POST-WILDFIRE GEOTECHNICAL HAZARD ASSESSMENT

Kanaka Bar Reserve

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SUMMARY

T'eqt''aqtn'mux (Kanaka Bar Indian Band, KBIB) retained Statlu Environmental Consulting Ltd. (Statlu) to complete a post-wildfire geotechnical hazard assessment of KBIB's reserve lands. The Kookipi Creek wildfire (V11337) burned the area upslope of KBIB reserve lands in August 2023. The watersheds of Siwash Creek, Niger Creek, Nekliptum Creek, North Nekliptum Creek, and Morneylun Creek were all burnt by the fire, although the extent and intensity of the fire varied from watershed to watershed. North Nekliptum Creek is the source of the primary water supply for the band. Siwash Road provides access to the reserve and crosses the drainages of Niger Creek, a tributary of Niger creek, Nekliptum Creek, and North Nekliptum Creek.

The developed area of the reserve consists of lands on a ridge between Nekliptum Creek and Morneylun Creek. Due to its position and elevation above the nearby creeks, the reserve lands are not at risk from most geotechnical hazards, even when considering the increased likelihood of hazards after wildfire. Post-wildfire bank erosion in Morneylun Creek may increase and could result in an increased likelihood of small landslides on the steep gully sidewalls between Morneylun Creek and reserve buildings but are unlikely to present an immediate increase in risk to any reserve buildings.

Floods, debris flows, and debris floods can all occur in the streams in the study area. Any of these events in North Nekliptum Creek, Nekliptum Creek, the Niger Creek tributary, or Niger Creek might cause sedimentation that could block or damage culverts on Siwash Road and result in water or sediment flowing onto, blocking, and damaging Siwash Road itself. Sedimentation caused by floods, debris floods, and debris flows in North Nekliptum Creek could also damage or destroy water supply and water treatment infrastructure.

In addition to floods, debris floods and debris flows, North Nekliptum Creek is also likely to experience increases in fine sediment transport and changes to water chemistry, even at flow levels well below flood flows. These effects will degrade water quality and can potentially damage water treatment infrastructure as well.

Measures to protect the community water supply from the effects of the wildfire could include building a check dam and sediment detention pond upstream of the water intake, or switching to an alternative source of water. The feasibility of a check dam and sediment detention pond would need to be confirmed with a detailed engineering design study and may be limited by upslope topography. If such a structure is built, it will also require ongoing maintenance to remove trapped sediment and retain capacity. Switching to an alternative source of surface water would not reduce the risks to the water supply, but it might be possible to switch to a groundwater source. It will be necessary to evaluate the nature of groundwater near the reserve, likely by drilling test wells, before confirming that this is a viable option, but it might be possible to construct a new well near the existing water treatment building and continue to use some or all of the existing water distribution infrastructure.

Measures to protect Siwash Road from flooding and sedimentation could consist of some combination of building upslope protective structures, upgrading existing culverts with larger structures, replacing existing culverts with swales, or doing nothing. Upslope protective structures for Siwash Road have the same topographic, engineering design, cost, and maintenance limitations as upstream protective structures for the water intake does, but because the consequences of water or sediment on the road are potentially less severe than disruption to the community water supply, it may be possible to install simpler protective structures, such as trash racks, which simply strain out larger debris but let finer sediment and water through, at a lower cost. Upgrading culverts or replacing culverts with swale crossings are likely to be broadly comparable with respect to cost and timing, but each have specific advantages and disadvantages with respect to long-term use. Doing nothing may be the cheapest option overall, but risks loss of road access at unplanned and inconvenient times.

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1.0 INTRODUCTION

T'eqt''aqtn'mux (Kanaka Bar Indian Band, KBIB) retained Statlu Environmental Consulting Ltd. (Statlu) to complete a post-wildfire geotechnical hazard assessment of KBIB's reserve lands. The area upslope of the reserve was burned by the Kookipi Creek wildfire (V11337) in August 2023. The fire was held back from the homes on Nekliptum 1 and Kanaka Bar 1A reserves but burned forested lands upslope as far as the height of land on Kanaka Mountain, including much of the catchments of Siwash Creek, Niger Creek, Nekliptum Creek, and Morneylun Creek. These watersheds supply drinking and irrigation water to KBIB. Furthermore, they have steep terrain subject to flooding, debris flood, and debris flow.

The assessment evaluated the extent of the fire, the proportion of area burned and intensity of the fire within each catchment, the likely effects on the frequency and magnitude of geohazards after the wildfire, and the potential effects of those geohazards on the reserve lands, water license infrastructure, and roads downslope.

2.0 OVERVIEW OF SETTING AND RESOURCES

T'eqt''aqtn'mux (Kanaka Bar Indian Band) reserve lands are located on the east side of Fraser River, 14 km south of Lytton and 29 km north of Boston Bar, in the Hozameen Range of the Cascade Mountains (Figure 1). The KBIB reserve lands include Nekliptum 1, Kanaka Bar 1A, Kanaka Bar 2, Pegleg 3, Pegleg 3A, and Whyeek 4 reserves, but this assessment was limited to the Nekliptum 1 and Kanaka Bar 1A reserves.

Canadian National Railway tracks and Highway 1 parallel Fraser River along the river's east bank. Most of the houses on the reserve are located on a bench upslope of Highway 1, on the Nekliptum 1 reserve lands, reached by Siwash Road. A few additional houses are located along Highway 1, both upslope and downslope of the highway (Figure 1).

A run of river hydro-electric power project is located at Kwoiek Creek, across Fraser River from Kanaka Bar on the Whyeek reserve. A cable car crosses Fraser River from a base station located near Highway 1 to reach the power plant.

East of the reserve, the valley sideslopes rise to the height of land on Kanaka Mountain. Siwash Creek, Niger Creek, Nekliptum Creek, and Morneylun Creek drain from these sideslopes and flow through, across, or near the reserve lands into Fraser River.

2.1 Geologic, Geomorphic, and Physiographic Setting

Bedrock in the area consists of two units. Clastic sedimentary rocks, consisting of sandstone, argillite, and slate, of the Cretaceous-aged Jackass Mountain Group are in the valley bottom, following Fraser River and underlying the reserve lands. Bedrock on the eastern hillsides up to Kanaka Mountain consists of older, Permian to Triassic aged granodiorite of the Mount Lytton Complex. The contact between the two bedrock units is at an elevation of about 750 m above mean sea level near the reserve.

The Fraser River Fault, separating the Coast and Cascade Mountains, follows the trend of Fraser River near the reserve, but is slightly offset to the west of the river. The Jackass Mountain sedimentary rocks are located along the fault, and the fault demarcates their western edge (iMapBC, 2023).

Surficial materials in the area include fluvial and glaciofluvial sands and gravels, comprising active gravel bars, terraces, and alluvial fans, as well as sandy to silty glacial till, and blocky to rubbly colluvium.

Nekliptum Reserve is situated on a broad bench at an average elevation of approximately 400 m a.s.l. This bench is covered with a deep blanket of glaciofluvial sand and gravel but is not a terrace landform; it is underlain by bedrock. Highway 1 runs along a second, lower bench west of the reserve, at an elevation of about 265 m a.s.l.; this bench is similarly underlain by bedrock. Finally, houses on the Kanaka Bar 2 reserve occupy a glaciofluvial terrace in the valley bottom near the CN Railway tracks, at an elevation of about 200 m a.s.l, about 70 m above river level.

2.2 Watersheds

From south to north, Siwash Creek, Niger Creek, Nekliptum Creek, North Nekliptum Creek, and Morneylun Creek drain the east slopes of Kanaka Mountain and flow to Fraser River. Siwash Creek and Morneylun Creek are the two largest streams and flow in deep, steep-walled gullies that are incised through both the sediments and the underlying bedrock. Niger Creek, Nekliptum Creek, and North Nekliptum Creek, by contrast, are smaller streams that flow down from the mountainside onto and across the bench surface south of the houses on Nekliptum reserve, across Siwash Road, and then down steeper slopes to cross under Highway 1 and then again down steep slopes below the highway into Fraser River.

The drainage areas and other physiographic parameters associated with each of these streams are listed in Table 1. North Nekliptum Creek is a tributary to Nekliptum Creek, and its drainage area is also included as part of the listed drainage area of Nekliptum Creek (iMapBC, 2023).

Table 1: Study Area Watersheds

Stream Name	Watershed Area (km^2)	Relief (m)	Channel Length (km)	Average Gradient (%)	Melton Ruggedness Ratio
Siwash Creek	11.3	1850	6.9	16%	0.55
Niger Creek	1.7	1170	2.2	69%	0.90
Nekliptum Creek	3.7	1690	4.9	46%	0.88
North Nekliptum Creek	0.8	1120	1.7	66%	1.3
Morneylun Creek	2.3	1790	4.5	40%	1.2

Many of the mapped stream channels within these watersheds, except for the main channels of Morneylun Creek and Siwash Creek, begin at an elevation of between 650 m and 750 m a.s.l. This elevation band is very close to the mapped location of the geologic contact between the granodiorite and sedimentary rocks, and it is possible these streams originate as springs draining a bedrock aquifer, which surfaces along the geologic contact.

2.3 Climate and Weather

The nearest long-term climate station is at Lytton, 14 km to the north, at an elevation of 229 m a.s.l. Climate normal data for Lytton is only available for the 1971 to 2000 climate interval, not for any more recent intervals, and thus is out of date. The 1971 to 2000 interval data indicate that

Lytton had average precipitation of 432 mm with 339 mm of rainfall and 117 cm of snowfall; the snowfall is very dry, and so the recorded 117 cm of snowfall corresponds to less than 117 mm of water equivalent. The extreme daily precipitation on record was 61 mm/24 hr in 1974 (Environment Canada, 2023).

Because the data from the Lytton climate station is out of date, I used the ClimateBC model to evaluate the present climate at Nekliptum Reserve, for a representative site at an elevation of 400 m a.s.l. (Wang et al., 2016). The model predicts that for the 1991 to 2020 climate normal period, mean annual precipitation was 520 mm, with 76 mm water equivalent of snowfall and 440 mm of rainfall. 375 mm of the total rainfall (72%) falls in the autumn and winter months.

ClimateBC does not estimate precipitation intensity, so I used IDF_CC 7.0 (Simonovic et al., 2015) to estimate precipitation intensities (Table 2). I considered two precipitation intensities for two separate frequencies and durations: total 1-day (24-hour) precipitation, and 1-hour precipitation, for the 50% and 1% (1-in-2 year and 1-in-100 year) annual exceedance probabilities. These precipitation intensities best represent relatively frequent and infrequent meteorological conditions. Because the interval of concern for this project is short-term, related to conditions over the next few years, I evaluated precipitation intensities for present (2023) climate conditions and did not consider long-term climate effects on future precipitation intensities.

Table 2: Predicted Precipitation Intensities, 1-in-2 year and 1-in-100 year, Nekliptum Reserve

Annual Exceedance Probability	Frequency	Duration	Intensity (mm/hr)	Total Precipitation (mm)
50%	1-in-2 year	1 hour	6.9	6.9
		24 hours	1.6	38.9
1%	1-in-100 year	1 hour	16.1	16.1
		24 hours	2.8	67.3

2.4 Water Licenses and Water Use

Water license points of diversion are located on Siwash Creek, Niger Creek, Nekliptum Creek, North Nekliptum Creek, and Morneylun Creek (Figure 1). These water licenses are held for domestic, irrigation, power generation, and enterprise purposes (WRBC, 2023). The Kanaka Bar Indian Band's main water intake takes water from North Nekliptum Creek and processes it at a water treatment building located between the channels of North Nekliptum Creek and Nekliptum Creek, about 250 m upslope (east) of Siwash Road. The band has a water diversion license to allow them to transfer water from higher up Nekliptum Creek into North Nekliptum Creek in order to augment streamflow in North Nekliptum Creek. The diversion consists of a shallow irrigation ditch, roughly 0.3 m wide and deep, which runs along approximately contour from Nekliptum Creek across the divide into the headwaters of North Nekliptum Creek.

2.5 Transportation

Siwash Road provides the only road access route to the Nekliptum Reserve. Siwash Road leaves Highway 1 about 500 m north of where Highway 1 crosses Siwash Creek, and climbs upslope to reach the reserve, crossing Niger Creek, Nekliptum Creek, and North Nekliptum Creek en route.

2.6 Power Transmission

A power transmission line from the Kwoiek Creek run-of-river hydroelectric plant crosses Fraser River and runs upslope to the height of land, running generally from west to east and remaining in the Nekliptum Creek watershed as it climbs away from the reserve. Near Siwash Road, the power line right of way follows the divide between Nekliptum Creek and Niger Creek.

3.0 KOOKIPI WILDFIRE

The Kookipi wildfire (V11337) started in Kookipi Creek south of Nahatlatch River in early July 2023. In late August 2023, driven by warm temperatures and strong southwesterly winds, it greatly expanded in size, crossed Fraser River, and then burned forests to the north. All of the terrain upslope of the reserve up to the height of land was burned, at variable intensities (Photo 1, Appendix 2). The final mapped area of the fire was 17,406 ha.

4.0 METHODS

This post-wildfire geohazard assessment included a review of background literature, aerial and satellite photos, online documentation, and field inspections. Field inspections included a helicopter overflight followed by a foot traverse along the eastern boundary of the reserve lands. I have also used information relevant to past geohazards that followed other wildfires in the area, most notably the 2021 Lytton Creek fire.

4.1 Literature Review

I considered supplemental information contained in the following reports and documents while conducting this assessment:

- Focus Environmental Inc. (2008). Kwoiek Creek Hydroelectric Project Ammended [sic] Application for an Environmental Assessment Certificate, Volume 1. Prepared for Kwoiek Creek Resources Limited Partnership.
- Kwoiek Creek Hydroelectric Project (2009). Assessment Report and Screening Report. BC Environmental Assessment Office with Transport Canada and Indian and Northern Affairs Canada.
- BC Ministry of Forests, Land Management Handbook 69 (2015). Post-wildfire Natural Hazards Risk Analysis in British Columbia.
- BGC Engineering Inc., 2019. Thompson River Watershed Geohazard Risk Prioritization. Technical report for Fraser Basin Council.
- BGC Engineering Inc., 2021. Memorandum re: potential post-wildfire debris flows and debris floods affecting property in and around Nicomen Band Village. Technical memorandum for Nicomen Band and Thompson-Nicola Regional District.
- BGC Engineering Inc., 2021. Re: Post-wildfire debris flow assessment, Devil's Creek at Nicomen 1 I.R. Technical memorandum for MFLNRORD.
- BGC Engineering Inc., 2021. Post-wildfire geohazard risk assessment, Lytton Creek Fire (K71086). Technical report for MFLNRORD.

- BGC Engineering Inc., 2023. Lytton Creek Fire (K71086), Detailed post-wildfire natural hazard assessment, Nicola Valley BC. Technical report for BC Ministry of Forests.
- Thurber Engineering Ltd., 2018. Debris flow hazard assessment update and conceptual mitigation options, North Bend BC. Technical report for Fraser Valley Regional District.
- Westrek Geotechnical Services Ltd., 2021. K71086 Lytton Creek Post-wildfire Natural Hazard Risk Assessment, Reconnaissance Report. Technical memorandum for BC MFLNRORD.
- Statlu Environmental Consulting Ltd., 2023. Debris flow design parameters for Nahatlatch FSR Stream Crossing, 0.9 km. Technical memorandum for BC Ministry of Forests.

4.2 Imagery Review

I reviewed digital versions of historic aerial photography covering the period from 1960-1999, and more recent Google Earth imagery from 2004-2023, to evaluate the history of recent past mass movement in the study watersheds.

The photo series, numbers, and dates that I reviewed were:

- BC4253 (1964), 43-44
- BC5212 (1966), 241-242
- BC7215 (1969), 151-153
- BC7721 (1975), 33-34
- BC80069 (1980), 63-64
- BC80120 (1980), 155-156
- 30BC83024 (1983), 162
- BCC613 (1987), 198-199
- 30BCC93093 (1993), 11-12
- 30BCC93043 (1993), 71-72, 119-121
- 30BCB95066 (1995), 40-42
- 30BCC97129 (1997), 59-60, 136-137
- 30BCC97226 (1997), 127-128

- 15BCB98022 (1998), 88-89
- 30BCB98017 (1998) 159-160
- Google™ Earth imagery from 2004, 2014, 2016, 2019, 2021 and 2023

4.3 Helicopter Overview Flight

Drew Brayshaw, Ph.D., P.Geo. and Eryne Croquet, M.Sc., P.Ag. P.Geo. of Statlu made a helicopter overflight of the Kanaka Bar area on the morning of September 9, 2023. Weather conditions during our flight were clear, except for wildfire smoke. We flew with Valley Helicopters from Hope, and made rising contours across the slope above the reserve, starting just above the reserve and finishing by flying over the top of the ridge between Jackass Mountain and Kanaka Mountain. We noted a variable intensity of burn across the study area watersheds. Siwash Creek, Niger Creek, and Nekliptum Creek watersheds had the highest burn intensity, both of the forest canopy and soils. Morneylun Creek had both less area burned and an overall lower intensity of burned areas.

4.4 Field Inspection

We made a site visit after the helicopter overflight, on the same day. We parked at the water treatment plant, and then followed North Nekliptum Creek upslope along the channel for about 200 meters. We traversed the hillside at an elevation of about 500 m a.s.l. north from Nekliptum Creek to Morneylun Creek and descended into the gully of Morneylun Creek to inspect the stream channel there. We descended along the southern divide of the Morneylun Creek gully to the reserve land and walked the firebreak along the east side of the reserve back to the truck. We could not go into the main Nekliptum Creek watershed or into Niger Creek watershed east of Siwash Road because there were still spot fires in that area with active firefighting crews, so we followed Siwash Road south, stopping to inspect the crossing structures in place where the road crosses North Nekliptum Creek, Nekliptum Creek, a Niger creek tributary, and the main Niger Creek drainage. We parked at the quarry on Siwash Road and walked the logging road south across the hillside to Siwash Creek to finish our assessment.

5.0 OBSERVATIONS

I did not note any debris flows, large rockfalls, or landslides in any of the drainages near Nekliptum Reserve over the entire period of photographic record, except for the November 2021 debris flow in Siwash Creek, which is visible on the 2023 imagery. It is possible that small events, of a scale that is below the resolution of the aerial photography to detect (0.5 ha or smaller), occurred over this interval but were not visible.

Evidence of geotechnical instability that we noted during the helicopter overflight consisted of extensive talus patches below bluffs, with boulders of up to 5 m in diameter (Photo 2). Talus patches are scattered in upper Nekliptum Creek and Niger Creek watershed, whereas in the headwaters of Morneylun Creek and Siwash Creek, the talus patches are more extensive and overlap the stream channels in the valley bottoms of these drainages. The November 2021 debris flow in Siwash Creek appeared to have initiated when high streamflow mobilized some of this talus in the stream channel, rather than initiating from a specific sideslope landslide that became a debris flow when it reached the channel.

During the field inspection, we observed glaciofluvial sands and gravels near the water treatment plant and along the firebreak that bounds the reserve on its east side. Sandy surficial materials with scattered cobbles and boulders underlie much of the drainage of North Nekliptum Creek and the divide with Morneylun Creek. Where these areas had burned, the underbrush and soil organic materials had all burned at high intensity, exposing erodible sand and ash (Photo 3). Steeper slopes in the gully of Morneylun Creek had patches of rubbly to cobbly talus at their bases.

The water intake infrastructure on North Nekliptum Creek consists of a concrete flume with a screened side diversion (Photo 4). Water is diverted from the side of the flume into the intake and down a pipe to the water treatment plant. Excess water is returned to the channel of North Nekliptum Creek via an overflow pipe near the treatment plant. Fine-textured sediments and brushy woody debris are in the channel of North Nekliptum Creek just upstream of the intake, where several dry side tributary draws converge on the main channel (Photo 5). Only the main channel had flowing water at the time of our assessment, but we noted erosion in the side tributaries, possibly caused by heavy rain during the 2021 atmospheric river storms. Near Siwash Road, the terrain between these streams is low-gradient with sandy surficial materials and was mostly moderately burned.

Along Siwash Road, North Nekliptum Creek, Nekliptum Creek, a tributary of Niger Creek, and Niger Creek all flow in draws that are incised a few meters below the level of the road. Metal pipe culverts (500 mm and 600 mm diameter) are in place in each creek channel. The intake to the Niger Creek tributary was damaged, possibly by machine cleaning, and partly blocked with brush and slash (Photo 6) while all of the other culverts were undamaged and free flowing.

An old logging road runs from Siwash Road south into the Siwash Creek drainage. The terrain between Siwash Road and Siwash Creek has sandy soils, mostly gentle slope gradients, and was heavily burned. Granitic bedrock is exposed in the road cut along the ridge above Siwash Creek. We noted sections of a plastic water pipe that followed the road. Parts of the pipe had completely melted while other sections were intact (Photo 7). Siwash Creek is 50 m or more downslope of the ridge crest in a deep gully with steep sidewalls. The road descends slightly in elevation to reach Siwash Creek after it crosses the ridge. The former crossing of Siwash Creek was destroyed in the 2021 atmospheric river debris flow.

6.0 HAZARD ANALYSIS

Post-wildfire geotechnical hazard analysis has two components. The first component is identification of pre-existing geohazards; the second component involves consideration of how the fire's extent and intensity will alter those geohazards.

The typology of geohazards initially presented by Cave (1993) and later codified by Fraser Valley Regional District (FVRD) and Engineers and Geoscientists BC (EGBC) provides a useful general list of categories of geohazards, some or all of which may be applicable to any particular geohazard assessment. This list includes the following hazards:

- Inundation by flood waters
- Debris floods
- Mountain stream erosion or avulsion
- Debris flows
- Small-scale localised land slip
- Snow avalanche
- Rock fall – small-scale detachment
- Major catastrophic landslide
- Earthquake-induced soil liquefaction landslides

Of that list of geohazards, the likelihood of earthquake-induced soil liquefaction near Kanaka Bar is negligible because of the absence of fine-textured glaciomarine or glaciolacustrine sediments nearby. All of the other hazards are potentially relevant to the study area. I will discuss all of the other hazards in turn and how the fire has altered those hazards. I also address specific post-wildfire effects that do not directly fit into the listed typology of hazards, such as stream sedimentation.

6.1 Flooding and Streamflow

The assessed areas are all located well above the banks of Fraser River, and are not at risk of flooding by Fraser River, nor will the wildfire increase the likelihood of or extent of Fraser River floods. Smaller streams in the study area, including Morneylun Creek, North Nekliptum Creek, Nekliptum Creek, Niger Creek, and Siwash Creek, are also subject to flooding, and the likelihood of flooding has increased after the fire based on the area burned and fire intensity within each of those watersheds. Because these streams all drain steep mountain watersheds, the likelihood of floods overlaps with the likelihood of debris floods and debris flows (Section 6.3), but in any of these streams, flood flows can still also happen without an accompanying debris flood or debris flow. Also, streamflow at levels below flood flow will transport increased amounts of sediment as a result of the fire.

The natural flood regime in the five streams in the study area is likely a combination of snowmelt, rain-on-snow, and rainfall-driven events. Spring snowmelt occurs every year and results in reliably high runoff in the March through early June period but does not always result in floods, particularly in large floods. Fall, winter, and spring rainfall, sometimes augmented by snowmelt during rain-on-snow events at the end of cold spells, can also result in flood flows, as exemplified by the November 2021 atmospheric river storms. Finally, in summer, convective rainfall from thunderstorms can result in rare instances of localized intense precipitation that can cause peak flows, especially in smaller, steep watersheds such as the streams in the study area. I expect that each of these flood generation mechanisms operates over different scales of frequency and magnitude, so that the smallest floods are those caused purely by snowmelt, while larger but less frequent floods are caused by rain-on-snow and rainfall events, and the largest, rarest floods are the result of summer convective precipitation. For instance, at Gladwin, 16 km northeast of Kanaka Bar in the Thompson River Canyon on Highway 1, where there is a good record of events going back to the 1940s, and where the streams are similarly small and steep, two destructive flood events (which may include debris floods and debris flows) have occurred in November as a result of fall rain and rain-on-snow events, three in the period from March to May as a result of spring snowmelt and rain-on-snow events, and one in July as a result of summer convective precipitation (BGC, 2019).

Flooding in Morneylun Creek and Siwash Creek does not present a risk to the Kanaka Bar reserves because these streams both flow in deep gullies that will prevent floodwaters from reaching infrastructure on the reserve lands. Floods on those streams might cause damage to Highway 1 or to the railway tracks downslope of the reserve lands but would not reach the buildings or roads on Nekliptum 1 Reserve or Kanaka Bar 1A Reserve or affect Siwash Road because the stream channels are 30 m to 50 m in elevation below the top of the gully sidewalls. There is no chance that, even when augmented by the effects of wildfire, floods in either of these streams would result in avulsions that would see water flowing onto the developed areas of either reserve.

Flooding in North Nekliptum Creek, Nekliptum Creek, or Niger Creek could affect Siwash Road because Siwash Road crosses all of these streams. I used two methods to evaluate potential flood magnitudes in these streams: A regional analysis based on small watersheds with long-period stream gauges in the Thompson-Okanagan hydrologic region, with expected increases for climate change between the period of record and the present (Hassan et al., 2014), and a Rational Method calculation based on watershed area and expected rainfall intensity (BC MOTI, 2019). For both methods, I evaluated expected 1-in-2-year (Q2, 50% annual exceedance probability) and 1-in-100-year (Q100, 1% annual exceedance probability) flood magnitude for a given watershed area (Table 3). The drainage areas given in Table 3 are for only those parts of the watershed upstream of Siwash Road, so they are slightly smaller areas than presented in Table 1.

Table 3: Study Area Watershed Expected Pre-wildfire Peak Flow Magnitudes for Specified Return Periods

Stream Name	Watershed Area (km^2)	Q2 Flood Magnitude Estimate (m^3/s)		Q100 Flood Magnitude Estimate (m^3/s)	
		Regional Method	Rational Method	Regional Method	Rational Method
North Nekliptum Creek	0.75	0.37	0.82	1.12	2.96
Nekliptum Creek	1.83	0.56	1.38	1.72	4.61
Niger Creek tributary	0.62	0.34	0.68	1.03	2.45
Niger Creek	1.00	0.42	1.09	1.29	3.95

The rational method produces consistently higher evaluations of peak flow than does the regional analysis method for these streams. I expect that the actual values which would best represent expected peak flows in these streams lie somewhere between these two estimates and that the regional method offers a more accurate estimate of frequent flood magnitudes at and near the Q2 instantaneous peak flow, while the rational method provides a better estimate of potential large, rare peak flow magnitudes like the Q100.

Wildfire can increase post-event streamflow magnitudes in several ways. Firstly, fires cause burned soils to become hydrophobic and repel water because some plant oils are heavier than air when burned, and sink into the soil, where they congeal and form a grease or wax layer in the soil which prevents water infiltration. This hydrophobicity can take up to several years after the fire to break down. Secondly, burned trees lose needles and branches, and precipitation interception by the canopy is reduced, so more precipitation reaches the ground in burned areas. This effect lasts until new forest growth replaces the burned forest, and can persist for up to several decades. Additional effects that affect post-wildfire runoff are root burning, which creates faster pathways for subsurface flow; decreased shading, which increases snowmelt rates on sunny slopes; and, decreased evapotranspiration, which leads to wetter soils and a consequently more rapid runoff response to precipitation or snowmelt. These additional effects can also persist for up to decades after a fire. None of these additional factors is as significant as the hydrophobic layer in increasing peak flow magnitudes, but they all persist for substantially longer.

When all of these factors are considered, the expected magnitude of post-wildfire peak flows might more than double compared to pre-wildfire peak flows. Table 4 lists the expected post-wildfire instantaneous peak flow magnitudes for the same streams as Table 3:

Table 4: Study Area Watershed Expected Post-Wildfire Peak Flow Magnitudes for Specified Return Periods

Stream Name	Watershed Area (km^2)	Q2 Flood Magnitude (m^3/s)	Q100 Flood Magnitude (m^3/s)
North Nekliptum Creek	0.75	1.9	6.9
Nekliptum Creek	1.83	3.2	10.8
Niger Creek tributary	0.62	1.6	5.7
Niger Creek	1.00	2.5	9.2

The numbers in Table 4 represent expected maximums for the first few years immediately after the fire. Assuming the climate does not change rapidly over the next few decades, these numbers will decrease back towards the range of numbers presented in Table 3, with the greatest decline in the first three years after the fire.

6.2 Mountain Stream Erosion and Avulsion

These linked hazards represent the potential for mountain streams to erode their banks and beds, causing bank retreat and channel scour, or to avulse, which means that the stream channels migrate across the floodplain. All of the streams in the study area are contained in draws and gullies, with ridges dividing the drainages, and consequently, even large floods similar in magnitude to the estimated post-wildfire Q100 are not likely to result in substantial avulsions. Even during and after large floods, streams will remain in their current channels. However, substantial volumes of erosion and sedimentation can be expected as a result of any flood event.

Forest fires increase erosion and sedimentation not only by increasing the magnitude of post-wildfire flood flows, but also by increasing the availability and supply of sediment to stream channels and by decreasing channel stability. Sediment supply is increased when roots, woody debris on the ground, and ground cover are burned. All of these factors retain sediment, and when they are burned, that retention is lost and sediment becomes more mobile. Woody debris supplies to streams are increased dramatically by fires, but existing woody debris in stream channels is also burned, so it loses strength. Burned wood loses strength and is less effective at forming stable woody debris jams which retain sediment. The net result is that a lower volume of relatively stable woody debris and sediment before a fire is replaced with increased volumes of both sediment and unstable woody debris after a fire. Streamflow transports higher volumes of both fine and coarse sediment after a fire relative to before a fire. Increased fine sediment transport not only degrades water quality by increasing turbidity but also increases the mobility of coarse sediment through lubrication. Increased rates of sediment transport typically result in increased erosion in steep channel reaches and increased rates of deposition in gentle reaches. For the streams discussed in Tables 3 and 4, this means that erosion is likely to increase in the steeper headwaters stream reaches of each watershed, and increased sediment deposition is likely in the lower-gradient reaches near

Siwash Road. Increased erosion and sedimentation from stream flows may overlap with the occurrence of debris flood or debris flow, as discussed below.

6.3 Debris Flood and Debris Flow

Debris flows and debris floods form a continuum of process with flood flows in steep streams (Church and Jakob, 2020). Ordinary flood flows transport sediment but are still largely composed of water. In debris flood, the sediment concentration increases as the entire stream bed becomes mobile. Sediment concentration increases again during debris flows, popularly termed mudflows, which may involve roughly equal amounts of sediment and water. Debris flows are viscous enough to transport whole tree trunks, large boulders, and other coarse sediments that would not move in either floods or debris floods, and in debris flows, the sediments are typically mixed together, while in debris floods, they remain stratified with water flowing over a bed of mobile sediment.

A single event may occur as a debris flow, debris flood, and flood at different points in a stream channel when streams flow from steep ground onto gentle terrain. In such conditions, coarse debris preferentially deposits near the base of the steep slopes while finer sediment is transported further downstream, so a single event may start as a debris flow and then transition downstream to a debris flood and then a flood as debris deposits.

Debris flood magnitude can be estimated for a given stream by scaling up the expected peak flow magnitude for a specified return period using an appropriate bulking formula to account for the additional sediment transport. Debris flow magnitude for a given return period cannot be directly evaluated from expected flood peak flow magnitude and must be evaluated from historic records of nearby debris flows in similarly steep streams and by extrapolation from past events and debris flow deposits. In addition to the 2021 Siwash Creek atmospheric river debris flow, other recent nearby debris flows and debris floods in comparable streams, both after fire and without fire effects, have occurred at North Bend, Chamoux, Gladwin, Hamilton Creek, Lytton Creek, Nicomen Reserve, and Nahump Creek.

Debris flows and debris floods are both much more likely to occur after wildfires and are often triggered by relatively low amounts of rainfall. For instance, after the 2021 Lytton Creek wildfire, two small debris flows occurred on Devils Creek at Nicomen Reserve in August and September 2021, and a larger debris flow at Thom Creek nearby. Heavier rainfall in November 2021 did not result in additional debris flows in either creek (BGC, 2021). Past work has suggested that moderately high intensity rainfall, in excess of the expected 1-in-2 year (50% AEP) 1-hour precipitation value, is sufficient to trigger post-wildfire debris flows (Cannon et al, 2008; BGC, 2021).

Debris flows and debris floods are both episodic events that do not occur in most years. Unlike floods, where a 1-in-2-year, 50% AEP flood magnitude can be estimated, debris flow and debris flood magnitudes cannot be estimated for very frequent return periods because these events do not recur frequently enough. An approximate lower return period where an event magnitude can meaningfully be estimated for debris flows and debris floods is the range of 1-in-10 to 1-in-20, 10% AEP to 5% AEP events – events that recur on average once every decade or two, at most.

Table 5 lists estimated 1-in-10-year and 1-in-100-year, 10% AEP and 1% AEP, predicted debris flow and debris flood event magnitudes (peak discharges and peak debris flow volumes) for the study area creeks, based on extrapolation from historic and modelled events in other nearby drainages.

Table 5: Study Area Watershed Expected Post-Wildfire Debris Flood and Debris Flow Magnitudes for Specified Return Periods

	Debris Flood Peak Discharge (m^3/s)		Debris Flow Peak Discharge (m^3/s)		Debris Flow Total Volume (m^3)	
Stream Name	**Q10**	**Q100**	**Q10**	**Q100**	**Q10**	**Q100**
North Nekliptum Creek	2.3	8.3	18	37	850	2075
Nekliptum Creek	3.9	12.9	34	69	2560	5375
Niger Creek tributary	1.9	6.9	16	33	675	1695
Niger Creek	3.1	11.1	22	46	1215	2820

Given the topography of the area upstream of Siwash Road, I expect that debris flows would begin to deposit near an elevation of about 520 m, which is about 100 m in elevation and 400 m to 450 m in ground distance east of Siwash Road, although the exact distance varies for each stream. I expect that during such events, given the predicted event volumes, debris deposition would mean that such events had transitioned from debris flows to debris floods by the time that they reached Siwash Road. The water treatment plant on North Nekliptum Creek is about 250 m east of Siwash Road, at an elevation of about 450 m, and it is possible that debris flow deposits in North Nekliptum Creek could reach the water intake and/or the area near the water treatment plant.

6.4 Rockfalls, Small and Large Landslides

Rockfalls, small landslides, and large landslides also form a group of similar processes which grade into each other. Rockfalls occur from and deposit below bedrock bluffs, with limited volumes and runout distances. Small and large landslides can initiate from any steep slope and travel for longer distances before depositing.

Given the lithology and surficial materials in the study area, rockfalls are the most common process. Rockfall deposits are evident and form talus patches at higher elevations throughout the watersheds of Morneylun, Nekliptum, Niger, and Siwash Creeks, in the area of granodiorite bedrock. These talus patches extend for from 50 m up to about 150 m downslope of bluffs, depending on the height of the bluff and the steepness of the slope below. The deposits consist of individual blocks ranging from about 0.5 m diameter up to about 5 m in diameter. I expect that the wildfire will change the frequency, but not the magnitude, of such rockfalls and that post-wildfire rockfall deposits will be limited to the size and extent of pre-wildfire rockfalls, remaining within the general extent of existing talus patches. I did not observe any rockfall deposits near Siwash Road, the water treatment plant, or the reserve lands during our helicopter and field traverses, and I do not expect that post-wildfire rockfalls will reach any of these resources.

Small landslides are most likely to occur within the study area along the steep sidewalls of major gullies, such as Morneylun Creek or Siwash Creek, where there are both steep slopes and thicker surficial materials. The historic air photos do not show any past landslides in any of these drainages over the period from 1963 to the present. The nearest visible landslide scars to the study area are four small landslide scars on the steep north-facing sidewalls of Hamilton Creek, about 3.5 km north of Kanaka Bar, and road fill landslides in Mowhokam Creek, about 8 km south-southeast of Kanaka Bar.

I expect that if small post-wildfire landslides do occur, they will be confined to steep gully sidewalls. If such landslides occur in the drainages of Nekliptum Creek or Niger Creek upslope of Siwash Road, they will likely trigger debris flows. The chance of such events occurring and their magnitude and runout distance are therefore already considered within the estimates of post-wildfire debris flow frequency and magnitude.

Small landslides might also occur on the sideslopes of Morneylun Creek just north of the reserve buildings. This area was not burned by the fire but could still see an increase in the likelihood of landslide frequency due to increased post-wildfire floods or debris floods in Morneylun Creek, which could scour the toe of the steep slopes and reduce their stability. If such landslides did occur, I expect that they could be up to hundreds of cubic meters in volume and result in slope retreat of up to 10 m along the top of the steep slopes. The nearest buildings on the reserve are set back by about 35 m to 40 m from the edge of the steep slopes, so I do not expect that landslides along the sideslopes of Morneylun would result in immediate increases of risk to the reserve buildings or to residents, if they occurred. If such an event does occur, a qualified professional should be asked to inspect it and make recommendations to protect residents and buildings over the longer term.

There are no large catastrophic landslide scarps or deposits anywhere upslope of the reserve or within the study watersheds. Large landslide scarps and deposits do occur in Mowhokam Creek, 7 km south of Kanaka Bar, and in the Thompson River canyon 18 km to 25 km northeast of Kanaka Bar. We noted no evidence of widespread instability that might indicate a future large landslide during our air and ground traverses of the study area, nor are such features visible on the LIDAR imagery provided by KBIB. Accordingly, I expect that there is a very low average annual likelihood (<0.01% AEP) of large catastrophic landslides within the study area, nor do I expect such events to become more likely as a result of the wildfire.

6.5 Snow Avalanches

Snow avalanches occasionally occur on steep slopes at high elevations within the study area, but given the shallow winter snowpacks and elevation ranges on Kanaka Mountain, such avalanches are generally small (Class 2 or less on the Avalanche Canada size scale) and confined to the highest elevations in the study area. There are no large avalanche paths in any of the study area drainages, and I do not expect that, even with the loss of tree cover and increased snowpack depth that will occur after the fire, that new avalanche paths will develop. There is negligible likelihood that the fire will result in any increase in avalanche risk to the KBIB reserve lands.

6.6 Other Hazards

Although it is not a geotechnical hazard, wildfires are also known to degrade water quality (Paul et al., 2022). Wildfires increase fine sediment and turbidity in streams. Other changes are chemical in nature. Nutrients and contaminants such as dissolved carbon, nitrates, phosphates, and heavy metals all increase in concentration in runoff from areas burned by wildfires. Water pH may change as a result of alkaline ashes entering the water. Water temperature typically increases as a result of loss of shade. These can change the quality of water, raising it above provincial or national standards for drinking water quality or reducing the efficacy of treatment methods. All of these effects are greatest in the first year or two after a fire and then typically return towards baseline levels, with effects typically ending within three to five years on average, and at most within 10 to 15 years after the fire.

7.0 DISCUSSION

Buildings on the reserves are largely free from exposure to hazards because of their position on the low-gradient bench on the broad ridge between Morneylun Creek and Nekliptum Creek. Flooding, debris flows, or debris floods in Nekliptum Creek and North Nekliptum Creek are unlikely to result in either water or debris reaching reserve buildings. Debris flows, debris floods, or floods in Morneylun Creek might cause bank erosion which could in turn cause sidewall landslides on the steep southern side of Morneylun Creek near the reserve, but such landslides are unlikely to be large enough to result in any immediate risk to reserve buildings.

The primary sources of post-wildfire geotechnical risk to the reserve are floods, debris floods, and debris flows in North Nekliptum Creek, Nekliptum Creek, the tributary of Niger Creek, and the main channel of Niger Creek. If any of these events occurred, they would likely transport enough sediment to block the culverts under Siwash Road. Water and sediment would deposit on and run down Siwash Road. At minimum, such debris could block traffic on Siwash Road. It is possible, but less likely, that culvert failures could also completely wash out Siwash Road.

Floods, debris floods, and debris flows in North Nekliptum Creek could also affect the community water supply. Sedimentation from any of these events, either during or after such an event, could damage or block the water intake. Sediment that reached the treatment plant, either by flowing overland, or by being carried down the water pipe to the interior of the plant, could also damage the treatment plant infrastructure or the plant itself. Given the high intensity of the ground fire in the drainage of North Nekliptum Creek upstream of the plant, and the consequent increase in sediment availability, it is also likely that sediment concentrations in the stream will increase significantly even at flow levels below flood flow for at least the first few months after the fire.

Debris flows, debris floods, or floods in Siwash Creek will not affect Siwash Road but could damage water supply infrastructure if the existing water license infrastructure is rebuilt after the fire.

The likelihood of small landslides and rockfall will increase after the fire on steep slopes in the headwaters of Morneylun Creek, Nekliptum Creek, and Siwash Creek, but the increased likelihood of such events does not present an increase in risk to the reserve lands or to Siwash Road because the deposits of these events will be hundreds of meters upslope of these resources.

8.0 RECOMMENDATIONS

Kanaka Bar Indian Band has several possible courses of action to reduce the potential consequences of post-wildfire flooding, debris flooding, debris flows, and stream sedimentation. These are presented as options for consideration.

The greatest risk is to the community water supply. Floods, debris floods, or debris flows could result in sedimentation that would damage the water intake or the water treatment plant infrastructure. Even without large, damaging floods, the increased transport of fine sediment and changes to chemical composition of runoff from the burned area is likely to degrade water quality in North Nekliptum Creek.

Several potential measures could be implemented to decrease the risk to the water intake and water treatment plant. Firstly, a sediment and debris detention pond could be designed for installation upstream of the water intake. This would entail building a check dam across the stream, so that if floods, debris floods, or debris flows occurred, some or all of the sediment would be trapped upstream of the water intake. Building check dams to withstand debris flows can be expensive, their capacity to store sediment may be limited given topographic factors, and they require regular and ongoing maintenance to clean after sedimentation events. All of these factors would have to be evaluated in a more detailed study before such a structure is designed and built.

Switching to another source of surface water is likely not a viable option because the fire burnt the entire area upslope of the reserve, but switching to groundwater sourced from a well or wells might be a viable alternative. If a new well was drilled near the water treatment plant, it might also be possible to tie it into existing infrastructure for water distribution. Groundwater is much less sensitive to post-wildfire degradation of water quality than surface water is. Given the surficial and bedrock geology, it is likely that there is at least one water table below the reserve which could be accessed with a well, but even then, the amount and quality of water that wells could supply is unconfirmed and would have to be checked by drilling a test well or test wells before KBIB proceeds with this option. The nearest wells recorded in the BC Water Well Database are 5 km north, at Siska, in a setting with similar bedrock and surficial geology (iMapBC, 2023).

Debris flows, debris floods, and floods also pose a threat to access to the reserve. Siwash Road provides the only road access to the reserve, and the existing culverts that are installed on North Nekliptum Creek, Nekliptum Creek, the Niger Creek tributary, and Niger Creek all seem to be undersized for the post-wildfire event peak discharges estimated in Tables 4 and 5. During these events, it is likely that sediment would block the culverts, causing water and sediment from the streams to overflow onto the road.

Potential mitigation measures for the road could include building sediment detention structures upstream of the road, upgrading the size of the drainage structures by replacing the existing culverts, or planning for the road to be temporarily blocked and coordinating rapid reconstruction after such events.

The first option, upstream detention structures, is subject to the same limitations as described above (topographic limitations, check dam volume, cost, and maintenance requirements) for a potential detention structure on North Nekliptum Creek above the water intake. Detention structures on the other streams could be easier to build than a detention structure on North Nekliptum Creek because the detention structures on the other streams could feasibly let some sediment through, as they wouldn't be intended to protect water supply infrastructure. Because structures on the other streams wouldn't have to completely hold back all of the sediment during such events, it would be enough for them to strain out the coarser material and reduce the size of sediment and volume of water reaching the culverts. Therefore, simpler designs, like trash racks, might be feasible. As with North Nekliptum Creek, the final option would need to be refined during the engineering design process for each structure.

Upgrading the existing culverts could be considered in conjunction with the installation of upslope debris detention structures or on their own. Given the design flow estimates in Tables 4 and 5, though, upgrading the culverts on their own may not be an effective solution because the potential debris flow and debris flood magnitudes are larger than what even very large replacement culverts might be able to pass. However, it is possible that the upslope debris detention measures, combined with larger culverts, might work together, with the debris detention structures reducing the volume of debris and water reaching the road to a volume that an upgraded culvert can pass without becoming blocked. As with the debris detention measures discussed for North Nekliptum Creek, upslope structures along Siwash Road will require maintenance access to periodically clear debris and sediment to ensure their continued function. Upgrading existing culverts under Siwash Road would also require temporary road closures while new culverts were being installed.

Instead of simply replacing existing culverts under Siwash Road with larger culverts, it might also be possible to replace the existing culverts with paved swales. In a swale design, the road dips to cross each stream, preserving a topographic low point. A small culvert can be installed to prevent normal streamflow from running across the road, but the design is intended so that in floods, debris flows, or debris floods, water and sediment flow across the road, contained within the swale dimensions rather than depositing against it or overflowing down it. Swales still require ongoing maintenance after such events, and their design may limit the size of the largest vehicles that can cross them, such as school busses or lowbed trucks. The time and cost of installing swales should be comparable to the time required and cost of replacing existing culverts with larger ones.

The simplest option for Siwash Road may be to do nothing. That is, assume that debris flows, debris floods, or floods will result in sedimentation that will block or damage the road, and then clear debris and rebuild the road only after such damaging events. This is likely to present the lowest cost overall, but the disadvantage will be that there is no choice in when to perform such maintenance. That is, if a culvert is being upgraded, it can be scheduled in advance for a time when equipment is available and when temporary road closures are least likely to inconvenience band members, whereas if the choice is made to wait for a culvert to block before repairing it and the road, the time at which the event occurs is likely to be less convenient, and there may be a longer wait until the road is repaired, during which time road access to the reserve might be completely cut off.

9.0 CONCLUSIONS

The Kookipi Creek wildfire (V11337) burned the area upslope of the Kanaka Bar Indian Band's reserve lands in August 2023. The watersheds of Siwash Creek, Niger Creek, Nekliptum Creek, North Nekliptum Creek, and Morneylun Creek were all burnt by the fire, although the extent and intensity of the fire varied from watershed to watershed. North Nekliptum Creek is the source of the primary water supply for the band. Siwash Road provides access to the reserve and crosses the drainages of Niger Creek, a tributary of Niger creek, Nekliptum Creek, and North Nekliptum Creek.

The developed area of the reserve consists of lands on a ridge between Nekliptum Creek and Morneylun Creek. Due to its position and elevation above the nearby creeks, the reserve lands are not at risk from most geotechnical hazards, even when considering the increased likelihood of hazards after wildfire. Post-wildfire bank erosion in Morneylun Creek may increase and could result in an increased likelihood of small landslides on the steep gully sidewalls between Morneylun Creek and reserve buildings but are unlikely to present an immediate increase in risk to any reserve buildings.

Floods, debris flows, and debris floods can all occur in the streams in the study area. Any of these events in North Nekliptum Creek, Nekliptum Creek, the Niger Creek tributary, or Niger Creek might cause sedimentation that could block or damage culverts on Siwash Road and result in water or sediment flowing onto, blocking, and damaging Siwash Road itself. Sedimentation caused by floods, debris floods, and debris flows in North Nekliptum Creek could also damage or destroy water supply and water treatment infrastructure.

In addition to floods, debris floods, and debris flows, North Nekliptum Creek is also likely to experience increases in fine sediment transport and changes to water chemistry, even at flow levels well below flood flows. These effects will degrade water quality and can potentially damage water treatment infrastructure as well.

Measures to protect the community water supply from the effects of the wildfire could include building a check dam and sediment detention pond upstream of the water intake, or switching to an alternative source of water. The feasibility of a check dam and sediment detention pond would need to be confirmed with a detailed engineering design study and may be limited by upslope topography. If such a structure is built, it will also require ongoing maintenance to remove trapped sediment and retain capacity. Switching to an alternative source of surface water would not reduce the risks to the water supply, but it might be possible to switch to a groundwater source. It will be necessary to evaluate the nature of groundwater near the reserve, likely by drilling test wells, before confirming that this is a viable option, but it might be possible to construct a new well near the existing water treatment building and continue to use some or all of the existing water distribution infrastructure.

Measures to protect Siwash Road from flooding and sedimentation could consist of some combination of building upslope protective structures, upgrading existing culverts with larger structures, replacing existing culverts with swales, or doing nothing. Upslope protective structures for Siwash Road have the same topographic, engineering design, cost, and maintenance limitations as upstream protective structures for the water intake do, but because the consequences of water or sediment on the road are potentially less severe than disruption to the community water supply, it may be possible to install simpler protective structures, such as trash racks, which simply strain out larger debris but let finer sediment and water through, at a lower cost. Upgrading culverts or replacing culverts with swale crossings are likely to be broadly comparable with respect to cost, but each have specific advantages and disadvantages with respect to long-term use. Doing nothing may be the cheapest option overall, but risks loss of road access at unplanned and inconvenient times.

10.0 LIMITATIONS

The recommendations provided in this report are based on observations made by Statlu and are supported by information Statlu gathered. Observations are inherently imprecise. Conditions other than those indicated above may exist on the site. If such conditions are observed or if additional information becomes available, Statlu should be contacted so that this report may be reviewed and amended accordingly.

This report was prepared considering circumstances applying specifically to the client. It is intended only for internal use by the client for the purposes for which it was commissioned and for use by government agencies regulating the specific activities to which it pertains. It is not reasonable for other parties to rely on the observations or conclusions contained herein.

Statlu prepared the report in a manner consistent with current provincial standards and on par or better than the level of care normally exercised by Professional Geoscientists and Professional Agrologists currently practicing in the area under similar conditions and budgetary constraints. Statlu offers no other warranties, either expressed or implied.

11.0 CLOSURE

Please contact me should you have any questions or if you require further clarification.

Yours truly,

Statlu Environmental Consulting Ltd.

2023-11-21

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Permit to Practice Number: 1000170

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Figure 1: Post-Wildfire Geohazard Assessment - Kanaka Bar

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Client: KBIB
Project Number: 23-179

APPENDIX 2: PHOTOS

Photo 1: Fire mosaic above reserve.

Photo 2: Large boulders in talus patches.

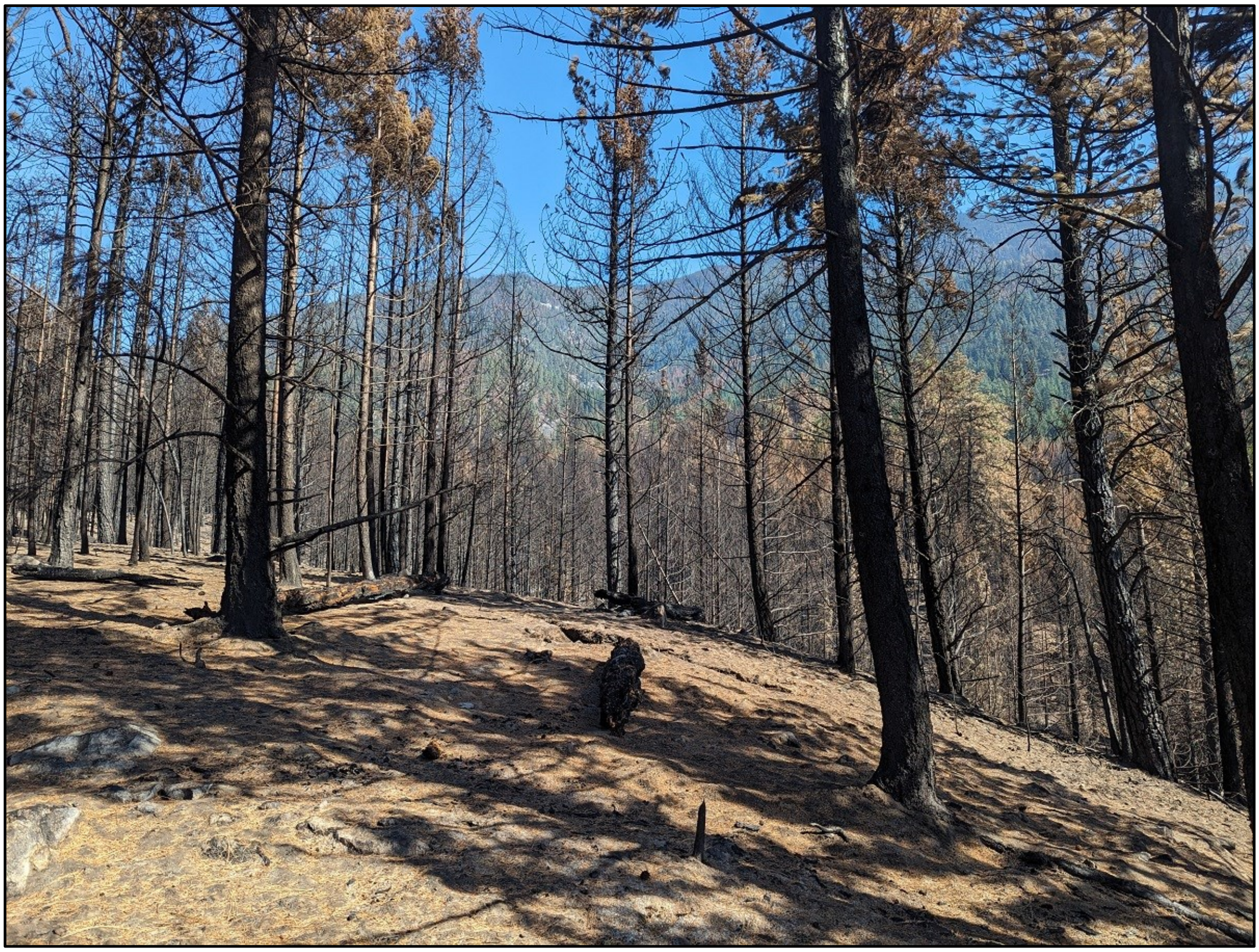

Photo 3: High intensity soil burn North Nekliptum above water intake.

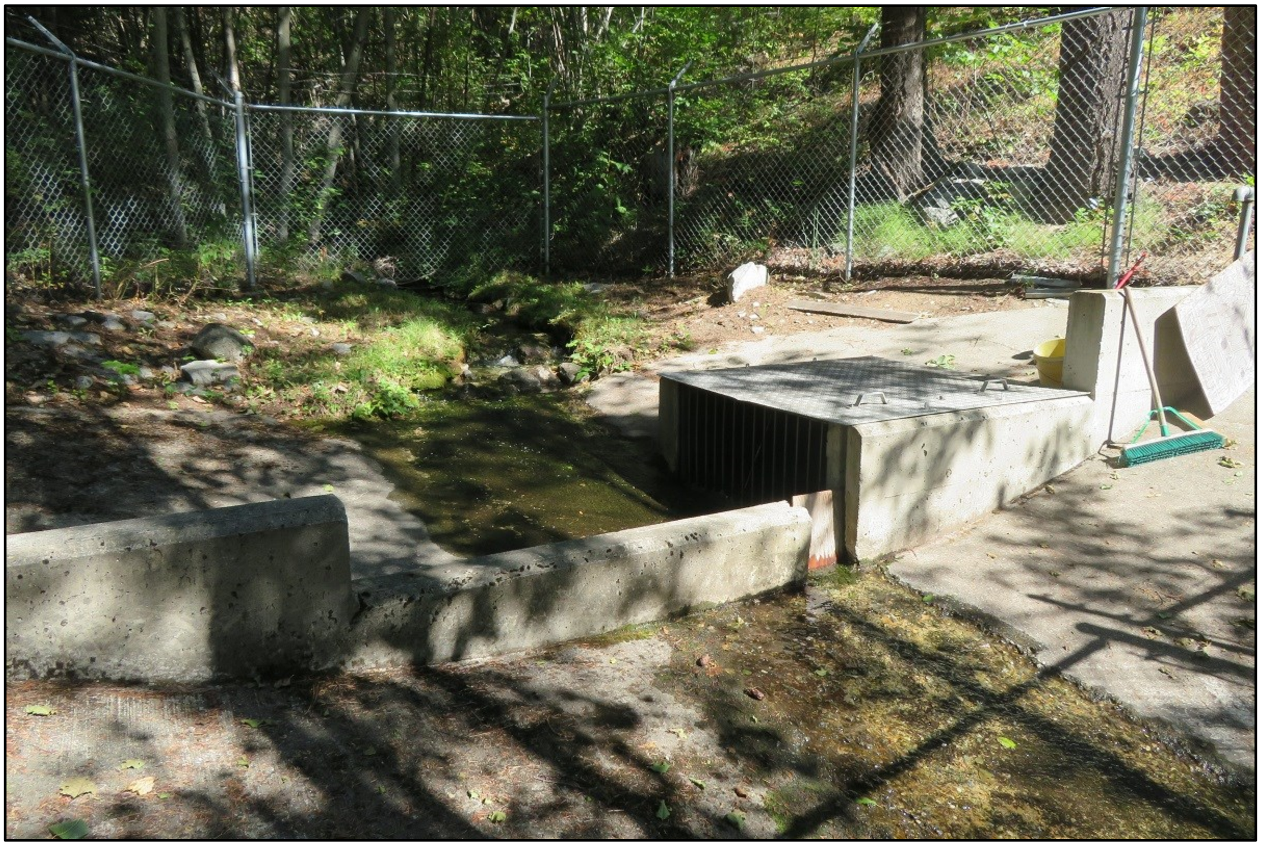

Photo 4: Concrete flume at water intake North Nekliptum.

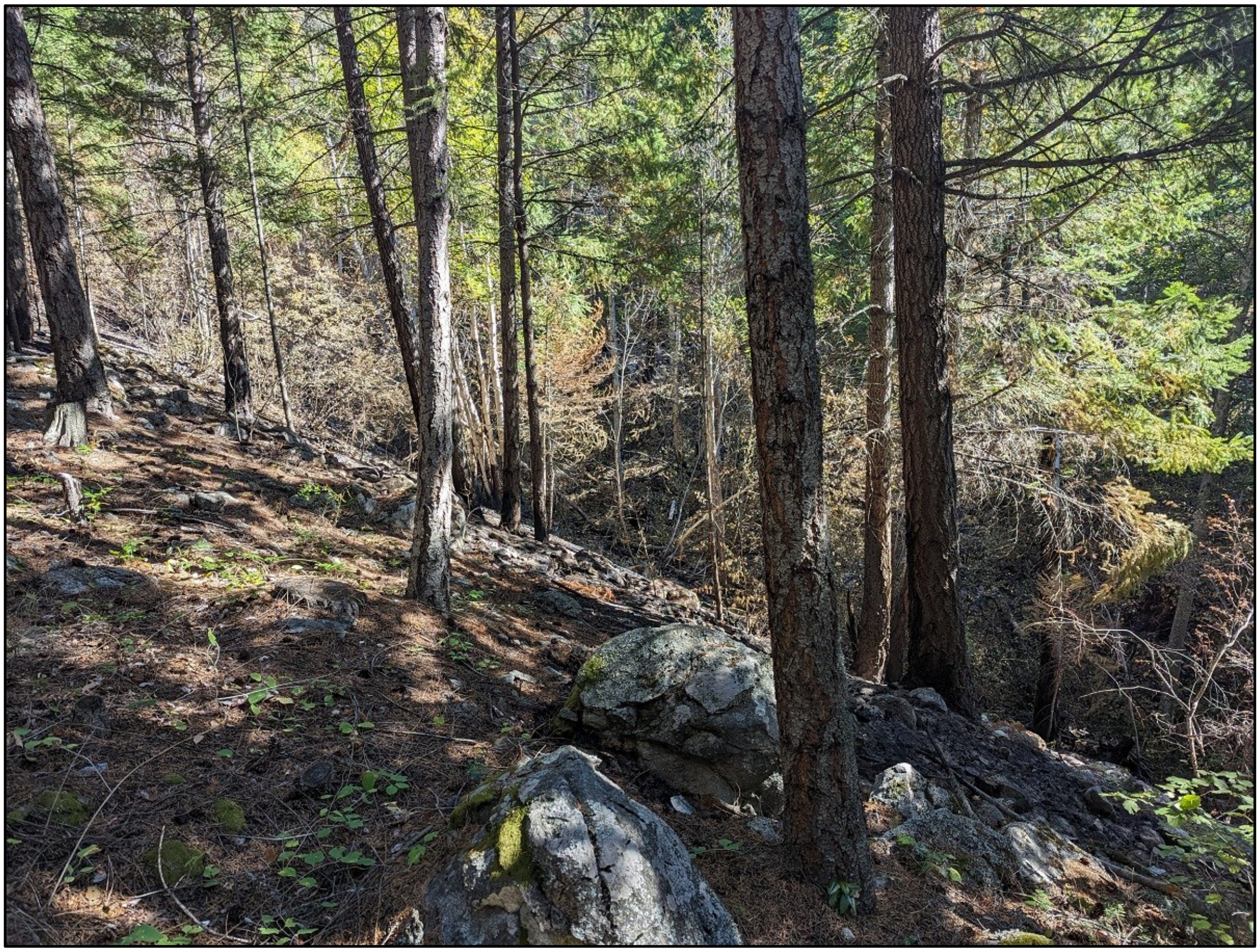

Photo 5: Brush and sediment in North Nekliptum Creek upstream of intake.

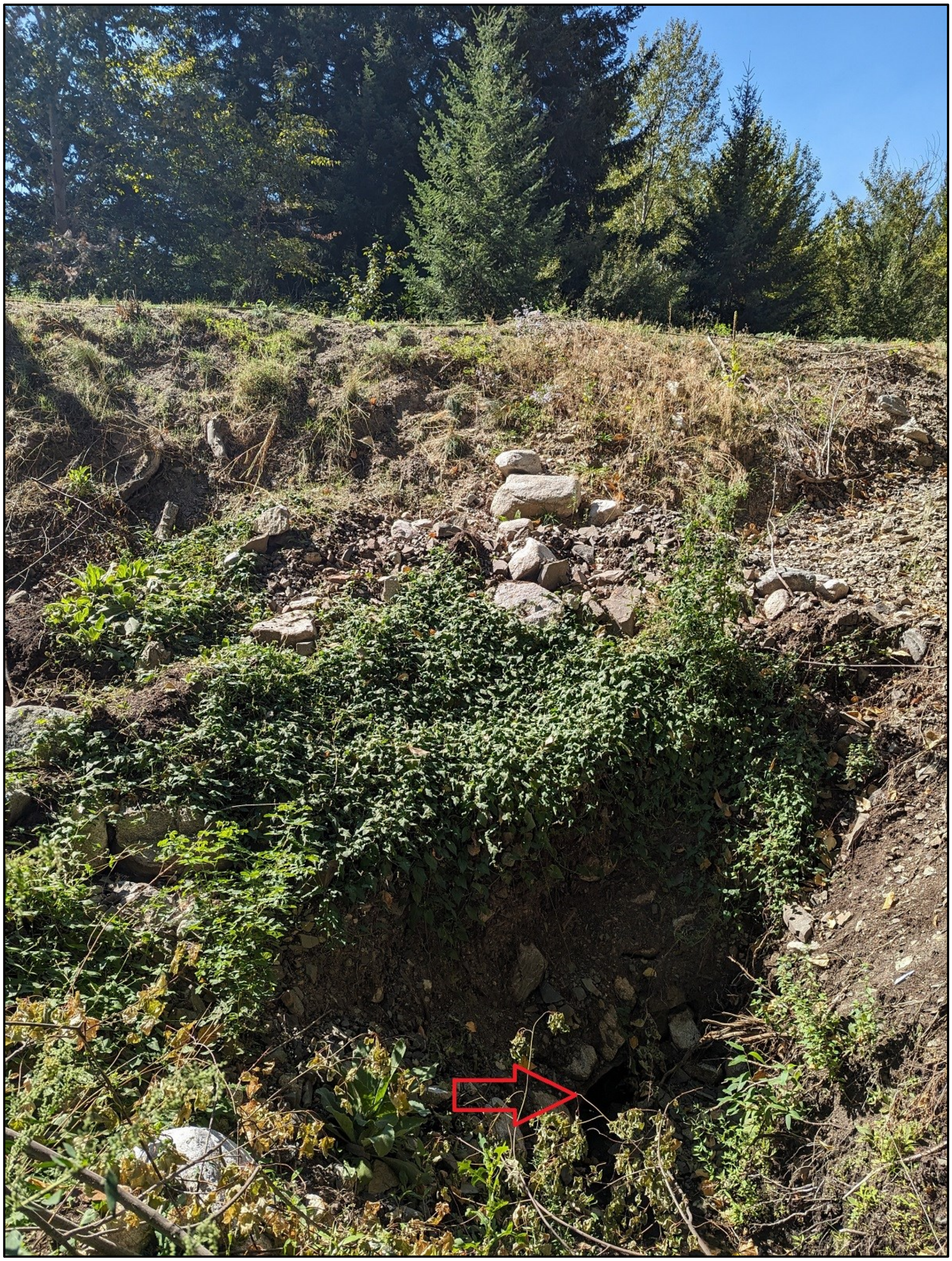

Photo 6: Niger Creek tributary at Siwash Road culvert partly blocked by debris.

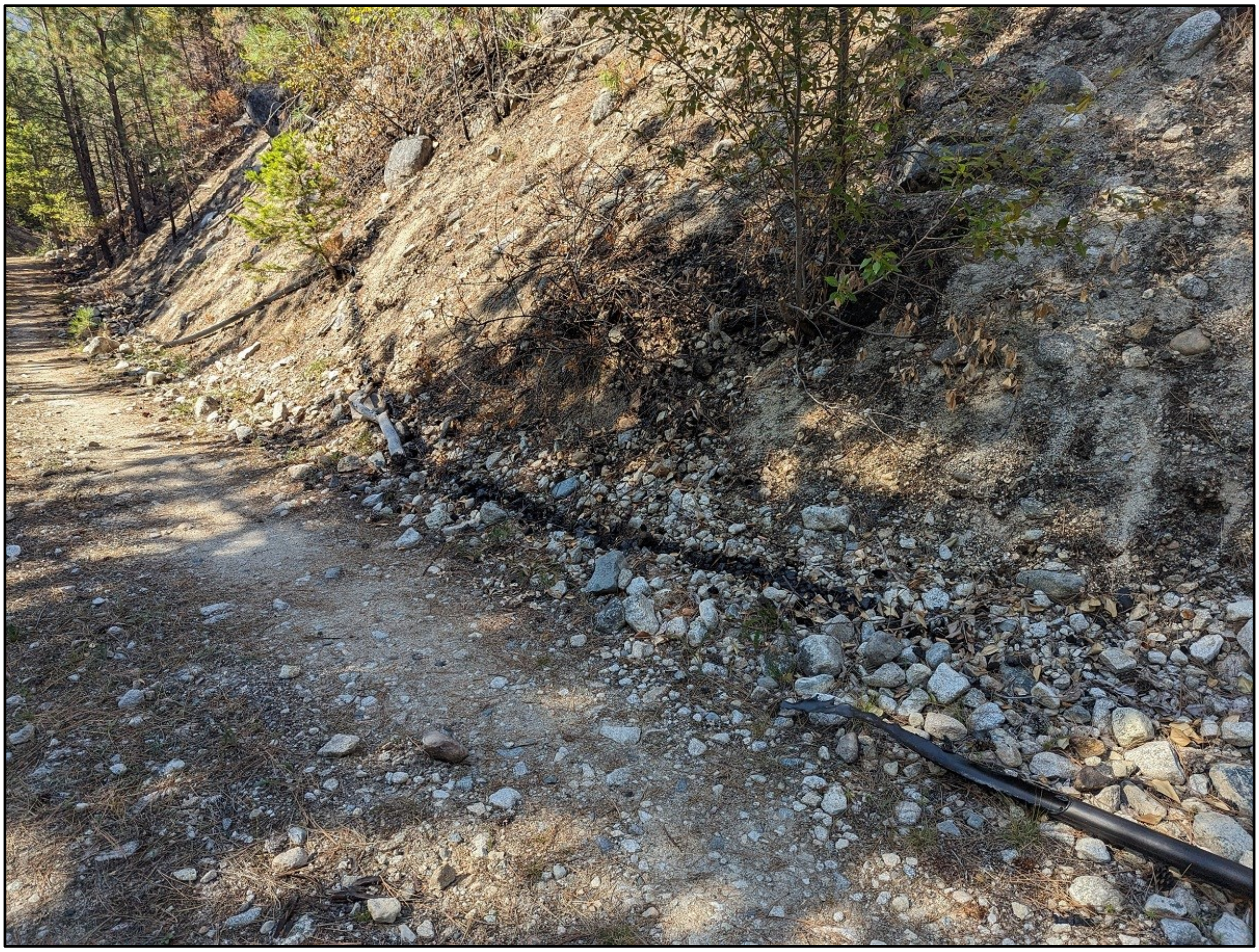

Photo 7: Burned and melted water line on Siwash Creek road.