ONSITE Engineering Ltd.

Post-Wildfire Natural Hazard Risk Assessment
Casper Creek Fire K71535
Seton Portage, BC

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1.0 Introduction

As requested by Gareth Wells, P.Geo, of the Ministry of Forests (MOF), Onsite Engineering Ltd. (OEL) has completed a Post-Wildfire Natural Hazard Risk Assessment (PWNHRA) for the Casper Creek fire (Fire K71535). The Casper Creek fire was discovered on July 11th, 2023, and was started by lightning or natural causes. The fire burned a total area of 11,284 hectares. The fire is located 24 km west of Lillooet, BC in the Anderson Lake – Seton Lake Valley. See Figure 1 for location map.

This assessment focuses on areas of concern and increased risks within, downstream, and downslope of the burn area. Areas of concern were identified during an overview assessment of the burn area that included a review of available topographic maps, watershed and hydrometric data, terrain stability mapping, burn severity mapping, and cadastral mapping identifying parcels of private land. Areas of concern were determined to consist of the following:

1) Gullied terrain upslope and downslope of Highline Road where debris flow events may initiate and impact the road and downslope properties;
2) The Whitecap Creek watershed due to the history of debris flood events from that system;
3) Gullied terrain upslope of Seton Portage;
4) Mission Mountain Road and associated terrain upslope and downslope of the road alignment;
5) Gullied slopes upslope of Mission Dam Road; and
6) Gullied slopes upslope of Road 40.

Known elements at potential risk from a natural hazard post-wildfire within, downstream, or downslope of the burned area include:

1) Seton Lake First Nations Band (Tsal'alh) and private land including Seton Portage, Shalalth, South Shalalth and Anderson Lake.
2) Highline Road between D'Arcy and Seton Portage, BC.
3) Mission Mountain Road and Mission Dam Road between Seton Portage, Terzaghi Dam, and Lillooet, BC.
4) Road 40 between Gold Bridge and Terzaghi Dam, BC.
5) Canadian National (CN) Railway on north shore of Anderson and Seton Lakes.
6) Numerous active points of diversion (POD) located on multiple creeks within and downstream of the burn area.
7) Mission Dam Recreation Site and Whitecap Campground.
8) BC Hydro (BCH) Transmission line throughout the study area. Note risk has been assessed to tower locations only and lines typically span the most concerning draws or gullies.

2.0 Rationale for the PWNHRA

This PWNHRA was commissioned at the request of the MOF. The Casper Creek fire encompassed the Bridge and Seton Rivers, Carpenter, Anderson, and Seton Lakes, and several small towns on Seton and Anderson Lakes were evacuated. As slope stability and gully processes are affected by wildfire, the area is of high risk to natural hazards post-wildfire. Therefore, the MOF has retained OEL to complete a PWNHRA for the wildfire area.

The objective of this PWNHRA is to undertake a partial risk assessment of the burn area and the associated roads, slopes, and water courses at risk from altered geomorphic and hydrologic effects due to the wildfire. The PWNHRA will also provide recommendations to reduce the hazard or risk to the identified elements at risk as required.

3.0 Methodology

This PWNHRA follows the guidelines recommended in *Land Management Handbook No. 69 (LMH #69) – Post-Wildfire Natural Hazards Risk Analysis in British Columbia* (2015).[1] This report will be used to inform residences, landowners, and industry stakeholders of the hazards and risks associated with the Casper Creek wildfire. Recommendations based on the findings will be given in this report to reduce the risks to First Nations communities, transportation corridors, utilities, residences, and water quality.

The study approach started with background research and was followed by a helicopter overview flight and field work that focused on identified areas of concern. Within the report, areas of concern are described, partial risks evaluated, and recommendations are given to reduce risks.

Fieldwork was completed from October 17 – 20, 2023, by Rod Williams, P.Geo., and Rayleen Wilson, GIT, of OEL. Fieldwork consisted of a helicopter overview flight by Blackcomb Helicopters on October 17th, followed by a review of areas of concern with respect to terrain stability within the burn area. Conditions at the time of field work were raining and overcast with sunny periods. There were no visibility barriers due to cloud cover as sites were revisited during clear periods. Fieldwork included photographs, drone photography, field notes, and hand-dug soil test pits. Data was collected on tablets with georeferenced maps on the Avenza app.

3.1 Risk Assessment Approach

Hazard and risk are defined in the LMH #69 as;

> **Hazard:** processes and situations, and actions or non-actions, that have the potential to damage, harm, or cause other adverse effects to human health, property, the environment, or other things of value [and] can be expressed in qualitative (relative) terms or in probabilistic (quantitative) terms;
>
> **Risk:** a combination of the magnitude and probability of adverse effects, based on the likelihood of something happening and the consequence if it does happen.[2]

Post-wildfire hazards include erosion, sediment transport, debris flows, debris floods, debris slides or slumps, rockfalls, and/or snow avalanches. This PWNHRA is a qualitative partial risk assessment that follows the approach in the Land Management Handbook No. 69 (2015). This report prioritizes hazardous sites and recommends mitigation techniques to reduce the hazard, and therefore reduce the risk. Partial risk is the probability of occurrence of a specific hazard and the probability of that hazard reaching or otherwise affecting the site occupied by a specific element and is expressed as the equation:

$$P(HA) = P(H) \times P(S{:}H)$$

Where,

> P(HA) = partial risk
>
> P(H)[3] = probability of occurrence of a specific hazardous event
>
> P(S:H)[4] = spatial probability that the hazardous event will reach the elements at risk.

The probability of the specific hazardous landslide was evaluated using a combination of the level of burn in a given watershed or face unit, the dominant hydrogeomorphic processes, and background level of activity for each watershed or face unit. A methodology documented in recent post wildfire assessment work by BGC[5] was adapted for this assessment. A burn severity index was determined for each watershed (or face unit) based on the percentage

[1] Hope, G., P. Jordan, R. Winkler, T. Giles, M. Curran, K. Soneff, B. Chapman. 2015. Post-wildfire natural hazard risk analysis in British Columbia. Prov. B.C. Victoria, B.C. Land Manag. Handb. 69.

[2] Hope, G., P. Jordan, R. Winkler, T. Giles, M. Curran, K. Soneff, B. Chapman. 2015. Post-wildfire natural hazard risk analysis in British Columbia. Prov. B.C. Victoria, B.C. Land Manag. Handb. 69.

[3] Probability of occurrence of a specific hazardous landslide.

[4] Spatial probability relates to the potential of a landslide to reach or otherwise affect the site occupied by an element.

[5] Post-Wildfire Geohazard Assessment for Emergency Decision Support. Report prepared for the Columbia Shuswap Regional District by BGC Engineering Inc. 2023

of the area with high, moderate, and low burn severity (or unburned conditions). The area of high burn severity is multiplied by 0.7, moderate is multiplied by 0.2, and low is multiplied by 0.1. The unburned area of the watershed is multiplied by 0. A heavier weighting is given to those areas with a high burn severity as experience has shown that these areas are generally most susceptible to surface erosion and landslides and have the greatest hydrologic impacts on a watershed.

A hydrogeomorphic process index was determined for each watershed based on the assessed dominant hydrogeomorphic processes and history of events. Process 1 watersheds are those primarily subject to clear water flood events with a low debris flood potential during the most extreme storms. These are primarily low gradient streams. No Process 1 watersheds were identified in the study area as all streams extend up to steep mountainous terrain. Process 2 watersheds have a Melton ratio indicating debris floods are possible and can be expected during moderate to extreme storms. Whitecap Creek has been categorized as Process 2 as it has a history of debris flood events in addition to seasonal clear water flood events. Process 3 watersheds have morphometrics (i.e. a Melton ration greater than 0.3) indicating that they may host debris flood or debris flows during moderate to extreme storms. Process 4 watersheds have Melton ratios greater than 0.6 and the larger watersheds in this category were noted to have evidence of past debris flow and/or sediment transport during the field assessment. Under burned conditions, many of the Process 3 and 4 watersheds will be susceptible to debris flows if a moderate to extreme hydroclimatic event impacts the area over the next 5-10 years.

One limitation of the Hydrogeomorphic Process Index based on Melton ratios is that larger watersheds with significant debris flow hazards are not discernable from smaller watersheds and face unit swales that may produce more frequent, smaller, and less destructive events. This is a limitation of a partial risk assessment; however, in Table 6.1 we have described the expected magnitudes and runout in addition to the process and burn severity classifications to better inform stake holders in this area of the post wildfire risks.

The burn severity index is combined with the hydrogeomorphic process index to determine the post wildfire hazard likelihood. The use of the burn severity index in this calculation allows this assessment to differentiate watersheds that have had a high level of burn and an increased susceptibility to such events from those watersheds that are prone to events under natural or forested conditions.

Table 3.1.1 Estimated likelihood of post-wildfire hydrogeomorphic event – P(H)

Estimated likelihood of a post-wildfire hydrogeomorphic event - P(H)		**Hydrogeomorphic Process Index**			
		Watersheds primarily subject to clear water flood events with debris floods possible in extreme storms.	Watersheds prone to debris flood events during moderate to extreme storms.	Watersheds with morphometrics indicating debris flood or debris flow events are possible during moderate to extreme storms.	Watersheds with morphometrics indicating debris flow events are likely during moderate to extreme storms.
Burn Severity Index		**Process 1**	**Process 2**	**Process 3**	**Process 4**
Very High	**>40**	High	High	Very High	Very High
High	**30-40**	Moderate	High	High	Very High
Moderate	**20-30**	Low	Moderate	High	High
Low	**10-20**	Low	Low	Moderate	High
Very Low	**<10**	Very Low	Low	Low	Moderate

The post-wildfire likelihood is combined with the expected likelihood of impact to the specific element at risk (i.e. P(S:H)) to determine the partial risk to the element at risk as per the matrix below.

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Table 3.1.2 Post-wildfire partial risk rating – P(HA)

Post-wildfire partial risk rating – P(HA)	**Spatial Likelihood P(S:H)**				
P(H)	Very Low	Low	Moderate	High	Very High
Very High	Moderate	High	High	Very High	Very High
High	Low	Moderate	High	High	Very High
Moderate	Low	Low	Moderate	High	High
Low	Very Low	Low	Low	Moderate	High
Very Low	Very Low	Very Low	Low	Low	Moderate

4.0 Background Data

The following information was referenced as part of this assessment:

1) Bedrock geology mapping – Mapping available online at iMapBC (http://maps.gov.bc.ca/ess/sv/imapbc/).
2) Biogeoclimatic ecosystem classification mapping – Mapping available online at iMapBC (http://maps.gov.bc.ca/ess/sv/imapbc/).
3) Wildfire mapping – Current and Historic – Mapping available online at iMapBC (http://maps.gov.bc.ca/ess/sv/imapbc/).
4) Canadian Climate Normals – Data available online at the Government of Canada (https://climate.weather.gc.ca/climate_normals/index_e.html).
5) Images and digital terrain model obtained from Google Earth, copyright of the province of BC. 2023. The date of this imagery is listed as 2005, 2010, 2013, 2019, and 2021.
6) Burn Severity Mapping produced for and provided by the Ministry of Forests, dated October 10th, 2023.
7) The following digital airphotos were retrieved from iMapBC[6] and reviewed as part of this assessment:

- BC4424 No. 025 1964
- BC4246 No. 160 1964
- BC7769 No. 216 1975
- BC4246 No. 168 1964
- BC7787 No. 189 1975
- BC008 No. 127 1991
- BC043 No. 038 2004

5.0 General Site Description

5.1 Physiographic Description

The study area is located on the leeward side of the Coast Mountain Range, characterized by high, rugged peaks and steep gradient creeks.[7] Seton Portage is located between Anderson Lake and Seton Lake at the base of steep mountain slopes. The elevation of Seton Portage is 255 m above sea level (asl), and the surrounding mountains rise to >2900 m asl. The mountains within the burn area have TSC-IV and V polygons on all slopes due to the steep and gullied terrain.

6 GeoBC Imagery Finder. a100.gov.bc.ca/pub/wimsi/AirphotoSearch

7 Soils of the Ashcroft Map Area. (1992). Young, G., Fenger, M.A., and Luttmerding, H.A. British Columbia Soil Survey.

The Casper Creek fire is 24 km west of Lillooet and has burned 11,284 ha (Figure 1). It was started by lightning or natural causes and was classified as being out on October 20th, 2023. It burned the north side of Anderson and Seton Lakes, the east end of Carpenter Lake, and impacted traditional territories. The fire encompassed the south slopes of Whitecap and Sebring Mountains, the south and west slopes of Nosebag Mountain, and the west slopes of Mission Mountain. The eastern portions of the Bridge River watershed and northern portion of the Seton River watershed have been burned and are tributaries of the Fraser River. The fire elevation ranges from 260 m at Seton Lake to approximately 2200 m on Sebring Mountain.

Several geological units form the bedrock underlying the Casper Creek fire (Figure 2). Marine sedimentary and volcanic rocks were deposited from the Mississippian to Middle Jurassic. Metamorphism occurred from the Mississippian to Middle Jurassic forming greenstone and greenschist grade rocks. Undivided sediments were deposited from the Jurassic to Cretaceous, and conglomerate, coarse clastic sedimentary rocks were deposited during the Cretaceous. Granodioritic intrusions occurred from the Late Cretaceous to the Paleogene, and during the Eocene.

Terrain stability mapping was conducted in the area. The entire Casper Creek fire perimeter was mapped for the Lillooet – North Carpenter, Lillooet – Mission Ridge, and Whitecap – McGillivray projects. Class IV (potentially unstable) and V (unstable) polygons are located on all slopes within the fire perimeter on Whitecap, Nosebag, Mission, and Sebring Mountains. The dominant surficial materials are colluvium with some till and glaciofluvial materials. The dominant slope processes are debris slides, debris flows, and rockslides on gully features.

5.2 Climate

The Casper Creek fire encompasses four separate biogeoclimatic ecosystem classification (BEC) zones (Figure 3). The BEC zones from lowest to increasing elevations include Interior Douglas-fir (IDF), Montane Spruce (MS), Englemann Spruce – Subalpine-fir (ESSF), and Interior Mountain-heather Alpine (IMA). The IDF zone has warm, dry summers and cool winters with moderate precipitation. The MS zone has short, dry summers, cold winters, and minimal precipitation. The ESSF and IMA zones have short, cool summers and long, cold winters with higher snowfall and steep, rugged terrain.[8]

The closest weather station with sufficient data to determine long-term climatic normals is located in Lillooet-Seton. Lillooet is 24 km east of Seton Portage. The station records an average annual precipitation of 349.0 mm with 322.5 mm falling as rain and is located at an elevation of 198.10 m asl.[9] BCH manages two hydrometeorologic stations at Shalalth and Mission Ridge. During fieldwork, the stations recorded 32 mm and 13 mm of precipitation mostly occurring on October 18th during a forecasted atmospheric river precipitation event. The precipitation readings for 2023 are 387 mm in Shalalth, and 330 mm on Mission Ridge.[10]

ClimateNA Data indicates that the 2011-2020 mean annual precipitation in the study area is 551 mm with 415 mm falling as rainfall. Under climate change, 2011-2040 mean annual precipitation increases to 615 mm with 423 mm as rainfall.[11] The increase in precipitation falling as rainfall is slightly greater than the proportion falling as snow.

5.3 Hydrology

The total drainage area of the Seton River watershed is approximately 1020 km^2, with 70 km^2 (<7%) burned by the Casper Creek fire. Seton Lake is controlled by the Seton Dam on the east end and water is diverted through a 3.7 km power canal before discharging into the Fraser River south of Lillooet.[12] The total discharge area of the Bridge River watershed is approximately 2680 km^2, with 43 km^2 (<2%) burned in the lower watershed. The upper portion was burned by the Downton Lake fire (Fire K71649) simultaneously, burning 96 km^2 (<4%). The Terzaghi Dam is located at the outflow of Carpenter Lake and diverts Bridge River through tunnels and penstocks to the Bridge River Generating Stations on Seton Lake. The remainder of the Bridge River flows through a large canyon and

[8] Biogeoclimatic Zones of British Columbia. (1999). BC Ministry of Forests.

[9] Canadian Climate Normals 1981-2010 Station Data. Government of Canada. (2023).

[10] BC Hydro – Generation and Hydrometeorologic Information. Shalalth (shh) and Mission Ridge (mis). bchydro.com/energy-in-bc/operations/transmission-reservoir-data/hydrometeorologic-data.html.

[11] ClimateNA_MAP – 13GCMs_ensemble_ssp585_2011-2040.gcm. climatena.ca/mapVersion.

[12] Fish & Wildlife Compensation Program. 2017. Bridge-Seton Watershed Action Plan. Fwcp.ca.

discharges into the Fraser River north of Lillooet. An active Water Survey of Canada hydrometric station is located near the wildfire area on Seton River near Lillooet (08ME003).[13] The station is downstream of the wildfire area and has recorded 86 years of data. As the only station near the wildfire area is a reservoir, hydrometric data is impacted by the operation of the reservoir. It can be assumed that the Seton and Bridge Rivers have similar characteristics to other Coast Mountain rivers which include[14]:

- Low flows from November to April under snow and ice cover.
- Flow increases from May to August from the spring freshet, and peak in June and July.
- Flow declines late summer.
- Spikes in flow in October from increased rainfall.

While the wildfire event is not expected to have a significant impact on flood events on the larger watersheds such as the Bridge River or Seton River, the IMA and ESSF BEC zones accumulate large snowpacks and the spring freshet has a large effect on stream discharge. Stream crossings, such as culverts and bridges, may become impacted by debris under post-wildfire conditions during periods of increased runoff. There are multiple crossings on Highline Road, Whitecap FSR, Mission Mountain Road, Road 40, and Seton Portage Road through the communities. These crossings should be monitored during periods of heavy rainfall and the spring freshet to ensure they are cleared of debris.

5.4 Natural Disturbance and Industry History

During the Pleistocene Ice Age, the Seton Glacier occupied the valley. After deglaciation around 11,500 years ago, Anderson and Seton Lakes were connected as one 47 km long lake. During the early post-glacial period, the southern flank of the valley on the Cayoosh Range failed in a deep-seated landslide event. "The Portage" was formed and separated the lake in two. The Portage is a 2300 m long and 1000 m wide landslide deposit at the base of the valley.[15]

More recent landslide events are studied in-detail in *BGC Engineering Inc.'s Seton Portage Area Integrated Hydrogeomorphic Risk Assessment* (2018) report. Bear and Pete's Creek has experienced debris flow events, and Whitecap Creek has experienced debris flood events, both following periods of high rainfall. Whitecap Creek is within the Casper Creek fire perimeter.

The area has been affected by 11 historical wildfires. The Casper Creek fire is the largest fire in the area dating back to 1920 when records began. In the summer of 2004, Fire K70198 was started by lightning and burned 2,104 ha in the upper Whitecap Creek watershed. No signs of significant post-wildfire landslides were observed following Fire K70198 in airphotos or Google Earth imagery; however, debris flood events did occur on Whitecap Creek. The Casper Creek fire has burned over a portion of this area of previous burn. The Downton Lake fire (Fire K71649) burned 9,565 hectares 50 km northwest of the Casper Creek fire starting July 13th, 2023. The Downton Lake fire affected the upper Bridge River watershed.

The main industries in the study area are hydroelectric power and mining. The Bridge River hydroelectric complex, owned by BCH and completed in 1960, consists of three dams and four generating stations. The dams are Lajoie Dam forming Downton Lake, Terzaghi Dam forming Carpenter Lake, and Seton Dam controlling Seton Lake. The Terzaghi Dam diverts the Bridge River through a tunnel under Mission Mountain dropping 329 vertical metres into Seton Lake.[16] There is a rich mining history in the Bridge River Valley dating back to the 1850s and ongoing gold exploration.

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[13] EEEC Station #08ME003, Seton River near Lillooet (1020 km^2, 86-year record from 1914-1918; 1924-1926; 1938-1940; 1945; 1950-2023 (active)).

[14] Seton Portage Area Integrated Hydrogeomorphic Risk Assessment. 2018. BGC Engineering Inc.

[15] Seton Portage Area Integrated Hydrogeomorphic Risk Assessment. 2018. BGC Engineering Inc.

[16] Bridge River. BC Hydro. https://www.bchydro.com/community/recreation_areas/bridge_river.html.

Logging has occurred in the study area. The Whitecap-Nosebag valley and north slopes of Mission Mountain were logged between 1964 and 1975 based on airphoto interpretation. The Whitecap valley was salvage logged after Fire K70198 in 2004. The north slopes of Nosebag Mountain were logged in the early 2000s along Carpenter South FSR. Mission Mountain has an extensive road network extending to Road 40 near the Bridge River Indian Reserve. FSRs include Carpenter South, Camoo Creek, Whitecap, and many BCH powerline roads.

5.5 Vegetation and Soil Burn Severity

Vegetation burn severity mapping was provided by the MOF (Figures 4 – 8). The mapping was created using a Differenced Normalized Burn Ratio (DNBR) calculation on pre- and post-wildfire imagery. The DNBR classifies the difference into four Burned Area Reflectance Classification (BARC) categories. The categories include (from LMH #69):

- High (red) – canopy trees blackened and dead, needles consumed, understorey burned;
- Moderate (orange) – trees burned and dead, scorched needles remain on canopy trees, understorey burned and blackened;
- Low (yellow) – canopy unburned, trunks partially burned, understorey lightly or patchily burned;
- Unburned (green) – vegetation in natural unburned state.

The vegetation burn severity suggests where post-wildfire hazards may be the greatest. In low vegetation burn severity areas, hydrologic processes may not be impacted as much of the forest canopy is still intact. In high vegetation burn severity areas, soil moisture, subsurface drainage, surface runoff, and direct snow and rainfall on the slope are anticipated to increase. In addition, changes to the soil such as decreased root cohesion and hydrophobicity will also impact the slopes and increase geomorphic hazards. The vegetation burn severity mapping for the Casper Creek fire was found to be mostly accurate with marginal error while in the field. Areas of ground burn are not portrayed on the vegetation burn severity mapping as the canopy is still intact and relatively unburned. Downslope of South Carpenter FSR within watershed SC4, the area was moderate to highly burned but showed unburned on the vegetation burn severity map. The area was small and not significant enough to alter the burn severity index in watershed SC4.

Soil burn severity was tested in the field by visual observations and water repellency tests in small hand-dug test pits (Appendix A). Vegetation burn severity does not necessarily correlate to soil burn severity. Ground fires will result in a high soil burn severity, while fast-moving fires result in a high vegetation and low soil burn severity.[17] The categories of soil burn severity include (LMH #69):

- High – forest floor is consumed, mineral soil has altered porosity and structure, soil is highly likely to develop hydrophobicity;
- Moderate – litter is consumed, duff is consumed or charred, mineral soil is unchanged, soils may develop hydrophobicity;
- Low – litter is scorched, charred, or patchily consumed, duff is intact and/or surface char, soil is unchanged, unlikely to develop hydrophobicity.

Much of the burn area was found to be of high soil burn severity and hydrophobic soils were encountered. It was found that the thin layer of mineral soil below the ash layer was hydrophobic, but the ash and lower soil layers were not, resulting in a muddy surface following the rainfall event. Hydrophobic soils are concerning as the condition limits infiltration and increases surface overland flow and soil erosion.

[17] Hope, G., P. Jordan, R. Winkler, T. Giles, M. Curran, K. Soneff, B. Chapman. 2015. Post-wildfire natural hazard risk analysis in British Columbia. Prov. B.C. Victoria, B.C. Land Manag. Handb. 69.

6.0 Post-Wildfire Natural Hazard Risk Assessment

The natural hazard risk assessments are separated into units for discussion based on location. All areas are listed in Table 6.1. The units are:

1. Highline Road;
2. Whitecap Creek;
3. Seton Portage Face Units;
4. Mission Mountain Road;
5. Tsee Creek;
6. South Carpenter FSR;
7. Mission Dam Road; and
8. Road 40.

Each unit will be described in detail and an assessment will be given based on the observations made during field work. Elements at risk will be identified and recommendations will be given to reduce the hazards as applicable.

6.1 Highline Road

The Highline Road extends northwest of Anderson Lake and is the main access road between Seton Portage and D'Arcy. There are several spur roads that lead to BCH transmission lines and residences. CN Rail is situated downslope of Highline Road along the lakeshore. The watersheds along Highline Road within the fire area extend from Six Mile Creek in the west up to the height of land and to Whitecap Creek in the east. Watersheds include Six Mile Creek, Sundquist Creek, and several unnamed watersheds referred to as H1 to H6 that flow southeast into Anderson Lake, with face units between watersheds. Nine PODs and private land are located within the unit.

The slopes along Highline Road have varying vegetation burn severities. The western portion is predominately low to moderate, and the eastern portion is predominately moderate to high. The slopes directly above Anderson Lake are unburned to low. The BCH transmission line roads appear to have been used in part as fire guards and the surrounding ground burned at high severity.

The east tributaries of Six Mile Creek are the limit of the fire boundary (Photo 1). The watershed has low to moderate vegetation burn severity and only a small area (16%) was burned. Six Mile Creek descends steep gullies before fanning out into Anderson Lake. Boulders have been deposited upstream of the culvert on Highline Road with scour below, indicating past debris flow event(s). The 2000mm CMP appears adequately sized for expected clearwater flood flows however it would likely be overwhelmed by a debris flow. As the alpine area and majority of the watershed is unburned, the debris flow hazard is not expected to significantly increase post-wildfire. The Six Mile Creek Face Unit adjacent to H1 had dry draws with no apparent surface flow. The road surface had areas of pooling water and cavities where stumps supporting the road fill have burned. An increased rockfall hazard can be expected for this section of Highline Road.

Stream H1 flows southeast into Anderson Lake and is moderately burned with patches of high burn severity. A stream channel at the location mapped as H1 on Highline Road was not observed but excessive water was pooling on the road surface in the general location (Photos 1 – 2). Within the watershed area three draws flow from the alpine with avalanche paths on the eastern draws. The streams bend west and there is a depositional area where a significant portion of the flow likely infiltrates into the ground. There is a residential property on an elevated bench on the western side of the incised stream channel.

Stream H2 flows down an incised bedrock canyon to a large fan on Anderson Lake, developed with several residences (Photos 3 – 7). At Highline Road, trim lines are apparent above and below the road, indicating a past debris flow event. The 1000mm CMP on Highline Road is likely undersized and the narrow sump is prone to plugging. Downstream on the fan, mitigation measures including multiple pipes, a small trash rack and a swaled crossing are in place to help prevent an avulsion in the case of a small debris flow event. These mitigation structures will prevent damage from debris flooding and small debris flow events. As the debris flow hazard has increased post wildfire due to the moderate and high burn severity (63%), larger events are possible. The H2 watershed requires a more detailed assessment as the residences on the fan could be at an elevated risk.

The H2 Face Unit contains primarily steep scree slopes. The draws were dry and significant changes in runoff are not expected. The rockfall hazard has increased and rocks were rolling onto Highline Road during field work.

Sundquist Creek descends a steep bedrock canyon before reaching the fan adjacent Anderson Lake (Photo 8). The watershed has moderate (40%) and high (32%) burn severity with much of the upper watershed highly burned. The 2000mm CMP in place on Highline Road appears to be suitably sized for clearwater flood events but would be overwhelmed by a debris flow.

The Sundquist Face Unit is an area of steep rocky slopes. The prevailing rockfall hazard has increased post-wildfire.

Watersheds H3 to H6 flow southeast into Anderson Lake and were burned at moderate to high severity (Photo 9). The slopes are steep, rocky faces that extend to Anderson Lake.

Stream H3 was dry during the field review but extends into private land below Highline Road. Although the upper watershed is highly burned (58%), there is not significant flow, limiting the debris flow likelihood. Rockfalls or debris flows in this watershed are expected to runout upslope of developed areas.

H4, H5, and H6 are small, rocky draws that make up the Highline Face Unit. The streams were dry during the field review but host seasonal flows. All culverts were partially or fully plugged. Areas of high burn severity occurred along the transmission lines and the upper watershed of H4. Increased frequency of rockfalls and small debris slurries can be expected within the Highline Face Unit.

6.2 Whitecap Creek

Whitecap Creek extends northwest from Seton Portage to the peak of Whitecap Mountain at 2918 m asl. The watershed is 74 km^2 with 2.7 km^2 still glaciated. Whitecap Creek is characterized as a hanging valley with steep bedrock canyons and an active fan. Whitecap Creek discharges into Portage River approximately 670 m downstream of Anderson Lake (Photos 19 – 21). A large (4 hectare) exposed till slope is being undercut by Whitecap Creek just upstream of the bedrock canyon and is a significant sediment source to the channel (Photos 11 – 13). The watershed is prone to floods and debris floods and past extreme runoff events occurred in 2015 and 2016. The events impacted Anderson Lake Road and CN Rail, and caused channel changes, avulsions, and high sediment transport into Portage River.[18]

There are several elements at risk downstream of Whitecap Creek and on the adjacent terraces and fan. Elements include three cabins, Tsal'alh Development Corporation administrative building, two PODs, Whitecap campground, CN Rail, Portage River, and community roads.

Whitecap FSR traverses the north side of the creek, with a spur road (Road 1; Photo 16) heading east above Seton Portage. A bridge over upper Whitecap Creek has been previously washed out and the road is inaccessible beyond (Photo 17). Whitecap FSR has been abandoned and has some landslide activity but has not been deactivated (Photo 18).

The middle portion of the Whitecap Creek watershed was burned by Fire K70198 in 2004 (Photo 14 – 15). The fire extended north and west of the Casper Creek fire and burned 2,104 ha. Fire K70198 did not appear to cause any significant landslides in the Whitecap Creek watershed. The south slopes of Whitecap Creek have high vegetation burn severity, including the areas previously burned. The north slopes of Whitecap Creek have moderate to high vegetation burn severity. The high burn severity did not extend into alpine terrain and the riparian area is mostly unburned. Near the mouth of Whitecap Creek, the burn severity is low to moderate.

For the entire Whitecap Creek watershed, only 30% was burned in the Casper Creek fire, resulting in a burn severity index of 12. However, as a large area was burned previously in 2004 and the system has a history of debris flooding events, the burn severity index was increased to 15 by accounting for the 2004 burn area. A burn severity rating of moderate was applied to the 2004 burn area that did not overlap the 2023 area. This is likely a conservative

[18] Seton Portage Area Integrated Hydrogeomorphic Risk Assessment. 2018. BGC Engineering Inc.

assumption as significant regrowth has occurred, but it illustrates that despite the large areas impacted by wildfire, much of the watershed area is not impacted. The watershed level hazards (debris flood) are expected to have a small increase because of the wildfire.

Three tributaries of the Whitecap Creek watershed were reviewed. WC1, WC2, and WC3 were found to consist of draws with minimal channels and with moderate to high vegetation burn severity. WC1 extends down to Whitecap Creek below the bedrock canyon and WC2 and WC3 are in the mid watershed.

WC1 is interpreted as a relic draw and likely has insufficient surface flow to result in a debris flow. It may develop smaller slurry type events during large runoff events as it originates in a mid-slope position below 900 m asl (Photo 22). It should be noted that our field work was during a forecasted atmospheric river event, yet no runoff was noted in these draws at the time of our fieldwork. WC2 and WC3 descend steep, gullied terrain. WC2 is a large draw with a relatively low gradient reach where it is crossed by the FSR. A significant channel was not noted on WC2. WC3 hosted a past small debris flow that deposited on Whitecap FSR. The debris flow hazard of WC2 and WC3 has likely increased, but significant runout to Whitecap Creek is not expected based on past events.

Hydrophobic soils were encountered in sample sites along the slopes of Whitecap FSR and Road 1. Three of four sites tested had high soil burn severity and hydrophobic soils occurred on all slope gradients.

6.3 Seton Portage Face Units

The Seton Portage Face Units drain the south slopes of Nosebag Mountain into Portage River and Seton Lake (Photos 23 – 24). Downslope communities are Seton Portage and South Shalalth, as well as Sk'il Mountain Community School and eight PODs. BCH roads traverse above the communities and were used as a fire guard. The watersheds are SF1 to SF5, Second Creek (SF6), Cedar Creek (SF7), and Omin Brook.

SF1, SF2, and SF5 are small swale features that do not extend up beyond 500 m asl and terminate at the base of a steep rocky face unit. None of the draws carry significant flow and all have a low to moderate vegetation burn severity. Second Creek (SF6) is a small, low energy groundwater stream. It has a low gradient, poorly incised channel with mature trees and deciduous vegetation. The riparian area is unburned with low burn severity within the watershed. Post wildfire landslide events in watersheds SF1, SF2, SF5 and SF6 are not expected and therefore are not assessed further.

SF3 and SF4 flow within broad, low gradient draws in their lower reaches but extend up to alpine terrain above Road 1. SF3 has two main branches extending upslope of the upper transmission line that confluence downslope of the steep rocky face unit. The watershed is highly burned (64% high severity; Photo 25) in the upper watershed. The two streams are conveyed across Road 1 in small culverts that are expected to be undersized for the anticipated post-wildfire flows. There is potential for the flow to be diverted if a culvert is blocked, potentially leading to a gentle over steep landslide concern. There is a low gradient depositional reach well upslope of Seton Portage Road that would limit the run out of any upslope debris slides or flows. Impacts at downstream PODs or the Seton Portage Road would be limited to sediment laden water during peak runoff events.

SF4 crosses under Road 1 in a small diameter culvert in a relatively low energy reach. A second swale approximately 50m east along the same road did not have a culvert and some water ponding was noted. Downslope of the transmission line the stream descends a steep bedrock draw before reaching a broad low gradient draw below 400 m asl. Where the lower draw was reviewed it did not host any surface flow and has moderate (46%) to high (32%) vegetation burn severity. Stream levels and surface runoff are expected to increase during the Spring 2024 freshet but debris flow events with the potential to impact Seton Portage Road are not expected. Where the draw intersects Seton Portage Road, a small groundwater sourced stream was noted but the stream presently has no surface flow connection to the upper watershed.

Cedar Creek (SF7) consists of two small channels at Road 1. The draws converge on the steep bedrock face unit below Road 1. Below the face unit the stream flows within a broad draw at a relatively low gradient. The channel is poor to moderately confined with dense, deciduous vegetation. The watershed is moderately burned (38%) with an unburned riparian area. Stream levels and surface runoff are expected to increase during the Spring 2024 freshet but debris flow events with the potential to impact Seton Portage Road are not expected.

Omin Brook was burned mostly at low (24%) to moderate (34%) vegetation burn severity. Water was flowing over Road 1 as culverts were plugged or buried. Below Road 1, the water is diverted to a BCH penstock and there is no surface flow downstream.

Concerns were expressed by the community for the safety of the Sk'il Mountain Community School. The community school is located on an elevated terrace between Cedar Creek to the west and Omin Brook to the east (Photo 26). The terrace is approximately 60 m higher in elevation than the stream channels. Debris flow events in either draw are not expected to impact the area of Sk'il Mountain Community School.

6.4 Mission Mountain Road

Mission Mountain Road is between the BCH facility in South Shalalth and the penstock intake on Carpenter Lake, providing access from Seton Portage to Lillooet. The vegetation burn severity of the south face from the height of land is low to moderate with patches of high (Photos 27 – 28). The high patches moderately correlate with BCH trails that were presumably used as fire guards. The vegetation burn severity of the north face is mainly high, reducing to moderate near Carpenter Lake (Photo 31). Watersheds include MM1 to MM6 that flow south into Seton Lake. MM1, MM2, MM4, and MM6 are very small watershed units not expected to host events that could impact elements at risk and therefore were not assessed further.

MM3 has predominately moderate vegetation burn severity (41%) and descends a steep gully adjacent the BCH penstocks. A debris flow occurred previously within the draw and deposited on Mission Mountain Road approximately 400 m downslope. The small diameter twin culverts in place where Road 1 intersects the Mission Mountain Road should be upgraded as they were plugged at the time of the field review.

MM5 has high vegetation burn severity (43%) and descends steep gullies originating from an area that was previously harvested and contains numerous bladed trails (Photo 28). If the area is impacted by an extreme hydroclimatic event, there is the potential for debris flow initiation in the upper watershed that could impact Mission Mountain Road. The stream channel was dry during field review but the culverts on Mission Mountain Road were infilled with sediment and the road crosses Stream MM5 four times.

The prevailing hazards on Mission Mountain Road, such as rockfalls and road washouts, have increased under post wildfire conditions. Increased surface runoff can be expected that will cause an increase in ravelling, ditchline infilling, and potentially rockfall hazard. Many culverts on Mission Mountain Road were plugged and causing erosion and ravelling of fill slopes. Trees and stumps supporting the road fill have burnt leading to the formation of cavities in the road. Along some sections, fill slopes will need to be rebuilt with properly placed and compacted material. Overall, Mission Mountain Road requires further assessment and the development of a maintenance / upgrade plan to ensure the road functions as intended. During our field work it was noted that BCH had already initiated some assessment work on Road 1 and Mission Mountain Road.

Logging trails and Camoo Creek FSR extend east from Mission Pass. The logging trails accessed old cutblocks and are very overgrown. The vegetation burn severity is moderate to high. Although the trails are not overly concerning, rehabilitation would decrease the landslide hazard and potential for concentration of surface runoff. Camoo Creek FSR traverses Mission Ridge above the MD1 watershed and has high vegetation burn severity (Photo 30).

Hydrophobic soils were encountered on the slopes within MM 5. The site tested had rocky, well-drained soil in moderate to high vegetation burn severity and high soil burn severity.

6.5 Tsee Creek

The Tsee Creek watershed is the southeastern limit of the fire boundary, with the middle and upper west tributaries of the watershed impacted (Photos 29, 32 – 33). Tsee Creek is east of Mission Mountain Road and discharges into Seton Lake through Shalalth. There are several PODs downstream of the burn area. Four logging trails were reactivated above the canyon as fire guards. Only 25% of the watershed was burned, with 11% at moderate and 5% at high vegetation burn severity. The debris flow hazard likelihood is expected to be only slightly elevated from pre-fire levels.

Tsee Creek has a steep, bedrock canyon that had minor bedload movement noted at the time of our field work. There is a deposit of sediment upstream of the Shalalth Road culvert and mud splattered on trees on the bank indicating past debris flow event(s) and a relatively high debris flow hazard under existing conditions (Photo 34). As the culvert was plugged during the last event, it should be considered for upgrade to account for potentially increased sediment delivery following the wildfire event.

6.6 South Carpenter FSR

The South Carpenter FSR, also known as South Carpenter – Nosebag FSR, branches west off Mission Mountain Road at Mission Pass (Photos 31, 36). There are five small watersheds; SC1, which flows east into MD1, and SC2 to SC5, that flow north into Carpenter Lake. A cellular tower site and BCH penstock intakes are located downslope. The mountainside was predominately burned at high vegetation burn severity, reducing to low and moderate near the lakeshore and to the west at the fire boundary. One mapping error was found near SC4. The burn severity map shows unburned but downslope of the FSR was burned at high severity.

SC1 flows east into a larger watershed (MD1), which then flows north along Mission Mountain Road to Carpenter Lake (Photo 35). SC1 has an incised channel, small flow, and is burned at high vegetation burn severity (83%). The slopes consist of thick, free-draining sand and gravel with a hydrophobic upper layer. The debris flow hazard has severely increased post wildfire as 95% of the watershed was burned at moderate and high severity.

SC2, SC3, and SC4 were dry draws with no stream channel (Photo 37). There was no flow at the upper or lower crossings, but culverts were in place. The percent burned at moderate and high vegetation burn severity are 85% for SC2, 79% for SC3, and 68% for SC4. The steep, upper watersheds are highly burned and decrease in severity closer to the lakeshore.

SC5 is on the fire boundary and is mainly unburned. The vegetation burn severity is low to moderate. There are two adequately sized culverts on the FSR crossing. As the watershed was only partially burned, it was not assessed further.

Hydrophobic soils were encountered on the upper slopes of South Carpenter FSR. The site tested had free-draining sand and gravel, high vegetation burn severity, and high soil burn severity.

6.7 Mission Dam Road

The Mission Dam Road extends from the BCH penstock intakes past the Terzaghi Dam on Carpenter Lake (Photo 38) to the Bridge River Canyon and beyond. The Terghazi Dam and Mission Dam Recreation Site are on the fire boundary at the east end of Carpenter Lake. There are 13 watersheds, MD1 to MD13, draining into Carpenter Lake and Bridge River. The slopes south of Carpenter Lake and west slopes of Mission Mountain are burned at moderate to high severity. The valley along Bridge River has varying burn severities.

MD1 is a large watershed with a small stream that flows north into Carpenter Lake (Photo 39). Deposition of sand and gravel outside of the channel on the lower poorly incised reach at the Mission Dam Road indicates recent high flows. The upper watershed was burned at high severity and 68% high severity overall. The culvert under the Mission Dam Road is relatively small and prone to plugging and should be cleaned out / upgraded to account for the increased likelihood of sediment movement post wildfire.

The MD1 Face Unit had small, dry draws (MD 2 and MD 3) with no stream channels. An increased rockfall hazard or debris slurry can be expected for this section of Mission Dam Road. There are currently no culverts or mitigation measures on this section of Mission Dam Road.

MD4 is a small watershed with a recent debris flow (Photo 40 – 41). The deposit is 5-10 m wide and >2 m deep. There were no surface flows during the field work, but water has incised through the deposit. The slopes are rocky and relatively unburned as there are few trees. The lower watershed has high vegetation burn severity (14%), including along the debris flow deposit. There is no culvert crossing Mission Dam Road. Mitigation measures should be considered above Mission Dam Road as more debris flow events and increased runoff can be expected.

MD2 Face Unit is between MD4 to the west and MD11 to the east. The face unit has varying burn severities as the steep, rocky slopes have little vegetation. Increased frequency of rockfalls and small debris slurries can be expected for this section along Mission Dam Road.

MD5 to MD10, MD12, and MD 13 are small to medium-sized watersheds. MD7 and MD8 are north of Mission Dam Road, while the other watersheds are south. All draws were dry with no surface flow at the time of our assessment. The terrain is steep and rocky with few trees. The ridgetops and upper watersheds are highly burned, with decreasing burn severities at lower elevations. MD12 has naturally occurring debris flows.

Watershed MD11 is a dry, rocky draw with past debris flow deposits. Much of the watershed is unburned (61%) as there are limited trees, but tributaries in the upper western portion of the watershed have high vegetation burn severity (11%). Although there would be no impact to Mission Dam Road, landslides could runout into Bridge River.

6.8 Road 40

Road 40, also known as the Lillooet-Pioneer Road, provides access from Lillooet to Gold Bridge. The section discussed is located on the north shore of Carpenter Lake between the Terzaghi Dam and the western extent of the fire. The high elevation slopes are rocky with few trees and colluvial deposits on the lower slopes. The slopes mainly have moderate vegetation burn severity. It is our understanding that Road 40 experiences frequent closures in the winter and during periods of heavy rainfall due to snow avalanches, rockfalls, and mudslides.

Watersheds in this unit include LP1, LP2, LP3 and Cougar Creek. All watersheds drain south into Carpenter Lake.

LP1 is the largest watershed with a relatively small stream (Photo 42). The upper watershed to the mountain peak at 2200 m asl has high vegetation burn severity (42%). The lower watershed is unburned but has minimal vegetation. There are boulders at the stream base indicating debris accumulation. The rocky draw has a 2000 mm CMP at the road.

The LP1 Face Unit is between watersheds LP1 and LP2. The rocky, steep slopes do not have defined channels or appear to host any significant flow. The burn severity is low to moderate, but the vegetation is sparse. The prevailing rockfall and debris slurry hazards and likelihoods have likely marginally increased under post wildfire conditions.

LP2 and LP3 were dry draws that likely host seasonal flows (Photo 43). Neither watershed has a defined channel at the mouth. LP2 has a moderate (47%) and high (45%) vegetation burn severity, and LP3 has high (66%) vegetation burn severity. Each draw has culvert that appears suitably sized for clearwater flows provided the inlets are maintained.

Cougar Creek is a small, lower elevation watershed with a small stream (Photo 44). The upper watershed is highly burned (42%), and the lower watershed is unburned to low vegetation burn severity. There is a sump upstream of the culvert that decreases the risk of the culvert plugging. The culvert should be assessed and upgraded as necessary.

Landslide and hydrogeomorphic hazards along Road 40 have increased post wildfire. The frequency of rockfalls and mudslides can be expected to increase, as well as the additional hazard of debris flows occurring within the watersheds. Culverts should be inspected and cleaned more frequently to reduce the risk of plugging, especially following storm cycles.

Table 6.1: Casper Creek PWNHRA and Recommendations

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
Six Mile Creek	4.9	2100	0.97	Debris Flow: History of debris flow. Small area burned. Large culvert in place.	4	High Low Mod Unburnt	2 6 8 84	4	**Moderate:** Debris flow extending down to Highline Road with the potential to washout the road and extend further downslope to the fan.	Water Intakes: **High** Private Land and Structures: **Moderate** Highline Road Crossing: **High** Railway Crossing: **Moderate** BCH Transmission Line: **NA** (line spans draw)	High Moderate High Moderate	• **Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized.** • Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023. • Advise CNR of potential for debris flow impacts at their crossing.
H1	3.97	2020	1.47	Debris Flow: Stream channel was not noted at Highline Road during field review. Upper watershed channels appear to runout and dissipate in depositional area above Highline Road. Transmission line towers are downslope of expected deposition area.	4	High Low Mod Unburnt	13 28 40 18	20	**High:** Debris flow extending down to deposition area upslope of Highline Road.	Water Intakes: **Low to Moderate** BCH Transmission Line: **Low** Private Land / Structures: **Moderate / Low** Highline Road Crossing: **V Low** Railway Crossing: **V Low**	Moderate to High Moderate High / Moderate Low Low	• Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized. • Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023. • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
H2	3.98	1920	0.91	Debris Flow: Watershed morphometrics and evidence of trim lines in the draw suggest system has the potential for large debris flows. The Highline road has an undersized culvert, and the fan area has residential developments.	4	High Low Mod Unburnt	22 21 41 17	25	**High:** Debris flow extending down to Highline Road with the potential to washout the road and extend further downslope to the fan.	Water Intakes: **High** Private Land / Structures: **High / Moderate** Highline Road Crossing: **High** Railway Crossing: **Moderate**	High High High High	• **Complete a detailed assessment including debris flow modelling to better assess the risk to private land development.** • Ensure any future development on private land on the H2 fan is subject to a landslide hazard assessment. • Advise CNR of potential for debris flow impacts at their crossing. • Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized. • Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023. • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.
Sundquist Creek	4.03	1340	1.14	Debris Flow: Watershed morphometrics and evidence of trim lines in the draw suggest system has the potential for large debris flows. The Highline road has a 2000mm culvert that appears appropriate for clearwater flows but would be impacted by a debris flow and may negatively contribute to the event through contribution of additional material or temporary impoundment of flows. The fan area is undeveloped apart from the railway extending along the toe.	4	High Low Mod Unburnt	32 18 39 11	32	**Very High:** Debris flow extending down to Highline Road with the potential to washout the road and extend further downslope to the fan.	Water Intakes: **High** Highline Road Crossing: **High** Railway Crossing: **Moderate** BCH Transmission Line: **NA** (line spans draw)	V High V High High	• Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized. • Advise CNR of potential for debris flow impacts at their crossing. • Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023. • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.

<table>
<tr><th>Watershed Name</th><th>Stream Length (km)</th><th>Relief (m)</th><th>Melton #</th><th>Dominant Hydrogeomorphic Process</th><th>Process Index</th><th colspan="2">Burn Severity (%)</th><th>Burn Severity Index</th><th>Hazard Likelihood P(H) and form</th><th>Elements at Risk and P(S:H)</th><th>Partial Risk P(HA)</th><th>Recommendation</th></tr>
<tr><td rowspan="4">H3</td><td rowspan="4">2.41</td><td rowspan="4">1340</td><td rowspan="4">1.14</td><td rowspan="4">Debris Flow: Stream channel at Highline Road is less than 1m wide with small amount of flow conveyed through a 600mm CMP. Draw extends below the road and diminishes on a broad bench on private land adjacent to Anderson Lake.

Stream channel is relatively small with a rocky upslope catchment. Significant debris flows are not expected. Smaller events would likely deposit material on road and potentially continue across the road to the downslope segment of the draw.</td><td rowspan="4">4</td><td>High</td><td>58</td><td rowspan="4">48</td><td rowspan="4">Very High: Debris flow extending down to Highline Road and potentially deposition area within private land adjacent to Anderson Lake.</td><td rowspan="4">Water Intakes: Moderate

Private Land / Structures: Moderate / Low

Highline Road Crossing: Moderate

Railway Crossing: Low

BCH Transmission Line: NA (line spans draw)</td><td rowspan="4">High

High / Moderate

High

High</td><td rowspan="4">• Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.
• Ensure any future development on private land on the H3 fan area is subject to a landslide hazard assessment.
• Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized.
• Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events.
• Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.</td></tr>
<tr><td>Low</td><td>6</td></tr>
<tr><td>Mod</td><td>35</td></tr>
<tr><td>Unburnt</td><td>1</td></tr>
<tr><td rowspan="4">Six Mile Face Unit</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td rowspan="8">Rockfall: Increased ravelling of talus slopes can be expected.

Debris Slurry: Small debris slurries or mudflows can be expected in small swales and/or draws within this face unit. Events can be expected to deposit material on the Highline Road with some of the larger events continuing beyond.</td><td rowspan="4">N/A</td><td>High</td><td>10</td><td rowspan="4">18</td><td rowspan="4">Low: Rockfalls or debris slurries would deposit on the gentle slopes prior to reaching Highline Road.</td><td rowspan="4">BCH Transmission Line: Moderate

Highline Road: Moderate

Railway: Low</td><td rowspan="4">Low

Low

Low</td><td rowspan="8">• Complete a detailed review of Highline Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized.
• Increase frequency of inspections on Highline Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events.
• Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.</td></tr>
<tr><td>Low</td><td>38</td></tr>
<tr><td>Mod</td><td>38</td></tr>
<tr><td>Unburnt</td><td>14</td></tr>
<tr><td rowspan="4">H2 Face Unit</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td rowspan="4">N/A</td><td>High</td><td>29</td><td rowspan="4">31</td><td rowspan="4">High: Rockfalls or debris slurries would deposit on Highline Road.</td><td rowspan="4">BCH Transmission Line: Moderate

Highline Road: High

Railway: Low</td><td rowspan="4">High

High

Moderate</td></tr>
<tr><td>Low</td><td>22</td></tr>
<tr><td>Mod</td><td>42</td></tr>
<tr><td>Unburnt</td><td>8</td></tr>
</table>

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Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)	Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
Sundquist Face Unit	N/A	N/A	N/A	Rockfall: Increased ravelling of talus slopes can be expected. Debris Slurry: Small debris slurries or mudflows can be expected in small swales and/or draws within this face unit. events can be expected to deposit material on the Highline Road with some of the larger events continuing beyond. Numerous transmission line towers on these face units increase the encounter probability although towers generally occupy ridges and higher ground areas.	N/A	High 25 Low 23 Mod 44 Unburnt 8	29	**Moderate:** Rockfalls or debris slurries would deposit on the gentle slopes above or on Highline Road.	Water Intakes: **Low** Private Land: **Low** BCH Transmission Line: **High** Highline Road: **High** Railway: **Low**	Low Low High High Low	All recommendations in row above plus: • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred. • Ensure any future development on private land downslope of these face units is subject to a landslide hazard assessment.
Highline Face Unit	N/A	N/A	N/A		N/A	High 33 Low 15 Mod 35 Unburnt 16	32	**High:** Rockfalls or debris slurries would deposit on Highline Road.	Water Intakes: **Low** BCH Transmission Line: **High** Highline Road: **High** Railway: **Low**	Moderate High High Moderate	

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
Whitecap Creek	18.4	2060	0.24	Flood / Debris Flood: Watershed hosted debris floods in 2015 and 2016 that impacted the Anderson Lake Road crossing over. **The process index has been increased from 2 to 3 to account for the known history of relatively destructive debris flood events that have occurred in the watershed.* ***The Burn Severity Index has been adjusted to account for the 2004-K70198 fire in Whitecap Creek watershed.*	3	High Low Mod Unburnt	13 6 28 53	*15	**Moderate:** Floods and debris floods would discharge into Portage River, possible avulsion channels, and large sediment supply. Potential to damage or destroy Anderson Road bridge and Whitecap Creek bridge.	Water Intakes: **High** Private Land and Structures: **Moderate** FN Reserve Land: **High** Community Road: **High** Whitecap FSR: **High** Whitecap Campground: **High** Railway: **Moderate** BCH Transmission Line: **NA** (line spans draw)	High Moderate High High High High Moderate	• Complete design and installation of deflection berms along Whitecap Creek between Whitecap campground and Anderson Lake Road bridge. • In conjunction with the defection berms along Whitecap Creek, consideration should be given to further armouring of the south bank of the Portage River below the confluence with Whitecap Creek. • Consider raising the Anderson Lake Road bridge as much as the vertical alignment will permit and founding it on driven piles to increase resiliency of structure. • **When significant hydroclimatic events are forecasted, preparations should be made to have heavy equipment on site to breach any sediment deposits in the Portage River and/or clear off the road.** • **An alternative egress route for the cabins adjacent to the Whitecap Creek campground should be considered in the event that the Whitecap Creek bridge is compromised.** • A more detailed review of the channel upstream of the canyon should be undertaken to better understand debris flood process and in particular determine if debris flood events initiate upstream of the canyon or primarily downstream. • Consider temporary closures of the Whitecap Campground Recreation Site during periods of expected high rainfall (October 15 to April 15) over the next 5 years until vegetation has recovered in the Whitecap Creek watershed. • Wherever possible areas of suitable terrain within the watershed should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through reforestation and operations can decrease the effects of hydrophobic soil layers due to mechanical disturbance.

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
WC1	1.47	1380	1.74	Debris Flow: Stream channel within draw was not noted during field review. Events expected to be relatively small and deposit within low gradient reaches of the draw or continue as fluid slurry down to the lower reach of the draw above the Whitecap Campground area.	4	High	59	48	**Very High:** Debris flow extending down to deposition area just above lower leg of Whitecap FSR.	Whitecap FSR: **Moderate** FN Reserve Land: **Low** Whitecap Campground: **Low** BCH Transmission Line: **NA** (line spans draw)	High Moderate High	• Review Whitecap FSR to ensure road drainage measures (ditchlines, culverts, crossings) are functional. If road will no longer be used or maintained, consider a deactivation plan. • Wherever possible areas of suitable terrain within the watershed should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through reforestation and operations can decrease the effects of hydrophobic soil layers due to mechanical disturbance.
						Low	11					
						Mod	28					
						Unburnt	2					
WC2	3.03	1500	0.80	Debris Flow: Stream channel was not noted during field review. Events expected to be relatively small and deposit within low gradient reaches of the draw or continue as fluid slurry down to the lower reach of the draw at the FSR.	4	High	41	36	**High:** Debris flow extending down to Whitecap FSR.	Whitecap FSR: **Moderate** Whitecap Creek: **Low**	High Moderate	
						Low	20					
						Mod	27					
						Unburnt	12					
WC3	12.40	1360	1.22	Debris Flow: History of small debris flows. Damaged culvert and evidence of flows over the FSR. Expect increased runoff in the draw and smaller debris flows that are expected to deposit within low gradient reaches of the draw or continue as fluid slurry down to the lower reach of the draw at the FSR and potentially Whitecap Creek. Rockfall: Increased frequency of rockfalls on steep scree slopes above Whitecap FSR.	4	High	26	28	**High:** Debris flow extending down to Whitecap FSR and potentially Whitecap Creek.	Whitecap FSR: **High** Whitecap Creek: **Moderate**	High High	
						Low	22					
						Mod	37					
						Unburnt	15					

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Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
SF3	4.44	1840	0.91	Debris Flow: Potential for debris flow in upper watershed or within steep gradient reach on face unit below Road 1. Runout is expected to terminate in low gradient reach above Seton Portage Road. Reserve land in this area extends up above Road 1 but is not developed.	4	High Low Mod Unburnt	64 9 24 3	51	**Very High:** Debris flow extending to deposition area below Road 1 and upslope of Seton Portage Road.	Road 1 (BCH): **High** FN Reserve Land (undeveloped): **High** Seton Portage Road: **V Low** Railway Crossing: **V Low** BCH Transmission Line: **NA** (line spans draw)	V High V High Moderate Moderate	• Review upslope road network to ensure road drainage measures (ditchlines, culverts, crossings) are functional. Deactivate roads as required if access is no longer needed. • Wherever possible areas of suitable terrain within the watershed should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through reforestation and operations can decrease the effects of hydrophobic soil layers due to mechanical disturbance.
SF4	3.51	1480	1.16	Debris Flow: Potential for debris flow in upper watershed or within steep gradient reach on face unit below Road 1. Runout is expected to terminate in low gradient reach above Seton Portage Road.	4	High Low Mod Unburnt	32 19 46 3	34	**Very High:** Debris flow extending to deposition area below Road 1 and upslope of Seton Portage Road.	Road 1 (BCH): **High** FN Reserve Land (undeveloped): **Moderate** Water Intakes: **Low** Seton Portage Road: **V Low** Railway Crossing: **V Low** BCH Transmission Line: **NA** (line spans draw)	V High High High Moderate Moderate	• Review upslope road network to ensure road drainage measures (ditchlines, culverts, crossings) are functional. Deactivate roads as required if access is no longer needed. • Wherever possible areas of gentle to moderate slope should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through reforestation and operations can decrease the effects of hydrophobic soil layers due to mechanical disturbance. • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.
Cedar Creek	3.63	1400	1.06	Debris Flow: Potential for debris flow in upper watershed or within steep gradient reach on face unit below Road 1. Runout is expected to terminate in low gradient reach above Seton Portage Road Low gradient stream may see elevated flows next spring freshet.	4	High Low Mod Unburnt	16 27 38 19	21	**High:** Debris flow extending to deposition area below Road 1 and upslope of Seton Portage Road.	Road 1 (BCH): **High** FN Reserve Land (undeveloped): **Moderate** Seton Portage Road: **V Low** Railway Crossing: **V Low** BCH Transmission Line: **NA** (line spans draw)	High High Low Low	• Review upslope road network to ensure road drainage measures (ditchlines, culverts, crossings) are functional. Deactivate roads as required if access is no longer needed.
Omin Brook	3.82	1630	0.87	Debris Flow: Relatively low energy groundwater sourced stream with lower reach diverted and put into pipes through BCH facility. Culverts on Road 1 need cleaning and/or upgrading, potential to plug and contribute	4	High Low Mod	10 24 34	16	**High:** Debris flow extending down to gentle gradient slope.	Road 1 (BCH): **High** BCH Access Road and Water Intake: **High** FN Reserve Land (undeveloped): **Low**	High High Moderate	• Review upslope road network to ensure road drainage measures (ditchlines, culverts, crossings) are functional. Deactivate roads as required if access is no longer needed. • Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
				to event. Upper water intake is within BCH facility.		Unburnt	32			Water Intakes (lower): **Low** Seton Portage Road: **V Low** Railway Crossing: **V Low** BCH Transmission Line: **NA** (line spans draw)	Moderate Low Low	
MM3	2.44	1320	1.42	Debris Flow: History of debris flows in BCH site due to sidecast tunnel muck in draw from historic penstock construction. Increased flows from burn are expected to increase this hazard. Note – plans are underway for BCH to remove this material in 2024.	4	High Low Mod Unburnt	26 18 40 15	28	**High:** Debris flow extending down to switchback on Mission Mountain Road.	Mission Mountain Road: **High** Community Road (South Shalalth): **Moderate** BC Hydro Site Roads: **Moderate to High**	High High High	• **Complete a detailed review Mission Mountain Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized.** • Increase frequency of inspections on Mission Mountain Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.
MM5	2.79	1320	1.15	Debris Flow: Draw has no defined stream channel. Upper watershed has moderate to high severity and will be subject to debris flows initiated by converging surface runoff and surface erosion. **Note:** Upper watershed is on private land and was previously harvested with trails left in place.	4	High Low Mod Unburnt	43 16 29 12	37	**Very High:** Debris flow would likely deposit on upper leg of Mission Mountain Road but may continue to lower legs in an extreme event.	Mission Mountain Road: **High** Community Road (Shalath Cutoff): **Low** FN Reserve Land (undeveloped): **Moderate** FN Reserve Land (developments): **Low**	V High High High High	• Complete a detailed review of Mission Mountain Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized. • Increase frequency of inspections on Mission Mountain Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Wherever possible areas of gentle to moderate slope should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through scarification and breaking up any hydrophobic soil layers and accelerated regrowth through planting programs. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
Tsee Creek	4.94	1720	0.92	Debris Flow: Stream has a history of debris flow events but hazard has not likely increased under post-wildfire conditions as only a small area of the watershed was burned.	4	High Low Mod Unburnt	5 8 11 75	7	**Moderate:** Debris flow extending to Shalalth Road, possibly Seton Lake.	Water Intakes: **High** FN Reserve Land (undeveloped): **High** FN Reserve Land (developments): **Moderate** Community Road (Shalath): **Moderate** Railway Crossing: **Low**	High High Moderate Moderate Low	• **Ensure culverts and stream crossings on Shalalth Road (Lakeview Drive) are adequately sized and clear of debris.** • **Inspect water intake infrastructure and monitor water quality until significant regrowth has occurred.**
SC1	3.16	600	0.63	Debris Flow: Small stream with surface runoff likely to see elevated flow in spring freshet. Burn severity is high throughout most of the watershed. Potential for surface runoff to accumulate in gullies resulting in a small debris flow. Mission Mountain Road in this area also has road fill supported by burnt out stumps and wood debris.	4	High Low Mod Unburnt	82 4 13 1	61	**Very High:** Debris flow extending beyond or initiating below South Carpenter FSR and depositing on Mission Mountain Road.	Mission Mountain Road: **High** BCH Transmission Line: **NA** (line spans draw)	V High	• **Review South Carpenter FSR to ensure road drainage measures (ditchlines, culverts, crossings) are functional.** • **Complete a detailed review Mission Mountain Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized. Fillslope reconstruction is expected to be required through several sections from Mission Pass to Carpenter Lake (see accompanying maps).** • Wherever possible areas of gentle to moderate slope should be assessed for salvage harvesting potential. Salvage harvesting (when completed appropriately) can increase recovery through scarification and breaking up any hydrophobic soil layers and accelerated regrowth through planting programs. • Increase frequency of inspections on Mission Mountain Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.
SC2	1.00	720	1.02	Debris Flow: Stream channel was not noted at Mission Mountain Road during field review. Potential for surface runoff to accumulate in gullies resulting in a small debris flow.	4	High Low Mod Unburnt	59 10 26 5	47	**Very High:** Debris flow would likely deposit on Mission Mountain Road.	Mission Mountain Road: **High** BC Hydro Penstock Intake: **Low** BCH Transmission Line: **NA** (line spans draw)	V High High	
SC3	1.59	940	0.93	Debris Flow: Small channel noted at South Carpenter FSR during field review. Potential for surface runoff to accumulate in gullies resulting in a small debris flow.	4	High Low Mod Unburnt	65 8 14 13	49	**Very High:** Debris flow would deposit on lower branch road.	Noaxe Branch Road: **Moderate** BCH Transmission Line: **NA** (line spans draw)	High	
SC4	0.98	720	1.31	Debris Flow: Stream channel was not noted on South Carpenter FSR. Potential for surface runoff to accumulate in gullies resulting in a small debris flow. Terrain is very steep and gullied. **Telus Cell Tower site on Noaxe branch Road within this draw.**	4	High Low Mod Unburnt	35 9 32 23	32	**High:** Debris flow would deposit on lower branch road and may impact cellular tower site.	Noaxe Branch Road: **Moderate** BCH Transmission Line: **Moderate** (line spans draw) Cellular Tower Site: **Moderate**	High High High	

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Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
MD1	3.27	1300	0.54	Debris Flood / Debris Flow: Upper watershed prone to debris flow, lower watershed prone to debris flood. Culvert needs cleaning and/or upgraded.	3	High Low Mod Unburnt	68 10 18 5	52	**Very High:** Debris flow extending down to Mission Dam Road and would deposit in Carpenter Lake.	Mission Dam Road: **High**	V High	• **Complete a detailed review of Mission Mountain Road to ensure road drainage measures (ditchlines, culverts, crossings, crowning) are functional and adequately sized.** • **Debris flow mitigation structure should be considered on Mission Dam Road.** • Increase frequency of inspections on Mission Dam Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events. • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023.
MD4	1.50	1240	2.09	Debris Flow: History of debris flow. Dry stream during field review. No mitigation measures in place on Mission Dam Road.	4	High Low Mod Unburnt	14 24 39 23	20	**High:** Debris flow extending down to Mission Mountain Road and would deposit in Carpenter Lake.	Mission Dam Road: **High**	High	
MD7	2.60	1480	0.95	Debris Flow: Dry stream channel during field review. Rockfall: Increased frequency of rockfalls on steep scree slopes above Mission Dam Road.	4	High Low Mod Unburnt	8 17 17 59	10	**Moderate:** Debris flow would likely deposit on Mission Dam Road (Road 40) before reaching Recreation Site.	Mission Dam Road: **High** Mission Dam Recreation Site: **Moderate**	High Moderate	• Consider temporary closures of the Mission Dam Recreation Site during periods of expected high rainfall (October 15 to April 15) over the next 5 years until vegetation has recovered in the MD7 watershed.
MD11	3.54	1600	0.78	Debris Flow: History of debris flow. Dry, rocky watershed. Rockfall: Increased frequency of rockfalls on steep scree slopes above Mission Dam Road.	4	High Low Mod Unburnt	11 12 16 61	12	**High:** Debris flow would deposit on fan area with a portion of the runout reaching Bridge River.	Mission Dam Road: **V Low**	Low	• Events are not expected to impact Mission Dam Road (Road 40) and no recommendations are made.
MD12	1.79	1320	1.18	Debris Flow: History of debris flows. Dry, rocky watershed. Rockfall: Increased frequency of rockfalls on steep scree slopes above Mission Dam Road.	4	High Low Mod Unburnt	48 9 19 24	38	**Very High:** Debris flow would deposit on fan area with a portion of the runout reaching Bridge River.	Mission Dam Road: **V Low**	Moderate	
MD13	4.90	1600	0.81	Debris Flow: History of debris flow. Dry, rocky watershed. Rockfall: Increased frequency of rockfalls on steep scree slopes above Mission Dam Road.	4	High Low Mod Unburnt	19 6 11 64	16	**High:** Debris flow would deposit on fan area with a portion of the runout reaching Bridge River.	Mission Dam Road: **V Low**	Low	

Watershed Name	Stream Length (km)	Relief (m)	Melton #	Dominant Hydrogeomorphic Process	Process Index	Burn Severity (%)		Burn Severity Index	Hazard Likelihood P(H) and form	Elements at Risk and P(S:H)	Partial Risk P(HA)	Recommendation
MD1 Face Unit	N/A	N/A	N/A	Rockfall: Increased ravelling of talus slopes can be expected. Debris Slurry: Small debris slurries or mudflows can be expected.	N/A	High Low Mod Unburnt	28 20 37 15	29	**High:** Rockfalls or debris slurries extending down to Mission Dam Road and potentially Carpenter Lake.	Mission Dam Road: **High**	High	• **Increase frequency of inspections on Mission Dam Road during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events.** • Rainfall shutdown procedure should be developed similar to that in place for Hwy. 99 where it was impacted by debris flows in 2021 and the area of Hwy. 1 impacted by the Kookipi wildfire in 2023. • No stopping signage is already in place for most of this road section and must be kept in place.
MD2 Face Unit	N/A	N/A	N/A	Rockfall: Increased ravelling of talus slopes can be expected. Debris Slurry: Small debris slurries or mudflows can be expected.	N/A	High Low Mod Unburnt	48 11 29 12	40	**High:** Rockfalls or debris slurries extending down to Mission Dam Road and would deposit in Carpenter Lake or Bridge River.	Mission Dam Road: **High**	High	
LP1	3.41	1720	0.79	Debris Flow: History of debris flow. Culvert is suitably sized for large runoff event or slurry but would be impacted by a debris flow.	4	High Low Mod Unburnt	42 12 18 28	34	**Very High:** Debris flow is expected to impact the road and the culvert.	Road 40: **High**	V High	• **Review Road 40 to ensure road drainage measures (ditchlines, culverts, crossings) are functional and adequately sized.** • **Increase frequency of inspections on Road 40 during extreme precipitation events. Ensure maintenance contractors are aware of the potential for increased frequency of mass wasting events from this hillslope.** • **No stopping signage is already in place for most of this road section and must be kept in place.**
LP2	2.25	1360	1.05	Debris Flow: Stream channel not significant. Suitably sized culvert for clearwater flows.	4	High Low Mod Unburnt	45 6 47 1	42	**Very High:** Debris flow is expected to impact the road and the culvert.	Road 40: **High**	V High	
LP3	1.48	960	1.14	Debris Flow: Stream channel not significant. Suitably sized culvert for clearwater flows.	4	High Low Mod Unburnt	66 4 30 1	52	**Very High:** Debris flow is expected to impact the road and the culvert.	Road 40: **High**	V High	
Cougar Creek	2.20	760	0.76	Debris Flow: Small stream. Suitably sized culvert for clearwater flows.	4	High Low Mod Unburnt	42 25 19 14	36	**Very High:** Debris flow is expected to impact the road and the culvert.	Road 40: **High**	V High	
LP1 Face Unit	N/A	N/A	N/A	Rockfall: Increased ravelling of talus slopes can be expected. Debris Slurry: Small debris slurries or mudflows can be expected in minor swales.	N/A	High Low Mod Unburnt	15 30 34 21	20	**Moderate:** Rockfalls or debris slurries extending down to Road 40 and would deposit in Carpenter Lake.	Road 40: **High**	High	

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7.0 Closure

Factual data and interpretation contained within this report were prepared specifically for The Ministry of Forests with whom Onsite Engineering Ltd. has entered into a contract. No other party may rely upon this report without the express written permission of OEL.

We trust that this report satisfies your present requirements. Should you have any questions or comments, please contact our office at your convenience.

Sincerely,

Onsite Engineering Ltd.
EGBC Permit to Practice – No. 1002678

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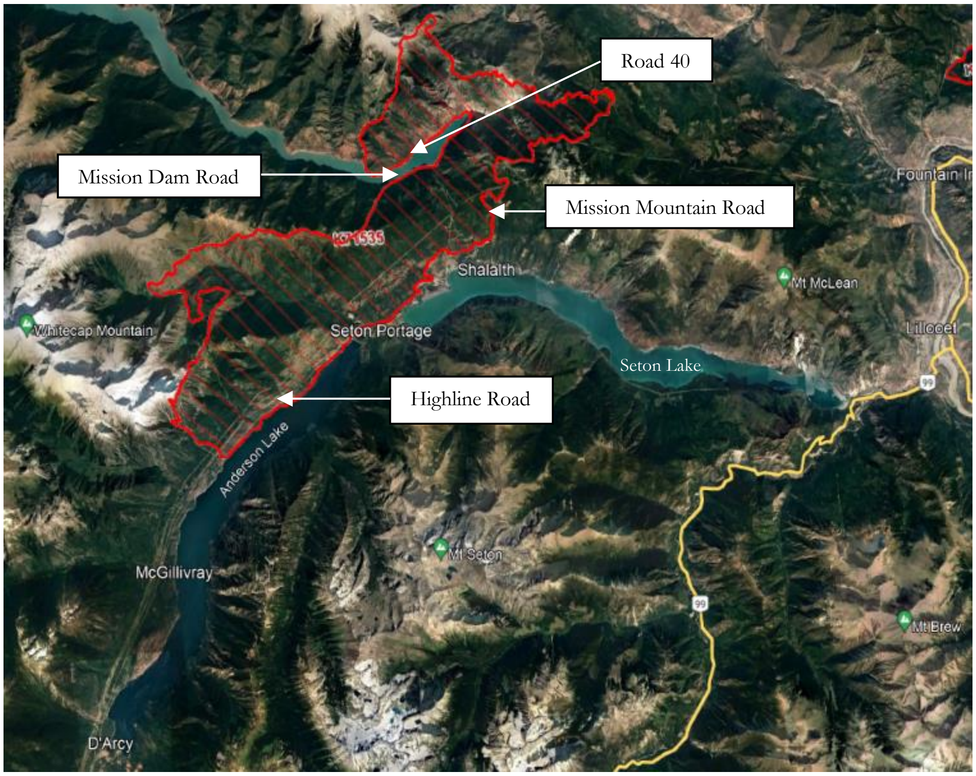

Figure 1 Location Map of the Casper Creek fire.

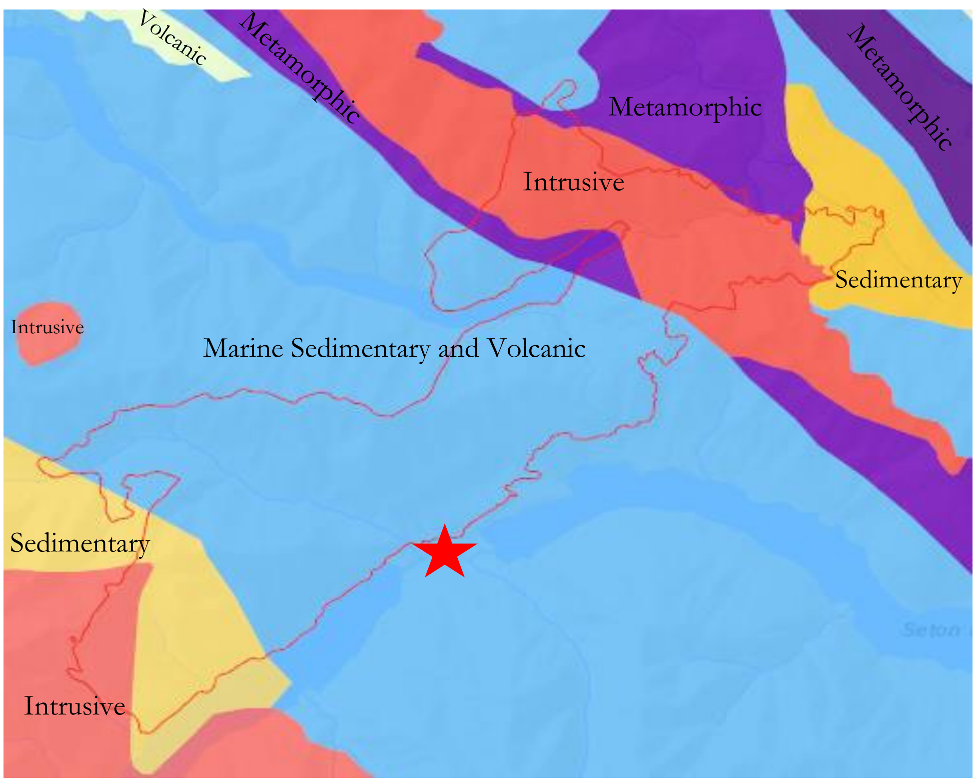

Figure 2 Bedrock geology of the Casper Creek fire. The star is Seton Portage.

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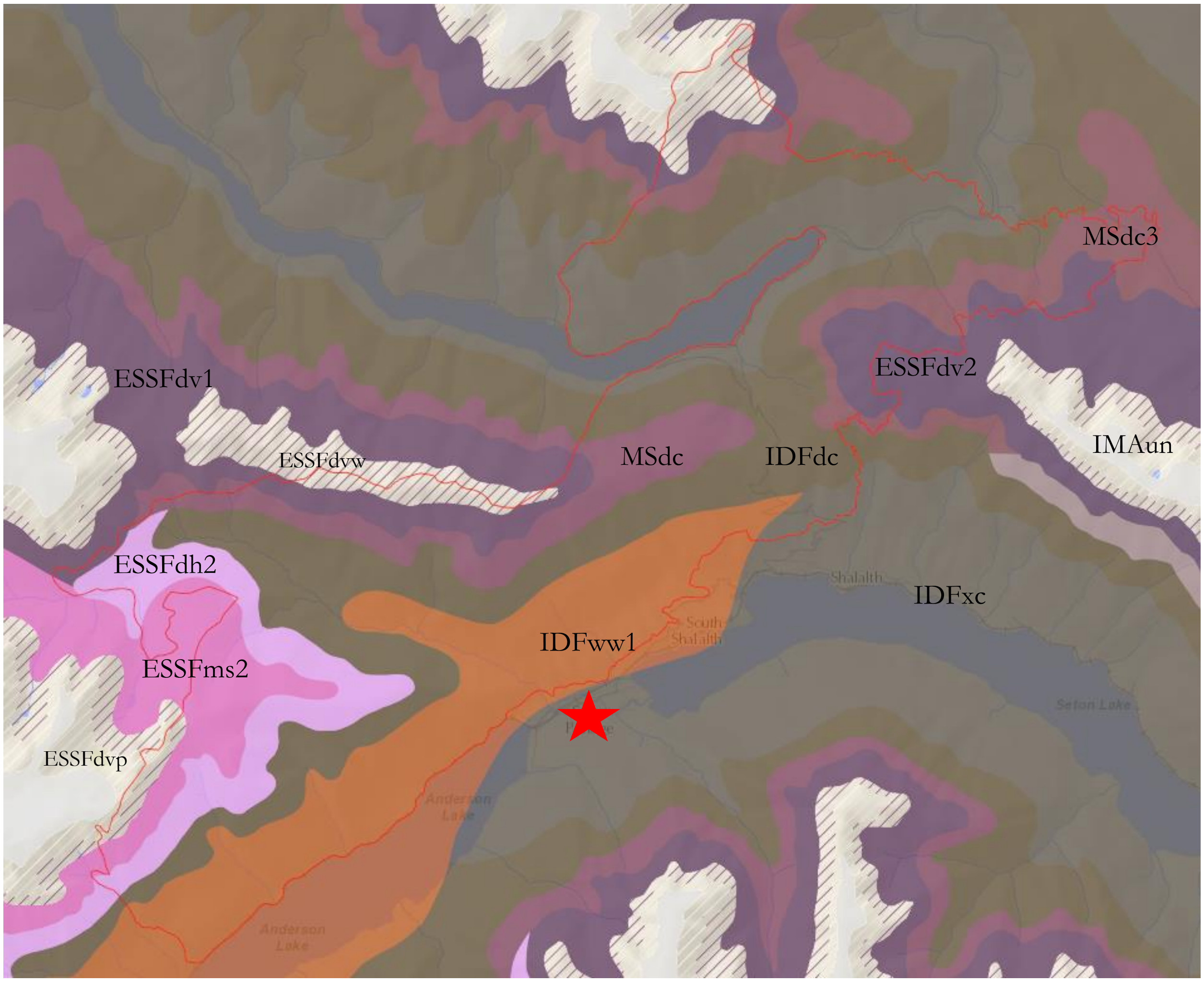

Figure 3 Biogeoclimatic ecosystem classification (BEC) zones of the Casper Creek fire. The star is Seton Portage.

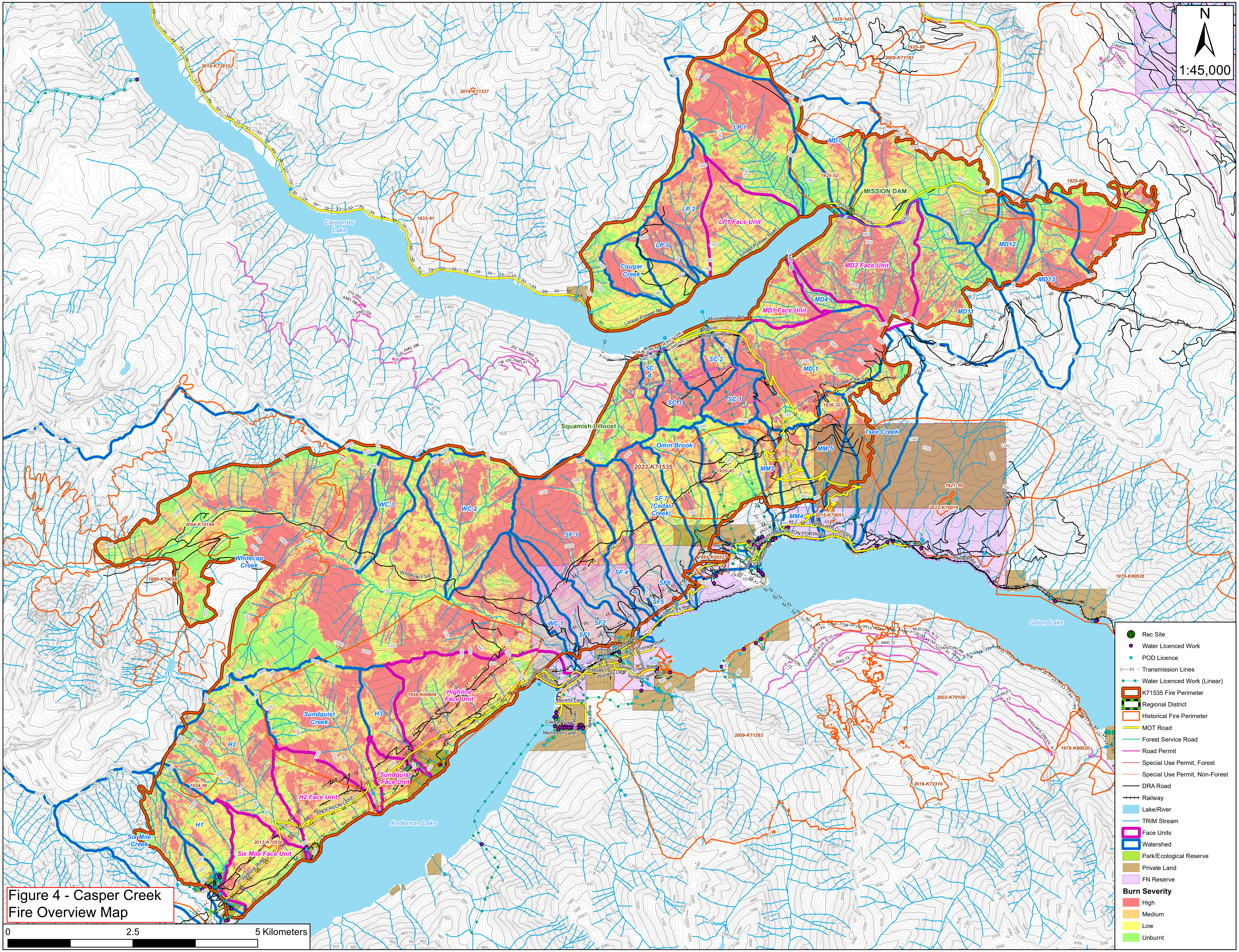

Figure 4 - Casper Creek Fire Overview Map

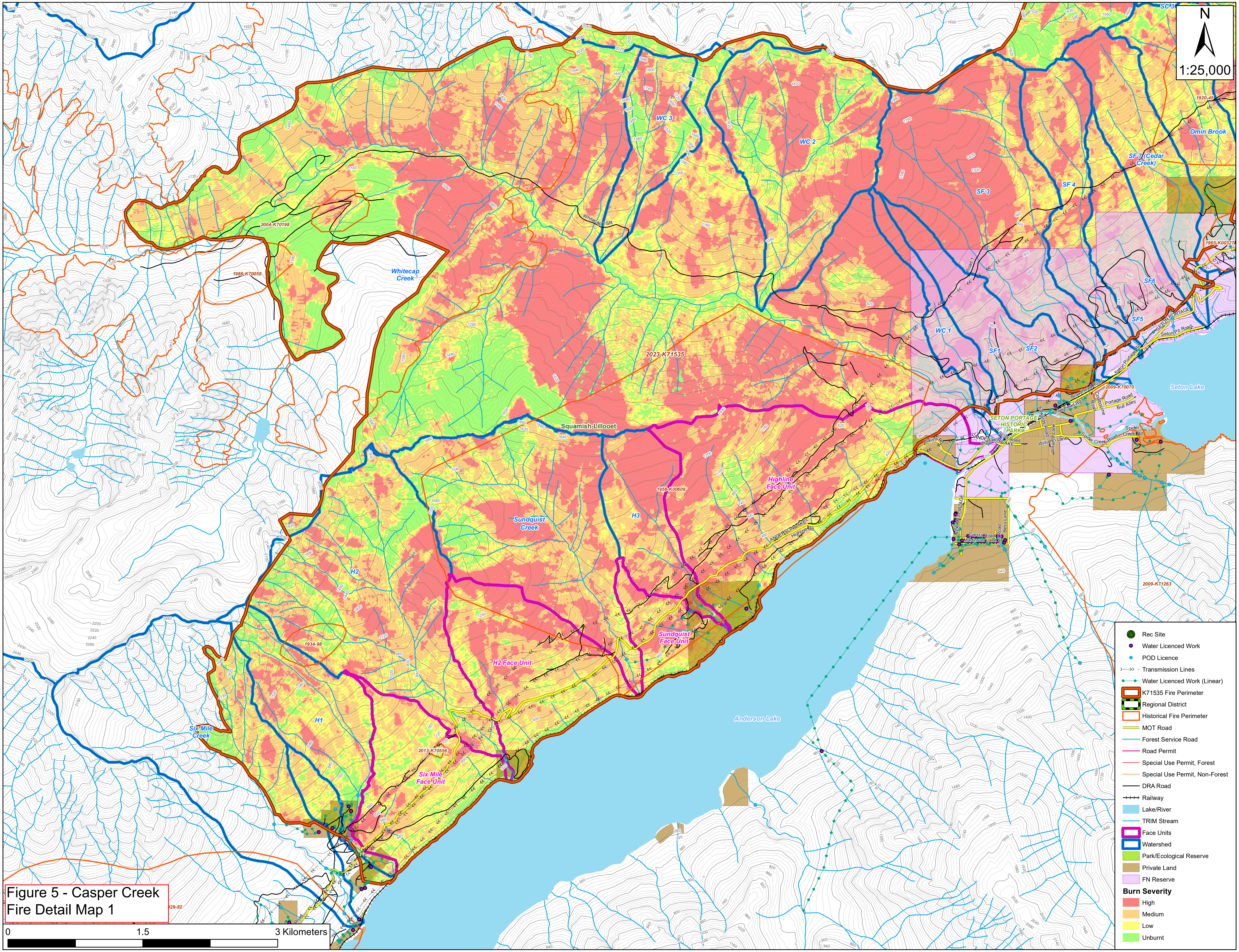

Figure 5 - Casper Creek Fire Detail Map 1

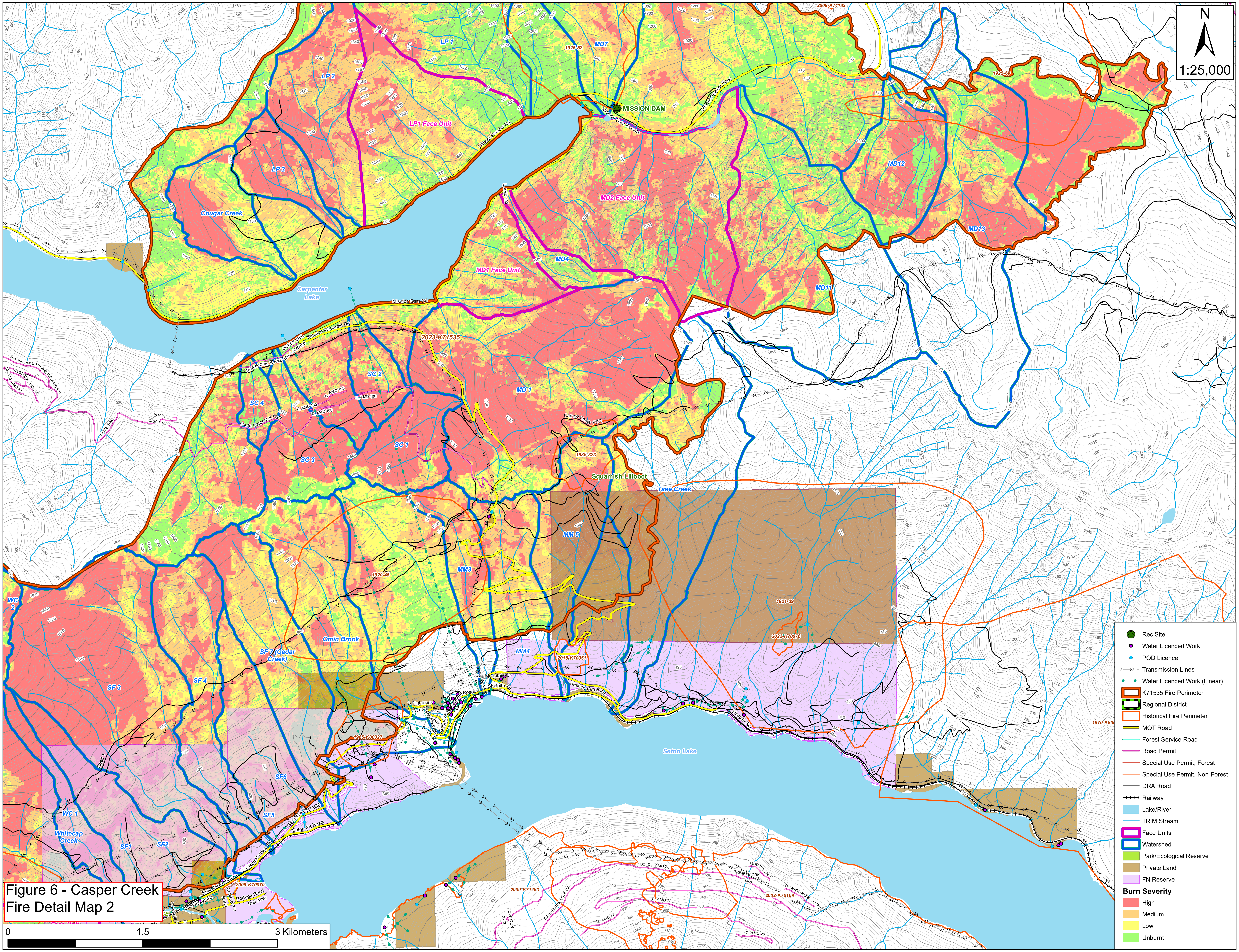

Figure 6 - Casper Creek Fire Detail Map 2

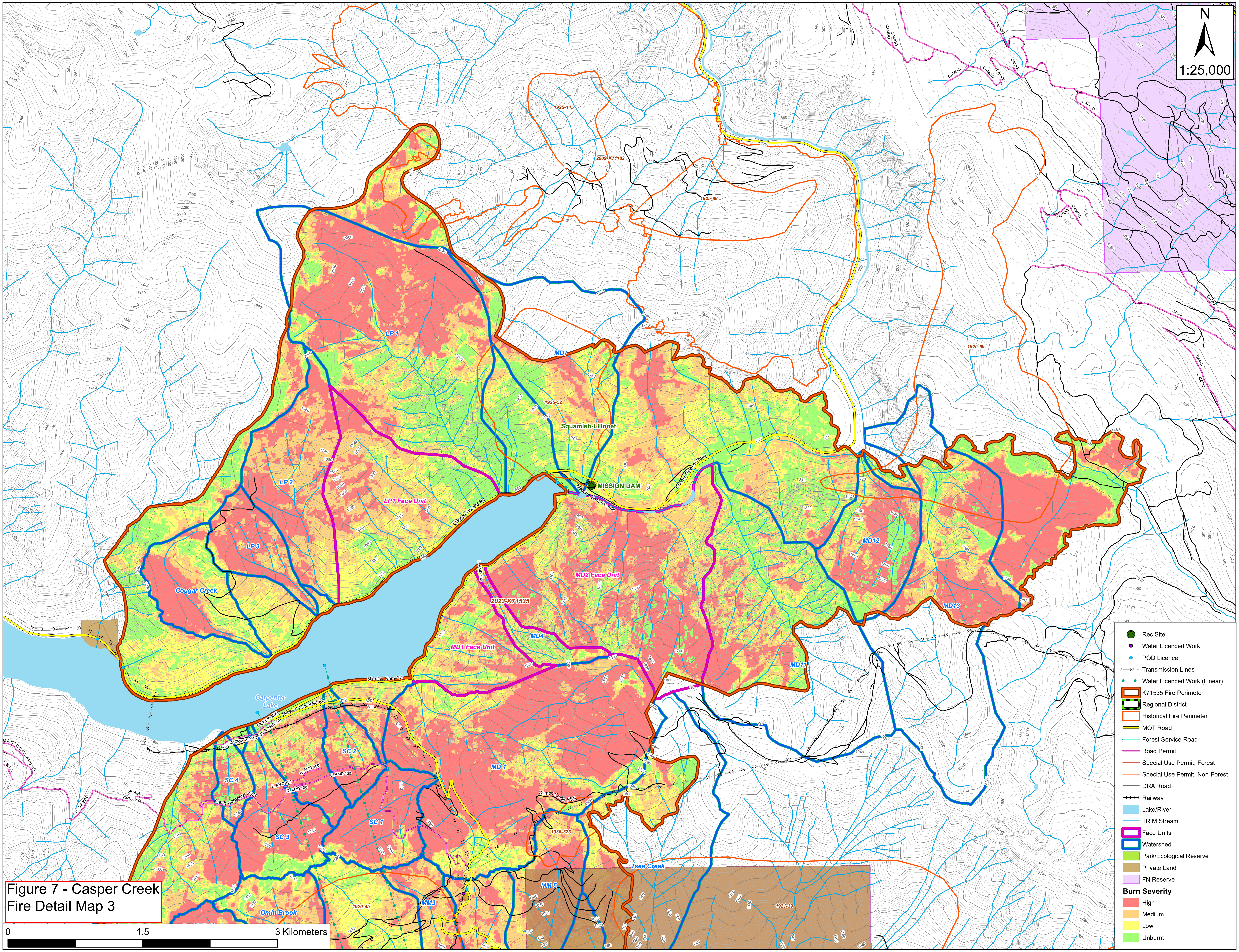

Figure 7 - Casper Creek Fire Detail Map 3

Appendix A – Soil Burn Severity Assessment

Fire: K71535	Date: October 18, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 21	GPS coordinates: 50.67 N, 122.39 W	Elevation: 575 m
Slope: Up: 65 %	Down: 65 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 % Green trees: 5 % Brown trees: 95 % Dead: 0 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 18, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 42	GPS coordinates: 50.76 N, 122.25 W	Elevation: 1254 m
Slope: Up: 50 %	Down: 50 %	Aspect: East

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 % Green trees: 0 % Brown trees: 5 % Dead: 95 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 48	GPS coordinates: 50.73 N, 122.35 W	Elevation: 898 m
Slope: Up: 40 %	Down: 45 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 10 % Green trees: 60 % Brown trees: 40 % Dead: 0 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 50	GPS coordinates: 50.73 N, 122.35 W	Elevation: 935 m
Slope: Up: 35 %	Down: 25 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 % Green trees: 0 % Brown trees: 60 % Dead: 40 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 51	GPS coordinates: 50.72 N, 122.33 W	Elevation: 779 m
Slope: Up: 70 %	Down: 60 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 %   Green trees: 0 %   Brown trees: 50 %   Dead: 50 %

Vegetation burn severity: Low   Moderate   High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low   Moderate   High

Size of surrounding area similar to plot: < ½ ha   1/2 – 2 ha   2-5 ha   >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 52	GPS coordinates: 50.72 N, 122.31 W	Elevation: 842 m
Slope: Up: 15 %	Down: 15 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 % Green trees: 0 % Brown trees: 5 % Dead: 95 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 56	GPS coordinates: 50.75 N, 122.22 W	Elevation: 1190 m
Slope: Up: 70 %	Down: 70 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 %   Green trees: 0 %   Brown trees: 20 %   Dead: 80 %

Vegetation burn severity: Low   Moderate   High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low   Moderate   High

Size of surrounding area similar to plot: < ½ ha   1/2 – 2 ha   2-5 ha   >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds

Fire: K71535	Date: October 19, 2023	Crew: Rod Williams, Rayleen Wilson
Plot number: Placemark 57	GPS coordinates: 50.72 N, 122.32 W	Elevation: 676 m
Slope: Up: 50 %	Down: 50 %	Aspect: South

Canopy Condition (circle one)				
Unburned	Mostly alive (green)	Mostly dead; needles remaining (brown or red)	Dead; no needles; some twigs and cones (black)	Dead; trunk and large branches only (black)

% Cover: Green understorey: 0 % Green trees: 0 % Brown trees: 5 % Dead: 95 %

Vegetation burn severity: Low Moderate High

Soil burn severity indicator	**Indicator Class** (circle one)		
Litter	Scorched, charred	Mostly consumed	Consumed
Duff (FH layers)	Intact	Spottily consumed	Mostly consumed
Woody debris – small	Charred	Partly consumed	Consumed
Woody debris – Logs	Charred	Some consumed	Many consumed, others deeply charred
Ash colour (if present)	Black	Grey	White
Mineral soil exposure	<5%	5-40%	>40%
Change to mineral soil	No	Minor	Yes
Depth to live roots or rhizomes (in min. soil)	0	0-5 cm	>5cm

Soil burn severity: Low Moderate High

Size of surrounding area similar to plot: < ½ ha 1/2 – 2 ha 2-5 ha >5 ha

Evidence of runoff/overland flow: sand deposits / needle deposits / rills / pedestals / terracettes / no

Water repellency – extent and class:

None – <10 seconds

Weak – >10 seconds and <40 seconds

Strong – >40 seconds


Placemark 21 Moderate soil burn severity.


Placemark 42 High soil burn severity.

Placemark 42 Hydrophobic soils.

Placemark 48 Moderate soil burn severity.


Placemark 50 High soil burn severity.


Placemark 50 Hydrophobic soils.

Placemark 51 Moderate soil burn severity. Soil is hydrophobic on surface and moist at depth.

Placemark 52 High soil burn severity.


Placemark 56 High soil burn severity.


Placemark 57 High soil burn severity, hydrophobic soil.

Appendix B – Photos

Photo 1 Six Mile Creek watershed on the fire boundary and H1, looking north.


Photo 2 Highline Road flooding near H1 during the atmospheric river event of October 18th, 2023, looking east.

Photo 3 H2 watershed with residence on fan, looking north.

Photo 4 Residences on H2 fan below Highline Road.

Photo 5 H2 fan below Highline Road. Note BCH transmission line tower near fan apex. Stream is well confined in a large draw adjacent to the structure.

Photo 6 Mitigation structure upstream of culvert inlet at the residential road crossing of H2 at the fan apex.

Photo 7 Upper H2 watershed, looking north.

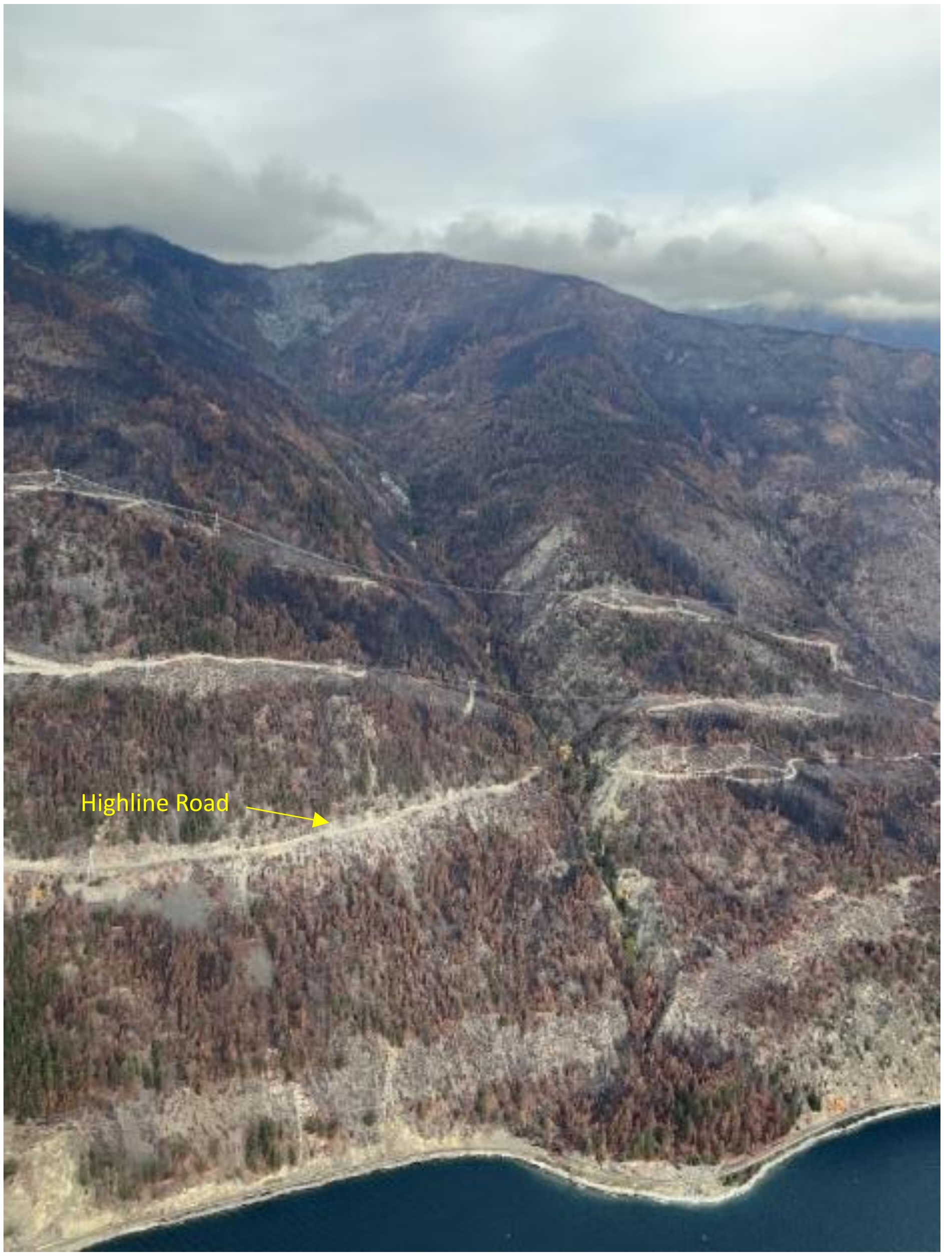

Photo 8 Sundquist Creek, looking northeast.

Photo 9 Rocky area above Highline Road, draws do not have significant surface flow, looking north.


Photo 10 Slopes above Highline Road showing mixed vegetation burn severity, looking west.

Photo 11 Till slope upstream of bedrock canyon on Whitecap Creek.

Photo 12 Whitecap Creek watershed, looking north. Whitecap FSR is on the east side of the valley.


Photo 13 Whitecap Creek falls, looking north.


Photo 14 Upper Whitecap Creek drainage where the 2023 wildfire area overlaps the 2004 wildfire area.


Photo 15 Looking down through the lower Whitecap Creek drainage. Note the immediate riparian area has a relatively low burn severity.


Photo 16 Road 1 climbing out of the Whitecap drainage and extending to the east.


Photo 17 Upper Whitecap Creek bridge that has been previously washed out, looking west.


Photo 18 Ravelled scree slope and rockfall deposits on Whitecap FSR, looking north.

Photo 19 Anderson Lake Road bridge at the top, Whitecap Creek bridge at the bottom, and the Whitecap-Portage River confluence.


Photo 20 Lower Whitecap Creek at the Portage River confluence.

Photo 21 Lower Whitecap Creek with the FSR bridge, cabins and office building.

Photo 22 WC1 draw, looking northeast. Note the extensive burn area above the upper transmission line.

Photo 23 Seton Portage face units, looking east. Note the steep bedrock face unit below the upper transmission line and the low gradient bench that the streams flow across in well incised low gradient draws.

Photo 24 Seton Portage face units, looking north.


Photo 25 High vegetation burn severity slopes in the upper SF3 watershed, looking east.

Photo 26 Sk'il Mountain Community School (star) on the terrace between Cedar Creek and Omin Brook, looking north.

Photo 27 South slopes of Mission Mountain Road, MM3, and MM5, looking north. Tsee Creek is on the right, and the BC Hydro BR site is on the left.


Photo 28 Mixed burn severities on the south slopes of Mission Mountain Road, upper MM5 watershed looking north.


Photo 29 Tsee Creek fan area, view looking north.

Photo 30 High vegetation burn severity on Camoo Creek FSR, upper MD1 watershed looking east.

Photo 31 North slopes of Mission Mountain Road looking south towards Mission Pass.

Photo 32 Tsee Creek on the right of Shalalth, looking south.


Photo 33 Tsee Creek watershed and bedrock canyon, looking north.

Photo 34 Bedload material and mud splatter on lower Tsee Creek at Shalalth Cutoff Road, looking upstream.

Photo 35 South Carpenter FSR and the SC1 watershed, looking west.

Photo 36 Mission Mountain Road descending towards Carpenter Lake. Note eroded fill in areas of burnt out vegetation in the fill.

Photo 37 South Carpenter FSR showing SC2 to SC5 and the fire boundary on the right, looking north.

Photo 38 Mission Dam Road on the lakeshore and Mission Mountain Road, looking south.

Photo 39 MD1 watershed showing high vegetation burn severity, looking southeast.

Photo 40 The upper reach of MD4, looking south.

Photo 41 Recent flow paths east of MD4.

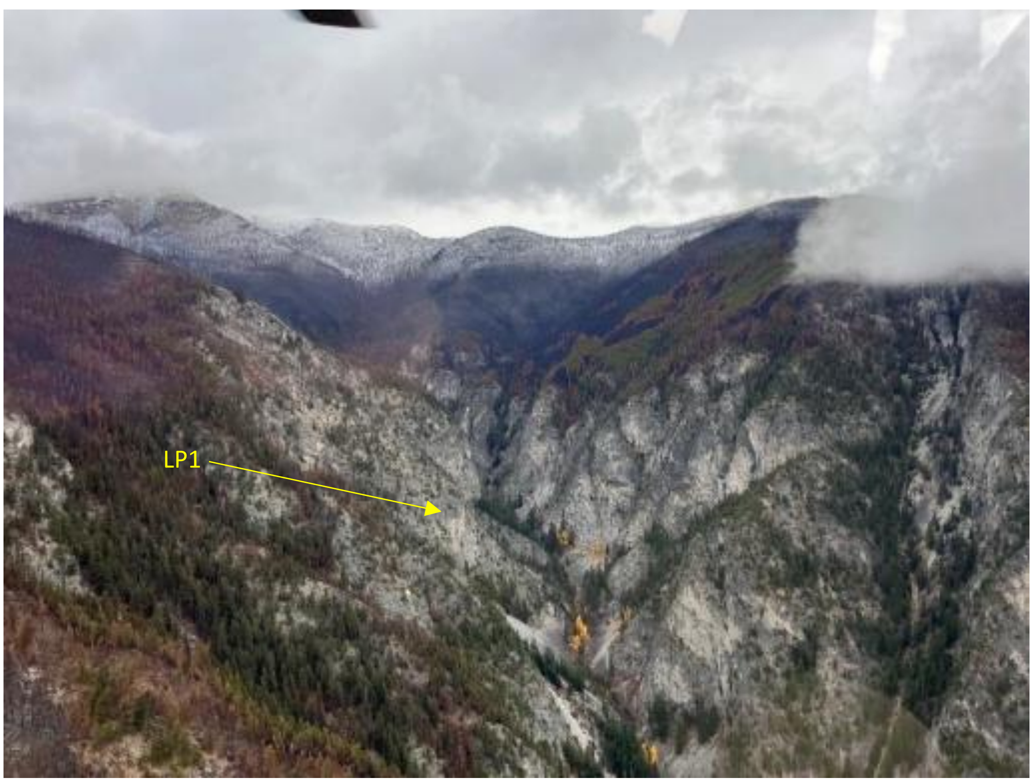

Photo 42 LP1 watershed showing high vegetation burn severity in the upper watershed, looking north.

Photo 43 LP3 (left) and LP2 (right) watersheds, looking north.

Photo 44 Cougar Creek (left) and LP3 (right) watersheds showing unburned to high vegetation burn severity, looking west.