draw on the mid-slope of the alluvial fan. There is potential for avulsion of the fan channel to the south as the creek becomes less confined on the alluvial fan. **There is a moderate partial risk to the residence at 8246 Highway 6. It is recommended that the property owner consider enlargement and armouring of the creek channel and construction of a berm along the south side of the channel to prevent debris and flow avulsion.**

The residence at 8252 Highway 6 is located between two potential creek channels on the mid-slope of the alluvial fan. There is potential for avulsion of the fan channels as the creek becomes less confined on the alluvial fan. **There is a moderate partial risk to the residence at 8252 Highway 6. It is recommended that the property owner consider enlargement and armouring of the creek channels and construction of berms along the south side of the northwest channel and along the north side of the southwest channel to prevent debris and flow avulsion.**

Note that the above recommendations are conceptual in nature and implementation of a berm structure and enlarged and armoured channel will require detailed study and design by an appropriate Qualified Registered Professional and may require authorization under the Water Sustainability Act.

The Highway is located 150 m west of the apex of the alluvial fan over moderate gradient slopes. There is potential for debris flow, debris flood or flood activity crossing the fan and impacting the Highway. The Highway is cambered to the uphill side and most of the flow will be directed into the ditch on the east side of the Highway.

There is a moderate partial risk to the Highway. Two potential creek channels reach the Highway and it is recommended that the MoTT clean and maintain the inlets of the culverts on both

channels and determine if the culverts are functional. It is also recommended that MOTT review the fan and creek channels to determine if their culverts are of sufficient size to convey the expected elevated streamflow and associated sediment load, and, if required, upgrade the culvert.

11.4. Vincent Creek

Vincent Creek has a short steep watershed which was moderately burned by the Fire (EBSI = 19.8; low incremental post wildfire hazard). The creek is assessed to be a debris flow prone creek, capable of producing and transporting debris flows to the apex of the alluvial fan.

The residences at 8990 and 9006 Springer Creek Road are located on the mid and lower portions of the gently to moderately sloped alluvial fan. There is potential for avulsion of the fan channel as the creek becomes less confined on the alluvial fan. There is a low partial risk to the residences at 8990 and 9006 Springer Creek Road.

The residence at 9002 Springer Creek Road is located on the upper portion of the gently to moderately sloped alluvial fan. There is potential for avulsion of the fan channel as the creek becomes less confined on the alluvial fan. **There is a moderate partial risk to the residence at 9002 Springer Creek Road. It is recommended that the property owner consider enlargement and armouring of the creek channel and construction of berms along the channel to prevent debris and flow avulsion.**

Note that the above recommendation is conceptual in nature and implementation of a berm structure and enlarged and armoured channel will require detailed study and design by an appropriate Qualified Registered Professional and may require authorization under the Water Sustainability Act.

11.5. Roads, Trails and Fireguards

Culverts and drainage infrastructure on all roads, trails and fireguards within and below the Fire should be inspected and maintained regularly by the appropriate permit holder or owner. Increased flows are expected in many of the creeks, especially those that were burned more severely (i.e., have a higher EBSI). In addition to increases in water, sediment load and calibre of sediment may increase and should be accounted for when reviewing the efficacy of ditches and culverts to convey the post wildfire flows.

12. Closure – Report Use and Limitations

This report was prepared for the exclusive use of MOF, EMCR, MoTT and RDCK. Copies can be distributed to other stakeholders and local residents. The material in it reflects SNT Geotechnical Ltd.'s best judgment and professional opinion in light of the information available to it at the time of preparation. Any use which a third party makes of this report or any reliance on or decision to be made based on it are the responsibility of such third parties. SNT Geotechnical Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decision made or action based, or lack thereof, on this report. No other warranty is made, either expressed or implied.

The report and assessment have been carried out in accordance with generally accepted professional practices in B.C. The discussion and recommendations presented are based on available information and limited field investigation and inferences from surficial features. No subsurface investigation was carried out as part of this assessment or development of conclusions or recommendations. Inherent variability in local precipitation, run-off conditions, soil and vegetation burn severity, surface and subsurface conditions may create unforeseen situations. Property boundaries (private, municipal, reserve, crown) referred to on maps and in the text were obtained via publicly available cadastral layers overlain onto orthoimagery and is approximate and may not be accurate for the purposes of locating risk mitigation strategies. Boundaries should be confirmed prior to design and implementation of risk mitigation strategies.

Report prepared by:

PROFESSIONAL
PROVINCE OF
T. R. GILES
20573
BRITISH COLUMBIA
GEOSCIENTIST

December 18, 2024

Tim Giles, P.Geo.
SNT Geotechnical Ltd.

EGBC Permit to Practice Number
1001083

Reviewed by:

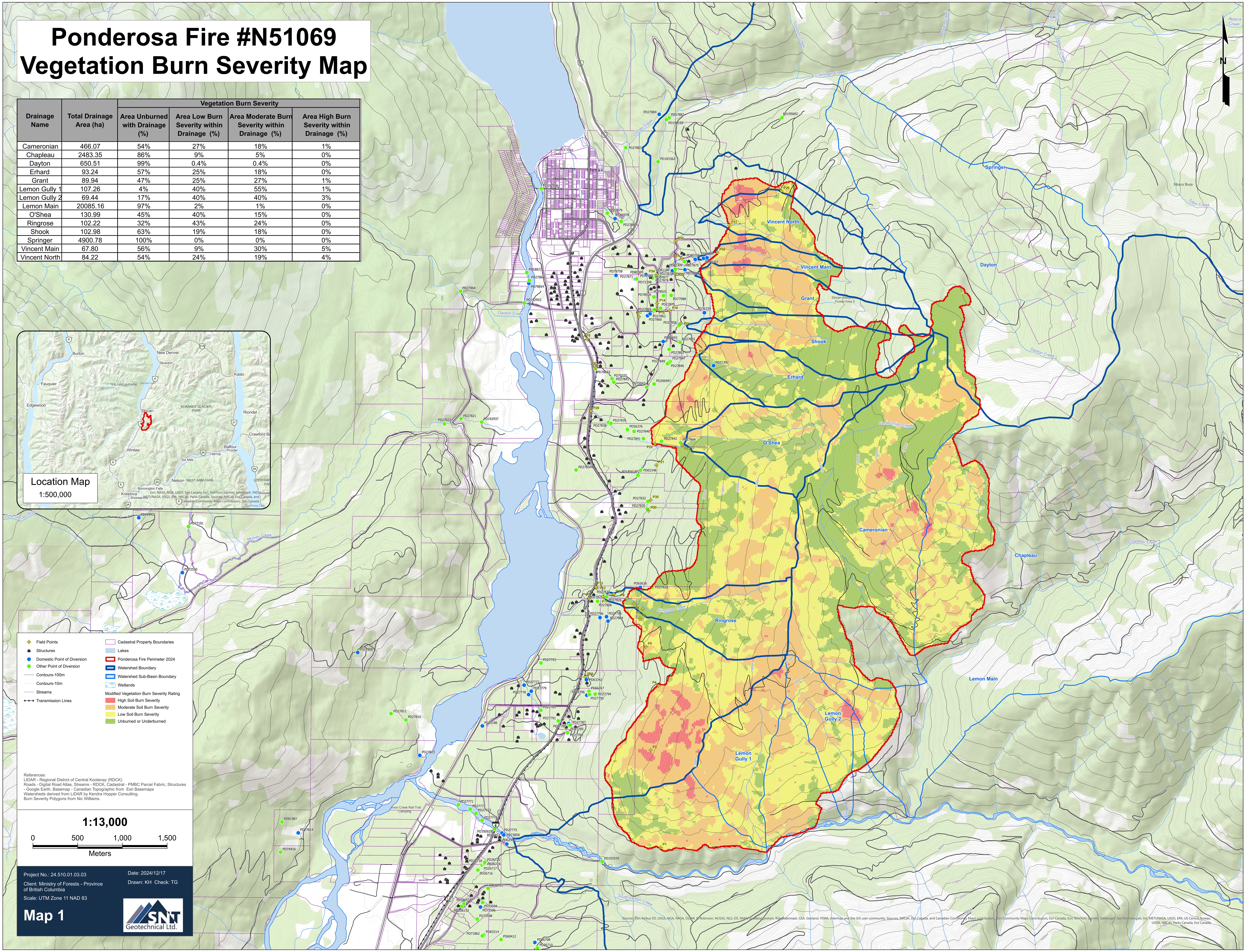
Ryan Williams, P.Geo
SNT Geotechnical Ltd.

Doug Nicol, P.Eng.
SNT Geotechnical Ltd.

APPENDIX A
Maps

Ponderosa Fire #N51069
Vegetation Burn Severity Map

Drainage Name	Total Drainage Area (ha)	Vegetation Burn Severity			
		Area Unburned with Drainage (%)	Area Low Burn Severity within Drainage (%)	Area Moderate Burn Severity within Drainage (%)	Area High Burn Severity within Drainage (%)
Cameronian	466.07	54%	27%	18%	1%
Chapleau	2483.35	86%	9%	5%	0%
Dayton	650.51	99%	0.4%	0.4%	0%
Erhard	93.24	57%	25%	18%	0%
Grant	89.94	47%	25%	27%	1%
Lemon Gully 1	107.26	4%	40%	55%	1%
Lemon Gully 2	69.44	17%	40%	40%	3%
Lemon Main	20085.16	97%	2%	1%	0%
O'Shea	130.99	45%	40%	15%	0%
Ringrose	102.22	32%	43%	24%	0%
Shook	102.98	63%	19%	18%	0%
Springer	4900.78	100%	0%	0%	0%
Vincent Main	67.80	56%	9%	30%	5%
Vincent North	84.22	54%	24%	19%	4%



References:
LIDAR - Regional District of Central Kootenay (RDCK)
Roads - Digital Road Atlas, Streams - RDCK, Cadastral - PMBC Parcel Fabric, Structures - Google Earth. Basemap - Canadian Topographic from Esri Basemaps
Watersheds derived from LiDAR by Kendra Hopper Consulting.
Burn Severity Polygons from Nic Williams.

1:13,000

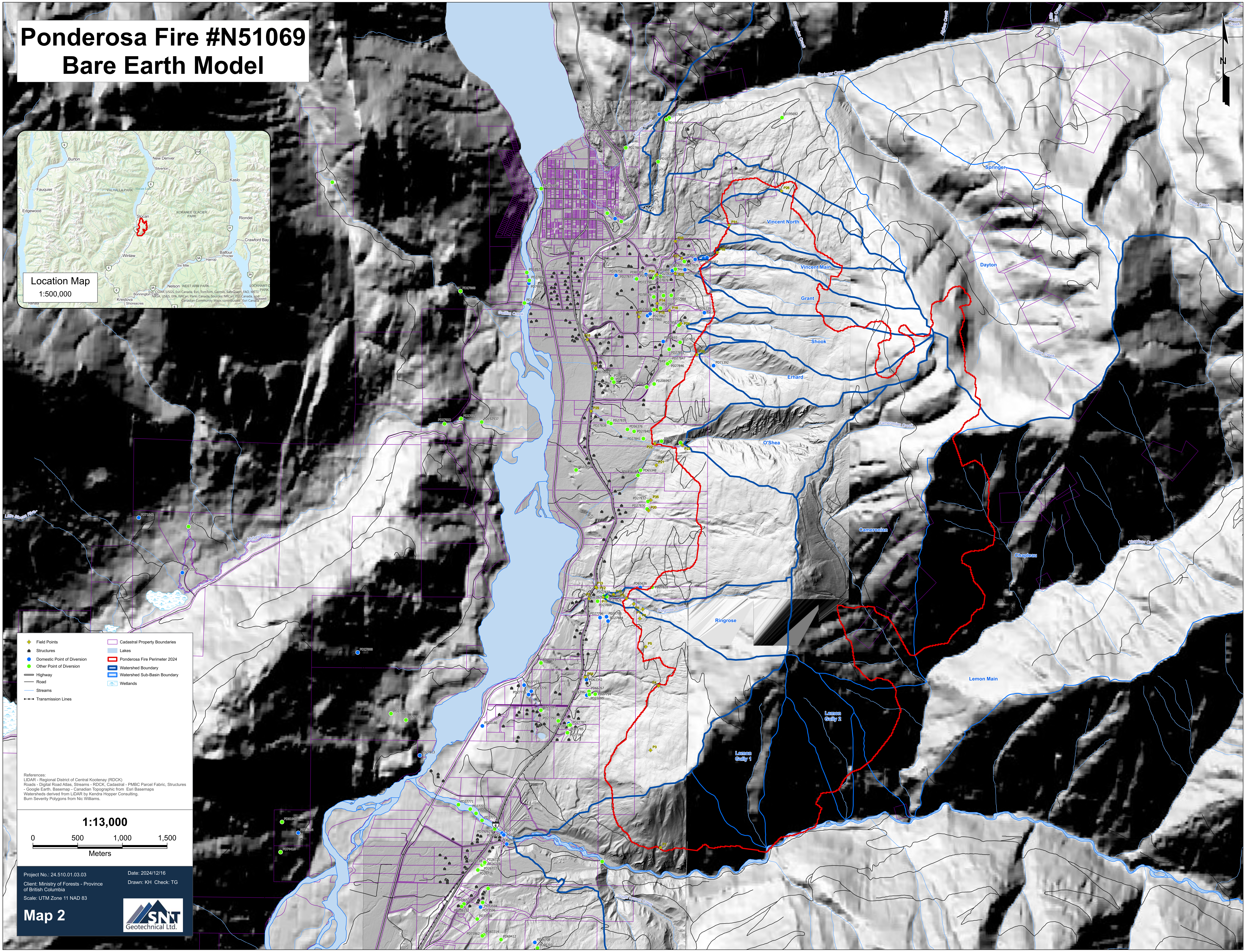
Project No.: 24.510.01.03.03
Client: Ministry of Forests - Province of British Columbia
Scale: UTM Zone 11 NAD 83

Date: 2024/12/17
Drawn: KH Check: TG

Map 1

SNT Geotechnical Ltd.

Ponderosa Fire #N51069
Bare Earth Model



- Field Points
- Structures
- Domestic Point of Diversion
- Other Point of Diversion
- Highway
- Road
- Streams
- Transmission Lines
- Cadastral Property Boundaries
- Lakes
- Ponderosa Fire Perimeter 2024
- Watershed Boundary
- Watershed Sub-Basin Boundary
- Wetlands

References:
LIDAR - Regional District of Central Kootenay (RDCK)
Roads - Digital Road Atlas, Streams - RDCK, Cadastral - PMBC Parcel Fabric, Structures - Google Earth. Basemap - Canadian Topographic from Esri Basemaps
Watersheds derived from LiDAR by Kendra Hopper Consulting.
Burn Severity Polygons from Nic Williams.

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Meters

Project No.: 24.510.01.03.03
Client: Ministry of Forests - Province of British Columbia
Scale: UTM Zone 11 NAD 83
Date: 2024/12/16
Drawn: KH Check: TG

Map 2

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APPENDIX B
Ponderosa FSR – Post-Wildfire Level 2 Reconnaissance Report

MINISTRY OF FORESTS: POST-WILDFIRE NATURAL HAZARD RISK ANALYSIS

PONDEROSA FSR - LEVEL 2 RECONNAISSANCE REPORT

NOTE: The results given on this form are reconnaissance in nature and are intended to be a warning of potential hazards and risks. ***A more detailed report will follow*** *and may alter the conclusions. Please read the appendix of this report for important limitations. Contact the author for more information.*

FIRE NUMBER: N51069 Ponderosa FSR	**FIRE YEAR: 2024**	**DATE OF REPORT:** September 11, 2024

AUTHOR: *Sarah Crookshanks, P.Geo., Ministry of Forests*

REPORT PREPARED FOR: Southeast Fire Centre, District Manager

FIRE SIZE, LOCATION, AND LAND OWNERSHIP: 1860 ha on provincially managed public land and private land southeast of the village of Slocan

VALUES AT RISK:

1. Private residences and/or potentially occupied buildings along Highway 6 and Martens Road
2. Domestic surface water quality on creeks originating from within the fire
3. Highway 6 and Austyn, Martens and Springer Roads

WATERSHEDS AFFECTED	TOTAL AREA	AREA BURNED	BURN SEVERITY (% of watershed area)
Lemon Creek	20200 ha	664 ha (3%)	0% H, 1% M
Ringrose Creek	126 ha	85 ha (67%)	0% H, 25% M
O'Shea Creek	128 ha	74 ha (57%)	0% H, 16% M
Vincent Creek	50 ha	22 ha (43%)	4% H, 28% M
Unnamed Creek N of Vincent	50 ha	23 ha (45%)	0% H, 19% M
Shook Creek	73 ha	29 ha (39%)	0% H, 22% M
Grant Creek	79 ha	41 ha (52%)	1% H, 27% M
Erhard Creek	74 ha	29 ha (39%)	4% H, 28% M

SUMMARY OF POST-FIRE HAZARD AND RISK

1. Hazard = P(H), the probability of occurrence of a hazardous event
2. Probability of spatial impact, P(S:H), the probability of a hazard reaching or affecting an element at risk
3. Partial Risk, the probability of a hazard occurring and affecting an element at risk = P(H) x P(S:H)
4: Location with the highest risk rating given; at other locations the risk may be lower

Debris flow or flood on Ringrose Creek impacting private residences

Hazard P(H)[1] = moderate Probability of spatial impact P(S:H)[2] = moderate Partial Risk[3,4] = moderate

Ringrose Creek is a small catchment with a small, round alluvial fan midslope above the valley bottom that spans the highway. The watershed is short and steep (640 - 1700 m) with a Melton ratio of 0.9. The morphology of the watershed and fan would suggest that it is subject to debris flows. However, the degree of watershed activity appears to be low. Most of the burn in this watershed is low, but the patches of moderate burn severity are located on steep ground in the drainage headwaters; therefore, the debris flow hazard is rated as moderate. Several houses are located on the Ringrose Creek fan, but none are located near its apex. Field investigation as part of a more detailed (level 3) assessment is recommended to confirm the probability of spatial impact and risk of avulsion.

Debris flow or flood on Ringrose Creek impacting Highway 6
Hazard P(H)[1] = moderate Probability of spatial impact P(S:H)[2] = high Partial Risk[3,4] = high

The highway crosses the fan a third of the way downslope from the apex. Ringrose Creek passes under the highway through a 500 mm culvert. If a debris flow or flood event were to occur on Ringrose Creek, the highway would almost certainly be impacted given the steep fan gradient, small culvert, and limited storage capacity in the ditch upslope of the highway.

Debris flow or flood on O'Shea Creek impacting private residences and Highway 6
Hazard P(H)[1] = low Probability of spatial impact P(S:H)[2] = moderate Partial Risk[3,4] = low

O'Shea Creek is a small catchment (1.3 km^2) with a large (0.6 km^2) fan at its outlet. The watershed is short and steep (700 - 1760 m), and the catchment's sidewalls are highly gullied with patches of exposed soil and rock that were exposed before the fire. Lidar hillshade imagery shows evidence of historical channels across the fan's surface. The morphology of the watershed would suggest that it is subject to debris flows, though the fan may indicate a greater susceptibility to debris floods. Additional field work is required to confirm the dominant process. Due to the mostly low burn severity in the O'Shea Creek watershed, the debris flow or debris flood hazard in this catchment has only slightly increased post-fire and is thus rated as low.

The RDCK mapping indicates 11 address points on the O'Shea Creek fan; most are located along the downslope perimeter of the fan, except for one structure located midway up the fan. Field investigation as part of a more detailed (level 3) assessment is recommended to confirm the probability of spatial impact and risk of avulsion.

Debris flow or flood on draws north of O'Shea Creek impacting private residences and Highway 6
Hazard P(H)[1] = low Probability of spatial impact P(S:H)[2] = moderate Partial Risk[3,4] = low

There are several long narrow drainages to the north of O'Shea Creek (Erhard, Shook, Grant and Vincent Creeks) that do not have mapped alluvial fans, yet they are small, steep watersheds with channel gradients averaging around 40%. Field investigation as part of a more detailed (level 3) assessment is recommended to evaluate how active these watersheds have been historically, as well as the probability of spatial impact to elements at risk. Lidar data would be very helpful in delineating the watershed areas of these draws, as well as better evaluating the hazards from these drainages.

Burn severity across these four drainages is mostly low and moderate, with several small high burn severity patches. The headwaters of these drainages remain largely unburned, and the total burned area in these watersheds are 40-50%. The hazard and probability of spatial impact are rated as low for these drainages, but additional work is recommended to better refine these estimates.

FURTHER ACTIONS

A more detailed (level 3) assessment for the Ponderosa FSR fire is recommended to verify the hazard and risk to private residences, infrastructure, and drinking water quality.

COMMENTS

The Ponderosa FSR fire was discovered on July 18, 2024, and burned over 1800 hectares. Only limited field assessment was conducted for this fire, given that a more detailed assessment is forthcoming. This analysis relies on vegetation burn severity mapping which was corroborated with visual observations made during a helicopter overflight of the fire on August 23, and several isolated soil burn severity plots near the south end of the fire that were collected on August 22. Watersheds were delineated using TRIM topographic data. Lidar data, if available, would significantly improve watershed area estimates.

The fire burned the western face between Lemon Creek to the south and Springer Creek to the north. This slope ranges in elevation from 600 m to 1700 m. The drainages to the north exhibit flat-over-steep terrain, where the upper portions of the watersheds are gently sloping and drain into steeper draws below. Ringrose Creek to the south has a more consistent channel gradient from top to bottom.

Due to the proximity to private land and the reliance on surface water for domestic use in the area, further analysis of post-wildfire natural hazards for this fire is recommended. A more detailed report will be released at a later date that will expand on the hazards and risks outlined here and may alter conclusions.

All members of the public, and specifically water users, should avoid spending time in debris flow prone creek channels during or immediately after intense rainstorms, or during periods of rapid snowmelt. Episodic water quality impacts to surface domestic water users on sources originating from within the fire perimeter are anticipated. More detail on this risk will be included in the forthcoming more detailed (level 3) report.

SIGNATURE, SEAL, FIRM PRACTICE #	ATTACHMENTS
SCrookshanks September 12, 2024 PROFESSIONAL GEOSCIENTIST PROVINCE OF BRITISH COLUMBIA S. D. I. CROOKSHANKS # 37362 Sarah Crookshanks, P.Geo. Ministry of Forests Permit to Practice #1003022 Reviewed by: Gareth Wells, P. Geo	See attached map, photos and Appendix

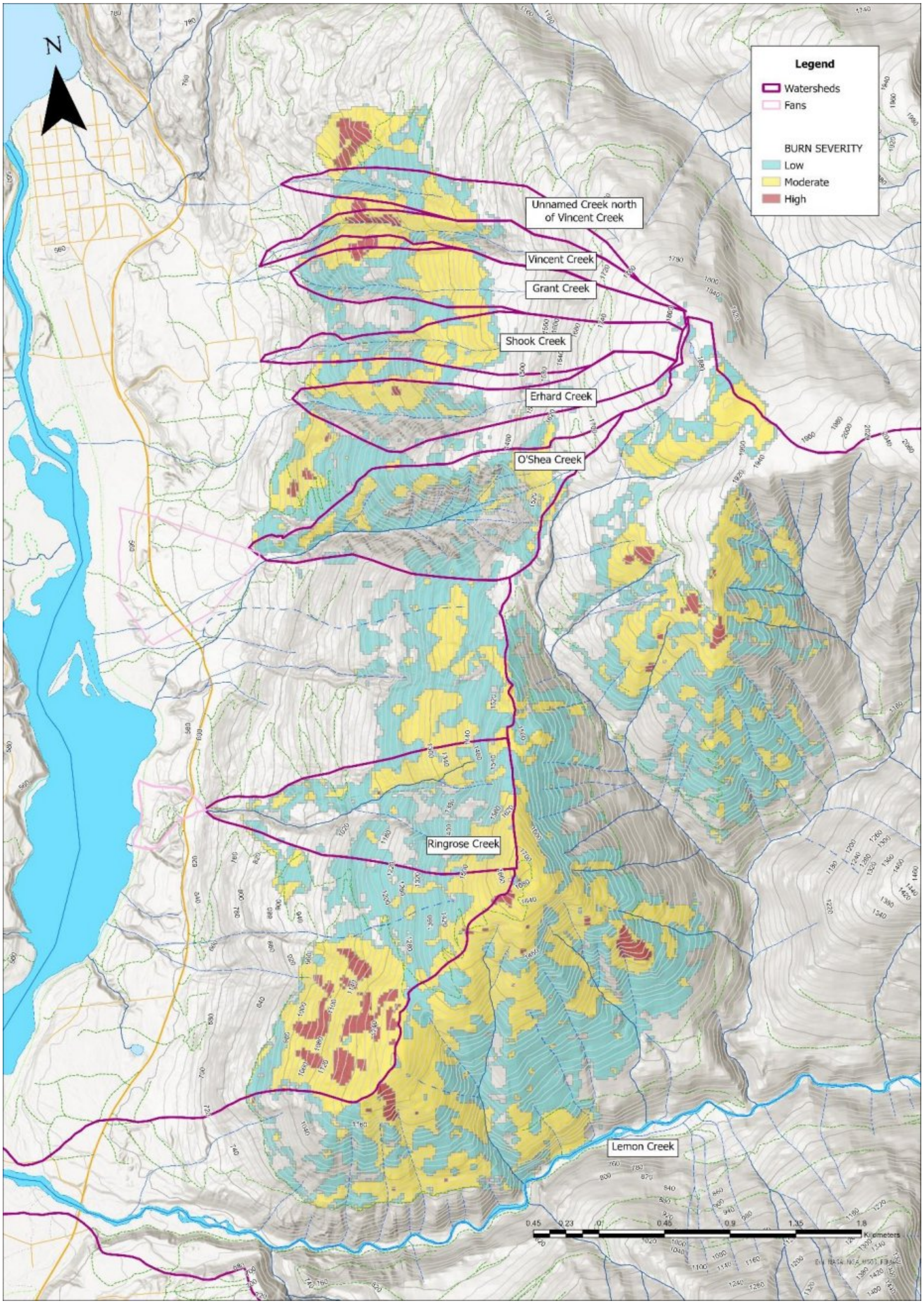


Figure 1 Soil burn severity map of the Ponderosa FSR fire showing estimated classes derived from Sentinel-2 imagery and some limited field work (prefire: July 7, 2024 post-fire: August 11, 2024). Further work may alter the estimated burn severity classes.

Figure 2. Overview of the Ponderosa FSR fire looking north (Photo: T. Giles, SNT Geotechnical).

Figure 3. Overview of the Ponderosa FSR face including O'Shea Creek and Ringrose Creek (Photo: T. Giles, SNT Geotechnical).

Figure 4. Overview of the Ponderosa FSR face including the drainages to the north of the O'Shea Creek (Photo: T. Giles, SNT Geotechnical).

Figure 5. Headwaters of Vincent Creek (Photo: T. Giles, SNT Geotechnical).

Appendix to PWNHRA Reconnaissance Reports

Scope of Reconnaissance (Level 2) Reports

Reconnaissance (Level 2) reports are primarily intended to identify whether post-wildfire hazards are likely to occur and need detailed investigation to protect identified elements at risk. Identified elements at risk are generally limited to public safety and infrastructure. Reconnaissance reports may also be used to assess safety conditions for wildfire fighters. In some cases, the MOF District Manager or other MOF personnel may request assessments for non-standard elements at risk or for other reasons.

Definitions of Hazard and Risk

Wildfire may produce conditions conducive to a suite of hazards. Debris flows, debris floods, and floods are often the most important hazards, but other types of landslide hazards including rockfall, debris slides and earthflows can also occur in response to wildfire. Wildfire can also cause snow avalanches and may affect water quality, cause erosion and result in sedimentation. Terrain, watershed, and channel conditions that produce post-wildfire hazards may also produce similar hazards in unburned conditions; these hazards may be mentioned but are not evaluated in this report.

P(H), P(S:H) and partial risk are presented for each identified elements at risk. Multiple types of channel hazards (debris flows, debris floods, floods) may affect an element at risk. These hazards are ranked by severity, with debris flow as the most damaging and destructive and flood as the least damaging and dangerous, and ratings are given for the highest rating hazard that may affect an element at risk. For example, where a channel has the potential for a debris flow and an element at risk may be affected, the lower ranking debris flood and flood hazards are not rated, since discharge and velocity are likely to be less than for a debris flow. These processes may cause erosion or sedimentation that affects the element at risk. Hazards that are unlikely to affect an identified element at risk are not discussed.

Table A1 shows the annual probability ranges for qualitative definitions of P(H). The probability of the hazard occurrence is for the post-wildfire period of elevated hazard, which in many cases may be less than five years, but in some cases may extend for several more years.

Table A1. Qualitative descriptions of post-wildfire hazard likelihood, hazard criteria, and related quantitative probabilities.

Post-wildfire hazard rating	Description	Annual Probability Range
Very High	An event is expected to occur. Most of the catchment or face unit has burned with a significant proportion burned at moderate and/or high severity	>0.2
High	An event is probable under adverse conditions. Most of the catchment or face unit has burned with a significant proportion (i.e., >50 %) of terrain conducive to post-wildfire natural hazard initiation burned at moderate or high severity. Existing indicators of pre-fire terrain instability within stream channels, on fans or face units.	0.01 - 0.2
Moderate	An event could occur under adverse conditions. It is not probable but possible over a several year period. More than 20% of the terrain conducive to post-wildfire natural hazards in the catchment or on the face-unit has burned with moderate and/or high severity. Historic geomorphic indicators of instability are present.	0.002 – 0.01
Low	An event could occur under very adverse conditions. It is considered unlikely over a several year period. Only a limited proportion of the catchment or face unit has burned. Few or no signs of pre-fire instability present along stream channels, fans or face units.	0.0004 – 0.002
Very Low	An event will not occur or is conceivable though considered exceptionally unlikely. A limited proportion/none of the catchment was burned. No terrain instability indicators are present	<0.0004

Table A2 defines spatial impact to an element of risk. Post-wildfire event magnitude is considered when rating spatial impact.

Table A2. Post-wildfire spatial impact.

Likelihood of spatial impact	Description	Probability range
H	It is probable that the event will impact the element at risk.	>0.5
M	It is possible that the event will impact the element at risk.	0.5 - 0.1
L	It is unlikely that the event will impact the element at risk.	< 0.1.

Table A3 is a matrix which combines the hazard likelihood (Table A1) with the spatial impact likelihood (Table A2) to determine partial risk.

Table A3. Post-wildfire risk matrix partial risk matrix.

Hazard Likelihood P(HA) (Table 1)	Spatial Impact Likelihood (P(S:H)) (Table 2)		
	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

Report Standards

FLNRORD Land Management Handbook 69 is the primary standard followed in this report. LMH 69 describes the process to complete a detailed report. This reconnaissance report uses the framework of LMH 69 but does not follow it where detailed assessment procedures are described.

Land Management Handbook 69 Post Wildfire Natural Hazards Risk Analysis in British Columbia 2015
https://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh69.htm

Additional guidance is provided in the MOF SOG for PWNHRA and the 2014 FLNRO Landslide Risk Management Procedure.

Other professional guidance standards that may be used for the preparation of reconnaissance reports are listed below. These guidelines have similar report content to this reconnaissance assessment, but are for different purposes, have different levels of appropriate effort, and do not recognize the potential emergency nature of this reconnaissance assessment. These guidelines include:

EGBC Guidelines for TSA in the Forest Sector 2010
https://www.egbc.ca/getmedia/684901d7-779e-41dc-8225-05b024beae4f/APEGBC-Guidelines-for-Terrain-Stability-Assessments.pdf.aspx

EGBC Guidelines for Legislated Landslide Assessments 2010
https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx

Legislated Flood Assessments in a Changing Climate in BC 2018
https://www.egbc.ca/getmedia/f5c2d7e9-26ad-4cb3-b528-940b3aaa9069/Legislated-Flood-Assessments-in-BC.pdf

Watershed Assessment and management of hydrologic and geomorphic risk in the Forest Sector
https://www.egbc.ca/app/Practice-Resources/Individual-Practice/Guidelines-Advisories/Document/01525AMW2ATQA5BSODHJAKBAGZDYTRL6FJ/Watershed%20Assessment%20a

nd%20Management%20of%20Hydrologic%20and%20Geomorphic%20Risk%20in%20the%20Forest%20Sect

Other standards may also apply, depending on the professional qualifications of the writer.

Statement of Limitations

Reconnaissance PWNH Level 2 assessments are typically done in constrained timelines where personnel, resources, data collection, and analysis methods are limited. Post-wildfire hydrogeomorphic hazards in BC are not well understood and therefore hazard and risk assessments are estimates only. While probabilities ranges are given in Tables A1 and A2, the state of the science in BC does not allow for precise assessments, particularly near the borders of classes. Numeric probabilities ranges do not imply precision.

Identification of elements at risk relies on BC government data layers, satellite imagery, and perhaps an overview flight. BCWS and the MOF district office may provide additional information. No further confirmation of elements at risk was conducted.

Comments, conclusions, and suggestions contained in this reconnaissance assessment reflect my experience and judgement considering the information available to me at the time that this report was prepared and are considered appropriate for the reconnaissance nature of the review. The review has been carried out in accordance with generally accepted professional practices. This assessment and its contents are intended for the sole use of post-wildfire hazard management by provincial agencies, First Nation governments and local governments. I do not accept any responsibility for the accuracy of any of the data, the interpretation, or the conclusions contained or referenced in the report when the report is used or relied on for any other purpose than specified. Any such unauthorized use of this report is at the sole risk of the user.

APPENDIX C
Landslide and Flooding Risk Awareness Brochures

Shorts Creek drainage, burned by 2009 Terrace Mountain fire.

Introduction

This pamphlet describes (1) how wildfire may increase the risk of natural landslides and flooding hazards, (2) what to watch for, (3) how this knowledge will help you avoid putting yourself and your family in danger, and (4) what to do in case of an emergency.

1 How does wildfire potentially increase the risk of landslide and flooding hazards?

Periodically, British Columbia experiences severe wildfires near urban or other populated areas, such as those that occurred in the summers of 1998, 2003, and 2009.

Severe wildfires damage the forest canopy, the plants below, as well as the soil. This can result in increased runoff after intense rainfall or rapid snowmelt, which can put homes and other structures below a burned area at risk of localized floods and landslides.

2 What are the specific hazards to watch for after a wildfire?

- Flooding, especially after intense downpours.
- Many types of landslides, however, the most common after wildfire are:
  - Debris flows, a specific type of fast-moving and powerful landslide resulting from heavy runoff carrying large amounts of soil, rocks, wood debris, and trees.
  - Rockfalls, resulting from fire-induced cracking of rocks, as well as the loss of stumps, logs, and roots, which normally hold loose rock in place.

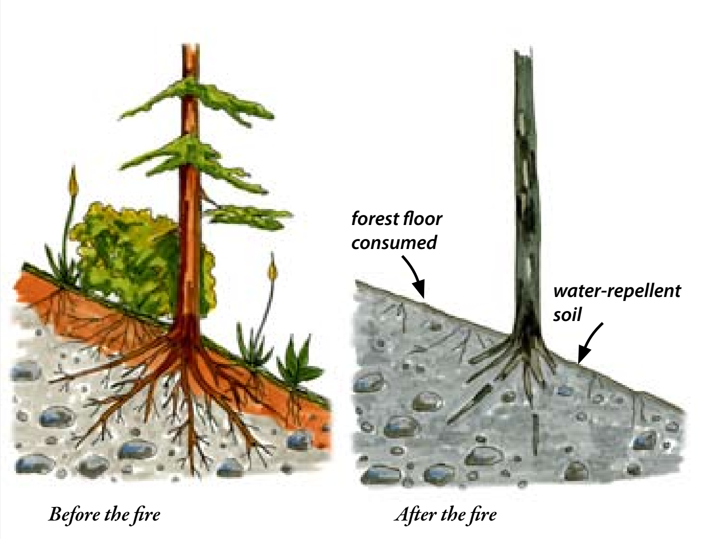
What are at risk?

- Residential, farm and industrial buildings that are downslope or downstream of a severe wildfire are at some risk of post-wildfire hazards. But the hazard may not be restricted to areas below large fires. Severe fires of only one or two hectares can in some cases trigger hazards. Structures that are below a recent wildfire, and near creeks, gullies or alluvial fans, are most at risk. Areas that have experienced flooding or landslides in the past are likely to have an increased chance of recurrences.
- Roadways, railway lines, pipelines and other infrastructure, including bridges downslope or downstream of fires, may also be obstructed, inundated, or washed out.
- Domestic or irrigation waterlines/intakes and other structures in gullies, streams, and creeks can be damaged or destroyed by a post-wildfire flood or landslide. These areas can be at risk during and even after an event due to channel blockages.

What are the weather conditions that trigger post-wildfire floods and debris flows?

The most common trigger is intense rainfall (e.g., 10 mm of rain in 20 to 30 minutes). The risk increases if this rainfall follows a prolonged dry period because dry weather can increase the water repellency of fire-altered soils. On the Coast, fall rainstorms are the most likely to cause post-wildfire floods or debris flows. Another trigger is rapid spring snowmelt in a drainage that has experienced a severe burn.

Evidence of concentration of overland flow on water-repellent soils. Kuskonook Creek drainage, August 2004.



Wildfires remove the protective ability of vegetation increasing runoff, erosion, debris flow, and the potential for landslides.

3 What are some things you can do to deal with post-wildfire hazards?

1. Be informed and be ready. Become familiar with the land and the normal drainage channels around you. Know where your home and property lies with respect to natural drainage channels. Find out if floods or landslides have occurred in your area in the past.
2. Contact your local authorities to learn about emergency response and evacuation plans for your area. Attend any meetings that are held to inform the public of local risks. Develop your own emergency plans for your family and business. Post-wildfire hazard events can occur with little advance warning.
3. If a fire has occurred on Crown land, a post-wildfire risk analysis may have been conducted to determine the safety risks to adjacent residential areas. Contact the local government office or Emergency Management BC (EMBC) to see if a risk analysis has been done for your area. Such analyses help determine the safety risks to residential areas adjacent to wildfires.

4 What should you do during a storm or heavy runoff event?

1. Be aware of forecasts that may include thunderstorms, or those with heavy rainfall warnings. Check the current forecast or use a VHF weather radio (www.msc.ec.gc.ca/msb/weatheradio/index_e.cfm).
2. Be alert when driving in an area that has had a recent wildfire. Washed-out bridges or culverts are especially dangerous, and roads below steep banks are susceptible to landslides. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of possible debris flows. Never drive across a flooded road.
3. If your home is in a location at risk, and severe weather is occurring or forecast, stay alert. Listen for unusual sounds—trees cracking or boulders knocking together—and watch for changes to water flows in local stream channels. Sleep in an upper floor of the house, not in the basement.
4. Do not enter channels or hike upstream to inspect waterlines or buildings. Consider leaving the area if it is safe to do so.
5. On forest land where a wildfire has recently occurred, avoid camping on floodplains, beside small streams, on alluvial fans or at the base of burned slopes. Also, be aware that forest roads may wash out if a flood occurs, cutting off access.

Kuskonook landslide near Creston, BC. This large debris flow occurred during a localized rainstorm on the night of August 6–7, 2004. The heavy rain caused rapid runoff in the headwaters of Kuskonook Creek, in an area burned by a severe wildfire the previous summer.

Mudflow from the 2009 Kelly Creek Fire after a severe rainstorm, August 2010.

How long does the post-wildfire risk last?

Post-wildfire risks begin as soon as an area is severely burned and last for another two or more years. However, increased floods and debris flow risks in some severely burned areas may last much longer. After two to three years, revegetation and breakdown of soil water repellency means the risk is considerably lower.

Do you need more specific information regarding your property?

Consulting geotechnical specialists can provide specific information about your property and post-wildfire hazards, risks, and potential mitigation techniques.

This bulletin provides general information only; it does not cover all hazards. Additional information resources are available:

- For current wildfires: www.bcwildfire.ca
- For current flooding information and Provincial Emergency Plan information and contacts: www.pep.bc.ca/Emerg_Mgmt_BC/Emerg_Mgmt_BC.html
- For Ministry of Forests and Range district offices and contacts: www.gov.bc.ca/for
- For more background information on natural hazards, and why they occur after wildfire please visit: www.for.gov.bc.ca/hre/ecoearth/wildfire

Citation
B.C. Ministry of Forests and Range. 2011. Landslide and flooding risks after wildfires in British Columbia. Wildfire Manag. Br., and For. Sci. Prog., Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/Docs/Bro/Bro91.htm

Landslide and Flooding Risks after Wildfires in British Columbia

What you can do to recognize and deal with the hazards

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Forests and Range

Debris Flow Hazard Awareness in the Kootenay Region

Debris flows are fast-moving mixtures of water, sediment, boulders and logs that flow down steep mountain creeks. In recent years, debris flows have caused fatalities, near misses and significant property damage in the Kootenays.

This document is intended to help you understand this hazard in the Kootenay Region, identify some indicators that could be cause for concern and learn how to report a potential emergency.

Figure 1. Debris flow material that was deposited on the Kuskanook Creek fan after a rainfall event in August 2004.

Figure 2. Debris flood on Memphis Creek. Note the large volume of floating debris in the lake and the uncharacteristically turbid water.

Get to know your watershed:

- Learn the history of debris flow hazards on or near your property and the areas you visit often, especially near the mouths of creek channels and alluvial fans. Flood hazard mapping is available through your local government and is a good initial reference. For example, the Non-Standard Flooding and Erosion Areas (NSFEA) hazard map can be accessed through the Regional District of Central Kootenay's Property Information Mapping System (mapinfo.rdck.bc.ca/Pims/).
- Be aware of dikes or flood control structures that may be protecting your property from flooding and/or debris flows. Structures that were built many years ago and are not being maintained may no longer be providing the protection it was designed for. A dam upstream of your property may also pose a hazard, depending on its condition and maintenance history. Refer to www.env.gov.bc.ca/wsd/public_safety/index.html to identify the locations of any such structures.
- If you live near or visit areas prone to debris flows, you should become familiar with the terrain between your property and the creek channel and fan apex. During a major flood event, creeks may suddenly change course and flow along a new or abandoned flood channel, and debris flow material may run out onto the fan area. Terrain features to be aware of include: abandoned creek channels; levees; scarred trees; and lobal deposit features.
- If you have concerns about debris flows impacting your property, you may wish to hire a qualified professional to provide additional assistance.

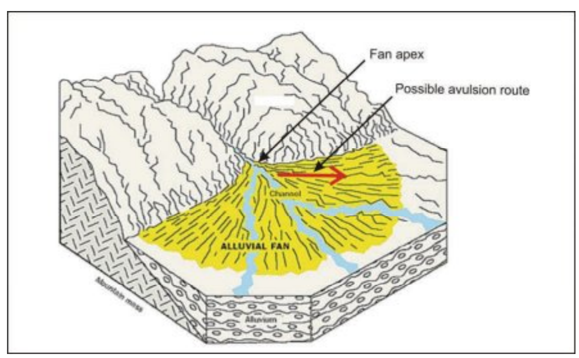


Figure 3. Schematic diagram of an alluvial fan, showing a possible flow route and geological features.

What you should do in an emergency:

- **To report a debris flow emergency that is occurring call 911.**
- **To report observations of these debris indicators, call the 24-hour provincial toll-free number: 1 800 663-3456**
- Local governments are responsible for responding to emergencies in their jurisdiction.
- The provincial government will provide technical expertise and assistance to local governments during emergencies. For more information, visit: www.embc.gov.bc.ca/index.htm

Debris flow hazard indicators:

- By monitoring the creeks near your property or the areas you visit frequently, you can become familiar with typical flow patterns and recognize any unusual events that may indicate a potential debris flow event.

- There are large natural variations in the water levels of creeks in the Kootenays associated with either snow-melt and heavy rainfall. Each creek responds differently, depending on the size and characteristics of its watershed.

  However, an unusually rapid increase or decrease in flow may indicate that the creek has been blocked by a landslide upstream or that a debris flow is about to occur. Call the provincial emergency number below to report your observations.

- Creeks in the Kootenays often flow dirty during spring runoff and after a major rainstorm. Dirty or turbid water does not necessarily indicate that a debris flow hazard exists.

  However, abnormally dirty water may signal that a landslide or bank failure has occurred up-stream. Pulses of sediment in a creek channel may also indicate that something unusual has occurred upstream. Call the provincial emergency number below to report your observations.

- A large volume of debris (logs, sediment, etc.) that accumulates in a creek channel or has recently been transported down the creek and is now floating near the mouth of the creek may indicate that a natural hazard event has occurred in the watershed.

  If you observe an unusually large and recent change in the accumulation of debris in a creek channel, call the provincial emergency number at 1 800 663-3456 to report your observations.

Figure 4. Turbid water in Gar Creek the day before the Johnson's Landing landslide on July 12, 2012.

Public Safety Advisory:

Use caution while spending time in a confined creek channel or gully that is prone to debris flows. Fatalities and close calls have occurred when people have been caught up in debris flows while working on their water intake systems.

To summarize, the following factors may indicate an upstream hazard:

- Abnormally dirty water
- Accumulation of large logs or debris in the creek
- Sudden changes in flow
- Pulses in flow (i.e. rapid changes in flow) or pulses of sediment
- Rapid accumulation of sediment or bedload along a flat section of a creek channel

Not all debris flows are preceded by these indicators.
Following the advice in this document does not ensure your safety.

To report the potential emergency, call the 24-hour toll-free number: 1 800 663-3456

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