Riparian Restoration and Erosion Stabilization of a Road Crossing near Richmond Lake Recreation Site

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Abstract

In the interior of British Columbia, road crossings are the single largest contributor to stream sedimentation (Beaudry & Associates, 2007; Elliot et al., 1996; Fisheries Target Committee, 1996) and when a new forest service road was constructed to access the Richmond Lake Recreation Site in north-central BC, significant concerns around soil erosion and sedimentation around a small stream crossing arose. Ecological restoration activities in areas developed for recreation must consider other values in addition to ensuring a functioning ecosystem: the safety of recreation users, their enjoyment of the area and community interest play a role in restoration (Govt of BC, 2020a). This project looked at how to balance the interests of people using the area while managing impacts to the ecosystem from road construction.

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Acknowledgements

This project was supported by the Nadina Natural Resource District, Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Seedlings were donated by BCTS Babine Business Area and grass seed was donated by the Wildfire Rehabilitation program at the District. I would like to thank Brad Lapham for his help in planting the seedlings and the Nadina District and BCTS engineering staff for sharing their knowledge. And, lastly, a big thanks to Rob Phillips for making time for this project and supporting my work.

1.0 Introduction

Recreation plays an important role in the lives of people in northern British Columbia and in the economy of the surrounding areas (Govt of BC, 2020a). Between 2015 and 2016, a 3 km gravel road was constructed to provide access to a recreation site at Richmond Lake, near the town of Burns Lake. This road was to replace an informal route along a CN Rail right-of-way that was blocked off after the adjacent land parcel was sold to a private landowner (Fig. 1). It was important to continue to provide access to Richmond Lake to stock the lake with rainbow trout (*Oncorhynchus mykiss*)- an activity that takes the pressure off native fish species- as well as to continue to provide recreation opportunities in the area. During construction of this new Forest Service Road, a rain event caused significant soil erosion of cut banks located on either side of an unclassified stream, approximately 500m west of Richmond Lake (personal communication, Nadina Natural Resource District, 2015). This restoration project was developed to address the erosion issues at the site of the road crossing and considered methods that may not normally have been implemented as part of regular road construction.

Following the damaging rain event, erosion was still occurring even with additional engineering erosion controls so I considered what else could be done at the site to address this. The site was not re-vegetating well, despite previous work, likely due to the continued erosion of very fine soils found on-site and loss of topsoil during road construction. I prioritized re-establishing vegetation on the site to address slope stability concerns.

Since the access road is permanent, the restoration will not return the site to its pre-disturbance condition, but rather it endeavoured to re-establish ecosystem processes. The restoration methods and recommendations for monitoring and further work considered the current use of the area and public values as well the need to ensure the ecosystem at the restoration site was relatively healthy.

Figure 1- Pre-construction conditions at the stream crossing (2015)

2.0 Project Description

Study Area and Reference Ecosystem

The project area is located approximately 30km to the east of Burns Lake, British Columbia, just south of the Endako River (Fig. 2). The restoration site is about 2 hectares in size and includes steep, north-facing cut banks, divided by a small non-fish bearing stream, that have been impacted by the road and 15m right-of-way (Appendix A). The stream drains into a wetland complex that feeds into the Endako River and is within the Fraser River watershed.

The new access road leading to the Richmond Lake Recreation Site was constructed within an undulating, mid-slope biogeoclimatic zone of sub-boreal spruce, dry cool subzone (SBSdk) forest and is north facing. Much of the densely forested region has been impacted by Mountain Pine Beetle and large wildfires in recent years, in large part because of the planting of lodgepole pine (*Pinus contorta var. latifolia*) monocultures combined with intensive fire suppression that has resulted in forests prone to disease and large, devastating wildfires- rather than small, more frequent natural disturbances, as would be typical in a natural disturbance type 3 (NDT 3) or an ecosystem with frequent stand-initiating events (Kohm and Franklin, 1997; Ministry of Forests and Range, 2012; Ministry of Forests, 1998). The overstory vegetation adjacent the site is comprised of hybrid spruce (*Picea glauca x engelmanni*), lodgepole pine, trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) with an open, low shrub understory. There are few tall shrubs or older tree regeneration and the forest is mature with some old-growth spruce (Grainger, 2015).

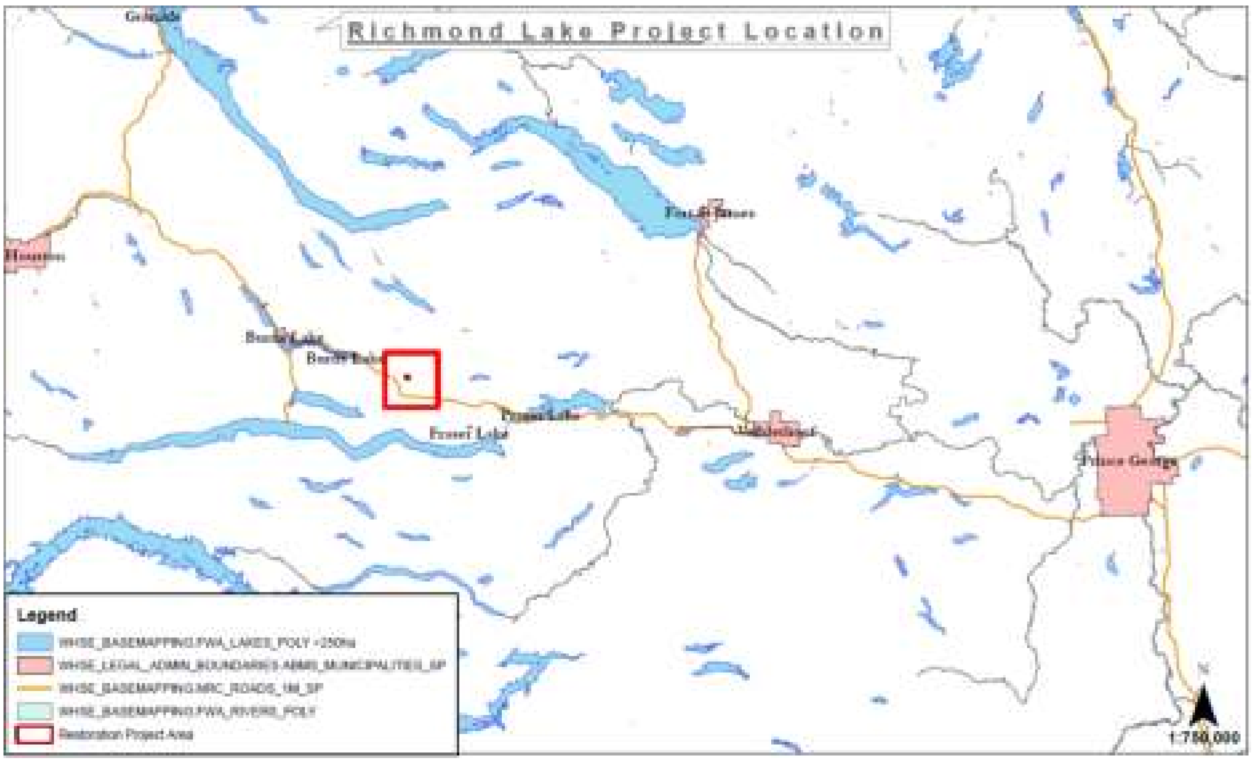

Figure 2- Site location map (ArcGIS 2020)

Current Use

The project site is adjacent to the Richmond Lake Recreation Site. The lake is stocked annually with Rainbow Trout by the Freshwater Fisheries Society of BC. The area remains a popular fishing and camping location with access in the winter for ice fishing. Hunters use the recreation site in the fall and there is a trapline in the area and within the project site. There is also active timber harvesting nearby and the area is part of the BC Timber Sales (BCTS) Babine Business Area operating area (personal communication, R. Phillips & Nadina District 2015).

Challenges

The old access road to the recreation site deteriorated after 1980 and fish stocking became challenging (Schultze, 1985). The land surrounding a portion of the road was then sold by CN Rail to a private landowner who subsequently blocked access to the lake. These factors led to the Freshwater Fisheries Society of BC being unable to continue to stock the lake with rainbow trout. In order to continue to provide angling and camping opportunities at Richmond Lake, a new road was constructed in 2015-2016.

There is no baseline data for the stream and little for the larger area, which makes restoration and monitoring more challenging. Additionally, any new linear development impacts wildlife and is something to consider when building new roads and in the restoration process.

The presence of archaeological sites and very fine, easily erodible soils add another layer of complexity to the site. As does the frequent public use of the road: vehicle traffic deteriorates the road and must be managed to prevent erosion and protect the archaeological sites. Any restoration activities undertaken must be done with people and public safety in mind.

Previous Work

Standard engineering methods of rock anchoring, hay bales and grass seed were in place to mitigate erosion before the rainfall event (Fig. 3); however, the rain on the very fine soils caused the newly disturbed area to liquify and undermine the erosion prevention measures. The engineering officer then installed four fibre sediment logs on either side of the southern side of the stream, erosion blankets were installed on the exposed slopes, more stabilization pools were created for sediment settlement and the ditch-lines were armoured with small rock (5-10cm diameter) (R. Phillips, personal communication 2020). Despite these measures, soil erosion and sedimentation in the riparian area and stream continued. The damage done to the site required restoration to re-establish the natural draining pattern. In 2018, I began to plan further work, in collaboration with Nadina District Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) engineering staff, around the stream at the road crossing where soil erosion was an issue.

Figure 3- Standard engineering rock anchoring and fibre rolls at stream crossing

Purpose and Objectives

The main purpose of this project was to address the impacts to the hydrology of the site by re-**establishing natural drainage patterns and mitigating erosion** of the cut banks and the riparian area within the road right-of-way. Standard engineering erosion controls were already in place; however, the site was still experiencing erosion and one of the best ways to address this was to establish perennial vegetation to reduce surface runoff (overland flow) and soil erosion (Bornsworth, 2015). It was important to **restore plant communities** on the cut banks and along the riparian area to hold the soil in place and capture sediment before it entered the stream and wetland complex. This reduces sedimentation and improves stream health and aquatic habitat (Fig. 4). This stream flows into a fish-bearing river and water temperature, sediment, impact to invertebrates and fish downstream are a concern. In the interior of British Columbia, road crossings are the single largest contributor to stream sedimentation (Beaudry & Associates, 2007; Elliot et al., 1996; Fisheries Target Committee, 1996).

Figure 4- Sedimentation in stream

To re-establish plant communities in the site, the primary objective was to **use and propagate local and native plant species, when possible**, as ground cover that would be resilient to use in the area (e.g., recreation, road travel, public safety) and to weather events, such as flooding and drought (Bornsworth, 2015). However, I was restricted to the materials available to me through my partner organization and transplanting local plants. I chose to plant whitebark pine (*Pinus albicaulis)*, a species that is native to this area, but at higher elevations (Fig. 5) since BCTS Babine had extra whitebark pine stock that would have otherwise been wasted. Whitebark pine is a hardy variety of tree that is known for its slope stabilizing properties, its ability to help slow loss of moisture from the soil and to provide cover and food for wildlife. It is also listed as endangered under the *Species at Risk Act*, with a declining range in British Columbia; this is an effort to see if it can be established in this area, to expand its current local range (Govt of BC, 2020b; Simmons, 2020).

When I considered the desired future condition of the site, my main concern was to establish a fully vegetated site with stable slopes, little sedimentation and a relatively healthy and functioning ecosystem (Ministry of Water, Land and Air Protection, n.d.). It is possible that with the changing climate the whitebark pine will not live to become old trees (Govt of BC, 2020b; Simmons, 2020). However, in the meantime if they stabilize the slope so other species, such as spruce, aspen, birch and lodgepole pine can grow, I am still achieving my objectives. I may even be helping to provide more whitebark pine seed sources.

Other considerations when undertaking this work were to **ensure the archaeological site remains protected** from erosion and from recreation users and to consider **public safety** when planning the restoration work. It was important to balance the impact of recreation users while **maintaining recreation values** and a relatively healthy functioning ecosystem.

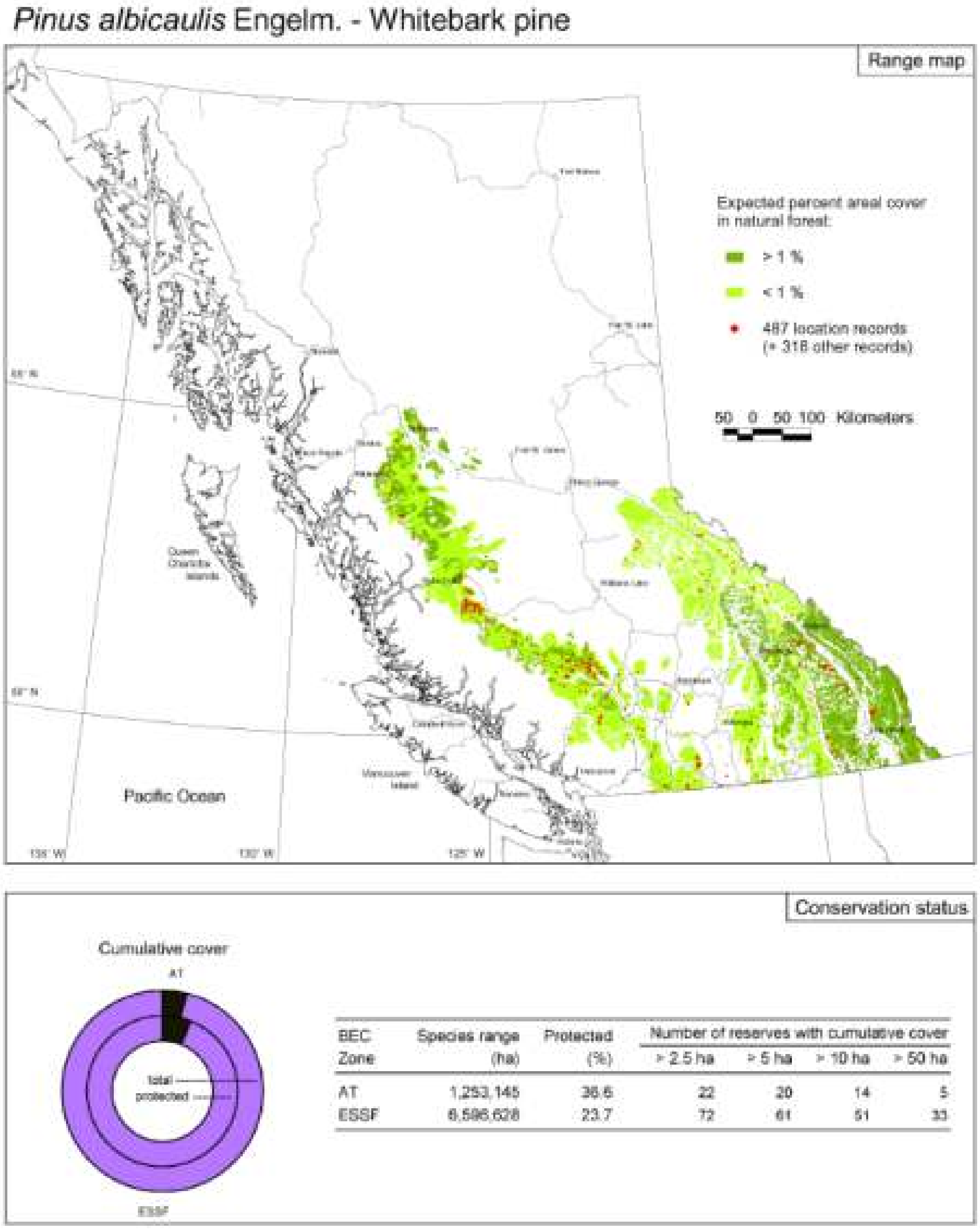

Figure 5- Whitebark Pine BC Range Map (Hamann, 2016)

3.0 Methodology

Ecosystem Description

The project area was divided into two polygons based on the site series' present within the 15m road right-of-way. It was important to determine site series to stratify the site into polygons for assessment and to implement appropriate restoration methods. Both polygons had been impacted by road construction activities, with the more significant impacts falling on the southern side of the road. The larger polygon (approximately 1.5ha) is comprised of the partially forested hillslope area (Fig. 6). The smaller polygon (approximately 0.5ha) includes the small stream and the surrounding wetland and riparian area (Fig. 7).

Polygon 1, the upper hillslope, has been significantly disturbed by road construction activities and falls within the site series SBSdk/05 (Sxw - Spirea – Feathermoss) (MoFR & MoE, 2010). The remaining forested area is an undulating landscape of mature stand of lodgepole pine and old growth hybrid spruce with paper birch and trembling aspen (Table 1). The soils in polygon 1 are very fine, easily erodible silt and sand with almost no topsoil or vegetation as a result of road construction activities. There is some seepage present, but the soils are mostly well drained (Appendix D).

The second polygon is within the small stream wetland and riparian area of the right-of-way. This polygon is in the SBSdk/10 (Sb - Soft-leaved sedge - Sphagnum (forested swamps)) site series (MoFR & MoE, 2010). This area has been impacted by road construction, but also by sedimentation caused by erosion and runoff of the soil on the upper hillslope area during heavy rain events. This polygon is wet most of the year and the water table is near the surface resulting in saturated silty-clay soils with obvious mottling (Table 2) (Appendix E).

Figure 6- Polygon 1 (2018)

Figure 7- Polygon 2 (2018)

Restoration Methods

The methods described below apply to the entire project site, unless specified otherwise. All work was completed by hand- no heavy equipment was used in the portion of the restoration I conducted. In total, I made three visits to the project area over a year (Appendices G & H).

Restoration Methods	Date(s)
○ I received donated hybrid spruce and whitebark pine seedlings from BC Timber Sales (BCTS) • Seedlings were planted a 50/50 mix on the slope south of the road. Total area planted ~ 1ha at 3m spacing ▪ Meeting stocking standards for commercial purposes was <u>not</u> the goal, rather it was limiting soil erosion,	July 2018

considering wildlife and plant communities and attempting to expand the range of whitebark pine. • Seedlings were planted so that they would not impede the line of sight on the road for the safety of recreational users travelling to the recreation site	
o Conducted a foot survey of the site at ~ 5m spacing to: • visually assess condition of site and effectiveness of previous erosion controls based on conditions during last site visit in 2018 • visually assess the health of the planted tree seedlings • check for new natural seedlings and other vegetation growth • inventory vegetation on the site • make note of any wildlife or habitat features • record any new human alterations or impacts to site o Completed a Ground Inspection Form for each of the 2 polygons o Visually assessed condition of archaeological site and determine any need for work to protect it	June 22, 2019
o Transplanted 32 aspen suckers along hillslope on south side of road, in between the whitebark pine and spruce seedlings (Fig. 8) o Completed a slope stability assessment for polygon 1: hillslope o Removed oxeye daisy, yellow hawkweed and bull thistle from roadsides and disposed of at landfill (Haaeussler, 2015; Ralph et al., 2017)	June 23, 2019
o Re-seeded entire disturbed portion of the project area with a 20 kg mix of grass seed recommended for the area to further manage the erosion of the cut bank and to prevent the spread of invasive and noxious plants. Not all of the seed species were native, rather they are non-invasive and were designed to manage erosion. The mix was composed of 35% annual ryegrass, 25% perennial ryegrass, 30% creeping red fescue and 10% red clover with an additional micronutrient fertilizer (Zuazo and Pleguezuelo, 2008) o Cut live willow stakes from wetland and planted in the areas most impacted with sediment near the stream in order to help slow down and filter water and sediment before reaching the stream as well as hold the existing soil in place. The cuttings were between 30-50cm in length and were buried in the wet silt in the riparian area around the stream ensuring that some of their buds or branches were buried in the ground to take root (Fig. 9). Cuttings were planted in groups of 2-4 for better coverage of drainage pathways to the stream (Alaska Dept. of Fish and Game, n.d.; Redfield, 2010).	June 24, 2019
o Follow up monitoring of restoration work conducted in June o Conducted a foot survey of the site at ~ 5m spacing to: • visually assess the health of the planted tree seedlings compared to the June assessment • visually assess health of transplanted aspen and willow	July 18, 2019

• check for new natural seedlings and other vegetation growth, including invasive species • Removed more invasive plants from roadsides • visually assess establishment of new grass seed and compared with photos taken at the site in June • visually assess area for new erosion and sedimentation and compared with photos taken at the site in June • make note of any wildlife on site o Filled in gaps near the culvert with cobbles and small boulders to block debris from draining into stream o Shored up a 1-2m section of the stream bank that was beginning to break away • Coarse woody debris (CWD) used to stabilize stream bank • Wove several willow stakes into stream bank to help hold the soil in place (Alaska Dept. of Fish and Game, n.d.; Redfield, 2010).	

Table 3- Restoration Methods

Figure 8– Trembling Aspen transplant

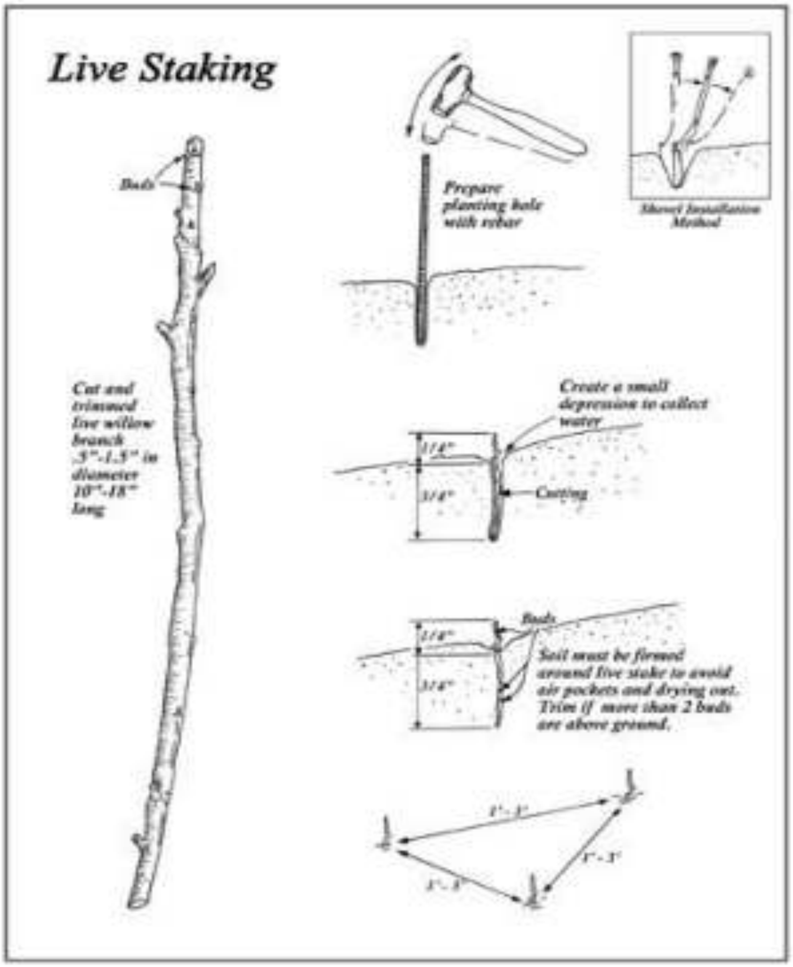

Figure 9- Live willow staking method (Alaska Fish & Wildlife, n.d.)

4.0 Results

Slope Stability

A slope stability assessment was completed in polygon 1 since there was evidence of past and current erosion at the project site. The slope in polygon 1 is moderately steep (67%) to very steep (133%), this combined with very fine exposed soils and damaging rain events has led to widespread gullying of the hillslope and soil slump (figs. 10 & 11). There is some water seepage in the hillslope that also contributes to soil movement. These factors indicate stability concerns and a high landslide hazard risk, so addressing the hydrology of the site and stabilizing the soil in this polygon was prioritized (Chatwin, 1994). This was done by establishing suitable vegetation (Bornsworth, 2015) to address erosion and mitigate further damage to the hillslope, as well as potential damage to the road and impact to the stream from sediment accumulation (Fig. 14) (Appendix F).

Tree planting and grass seeding in June appeared to reduce the amount of erosion occurring on the slopes and the amount of sediment being carried downslope to the stream. Ongoing monitoring of the slope will need to occur to determine if more work is needed.

Figure 10– Soil erosion at the project site, June 2019

Figure 11– Same location post grass seeding and rainfall, July 2019

Re-establishment of Vegetation

The vegetation present in each polygon is listed in Tables 1 & 2 below. While surveying the site, I noted the previously existing vegetation was beginning to recolonize the exposed soil near the forest edge, including several natural spruce seedlings and aspen suckers. At my last site visit in July 2019, there was still a significant amount of exposed soil (~50%), but native mosses, grasses and forbs were present in some areas and the density of seeded grasses had increased by 25-50% as a result of the most recent seeding in June 2019. It seems that the recent grass seeding helped stabilize the soil allowing other plants to grow.

Polygon 1- Hillslope SBSdk/05	
UNDERSTORY <10m in height	
Common Name	Latin Name
- Red-stemmed feathermoss - Step moss - Fireweed - Little buttercup - Heart-leaved arnica	- *Pleurozium schreberi* - *Hylocomium splendens* - *Epilobium angustifolium* - *Ranunculus abortivus* - *Arnia crodifolia*

- Creeping Red Fescue	- *Festuca rubra*
- Pine grass	- *Calamagrostis rubescens*
- Annual ryegrass	- *Lolium multiflorum*
- Perennial ryegrass	- *Lolium perenne L.*
- Timothy	- *Phleum pretense*
- Pumpelly brome	- *Bromus inermis* ssp. *pumpellianus*
- Pink Spirea hardhack	- *Spirea douglasii* ssp. *menziesii*
- Birch-leaved spirea	- *Spirea betulifolia*
- Kinnikinnick	- *Arctostaphylos uva-ursi*
- False Solomon's-seal	- *Smilacina racemose*
- Red raspberry	- *Rubus idaeus*
- Bunchberry	- *Cornus canadensis*
- Purple peavine	- *Lathyrus nevadensis*
- American vetch	- *Vicia Americana*
- Prickly rose	- *Rosa acicularis*
- Red clover	- *Trifolium pretense*
- Northern bedstraw	- *Galium boreale*
- Soopolallie	- *Shepherdia canadensis*
- Whitebark pine *planted	- *Pinus albicaulis*
- Hybrid Spruce *planted & natural seedlings	- *Picea glauca x engelmanni*
- Trembling aspen *natural and transplanted	- *Populus tremuloides*
- Black twinberry	- *Lonicera involucrate*
- Common Dandelion	- *Taraxacum officinale*
- Oxeye daisy	- *Chrysanthemum leucanthemum*
- Yellow hawkweed	- *Hieracium* ssp.
- Bull thistle	- *Cirsium vulgare*
- Yarrow	- *Achillea millefolium*
- Highbush cranberry	- *Viburnum edule*
OVERSTORY >10m in height	
*None in disturbed roadside	
- Hybrid spruce	- *Picea glauca x engelmanni*
- Lodgepole pine	- *Pinus contorta var. latifolia*
- Trembling aspen	- *Populus tremuloides*
- Paper birch	- *Betula papyrifera*

Table 1- Vegetation Summary for SBSdk/05

Polygon 2- Wetland and Riparian SBSdk/10	
UNDERSTORY <10m in height	
Common Name	Latin Name
- Red-stemmed feathermoss	- *Pleurozium schreberi*
- Step moss	- *Hylocomium splendens*
- Common horsetail	- *Equisetum arvense*
- Skunk cabbage	- *Lysichiton americanum*

- Crisp starwort - Fireweed - Little buttercup - Northern bedstraw - Fireweed - Willow - Timothy - Annual ryegrass - Perennial ryegrass - Creeping red fescue - Red clover - Sitka alder - Pink spirea hardhack - False Solomon's-seal - Northern scouring rush - Wild Mint - Water sedge	- *Stellaria cripa* - *Epilobium angustifolium* - *Ranunculus abortivus* - *Galium boreale* - *Epilobium angustifolium* - *Salix* ssp. - *Phleum pretense* - *Lolium multiflorum* - *Lolium perenne* l. - *Festuca rubra* - *Trifolium pretense* - *Alnus crispa* ssp. *sinuate* - *Spirea douglasii* ssp. *menziesii* - *Smilacina racemose* - *Equisetum variegatum* - *Mentha arvensis* - *Carex* ssp.
OVERSTORY >10m in height	
- Hybrid Spruce	- *Picea glauca x engelmanni*

Table 2- Vegetation Summary for SBSdk/10

Invasive/Noxious Plant Species	Density	Location
Oxeye Daisy	3%	Ditches, roadside landing
Yellow Hawkweed	1%	Ditches, roadside landing
Bull Thistle	1%	Ditches, roadside landing

Table 3- Invasive and noxious weeds

In July 2018, I planted a mix of approximately 300 whitebark pine and hybrid spruce seedlings south of the road on the exposed hillslope and at the base of the hills adjacent the stream. The areas planted with seedlings were those experiencing the most erosion (personal communication, R. Phillips; Zuazo and Pleguezuelo, 2008). I also transplanted 32 aspen suckers in June 2019 to the hillslope from the forest above. The tables below show the relative health of the seedlings and transplants based on the surveys I conducted in June and July 2019. In June 2019, I also planted live willow cuttings from the willows in the polygon 2 riparian area next to the stream to stabilize the soil and to slow down and filter water and sediment coming from the hillslope before it gets to the stream (Alaska Dept. of Fish and Game, n.d.; Redfield, 2010).

The tables below show that the whitebark pine is growing the best with the least trees showing stress. Despite this site being outside of their traditional range due to elevation, they are the healthiest seedlings and showed evidence of new growth (Fig. 12). The hybrid spruce seedlings struggled in their first year, likely due to the late season planting and a dry summer in 2018, since I was not able to irrigate the site. My second site survey in July 2019 showed both the spruce and pine were less yellow as there had been more precipitation that spring than the year before. The aspen suckers I transplanted in June had mostly died by July. They did not get adequate water to re-root on the hillslope and I could not irrigate. The willow had an almost 65% survival rate and new shoots were forming less than a month after planting (Fig. 13). It is possible more willow staking could be done depending on how many transplants survived over 2020. These results and the presence of natural spruce regeneration lead me to think that planting will not need to occur again, especially as natural aspen, spruce and many local plant species are finally starting to recolonize the site (Fig. 14).

Seedling Condition	**Whitebark Pine (Pa)**	**Hybrid spruce (Sx)**
% Healthy	62.9	14.8
% Un-healthy	24.7	76
% Dead	12.3	0.1

Table 4- Survey transect seedling results, June 23, 2019

Transplant Condition	**Trembling aspen (At)**	**Willow (Wx)**
% Healthy	12.5	64.3
% Un-healthy	0	0
% Dead	87.5	35.7

Table 5- Survey transect seedling results, July 18, 2019

Whitebark Pine Seedling

Hybrid Spruce Seedling

Figure 12– Typical condition of planted seedlings, June 2019

Figure 13– Live willow stakes in riparian (flagged yellow), July 2019

July 2018	July 2019, 1 year later

Figure 14- Polygon 2 pre and post grass seeding and tree planting

Other Considerations

I visually assessed the archaeology site to determine if the road work had impacted it or if erosion was a concern. The buffer for the site begins just on the forested side of the ditch and is surrounded by large trees and shrubs. There is no construction damage and no erosion occurring near the site. As long as future road work does not remove the trees on that side of the road, there should be no impact to the site. Additionally, the exact locations of archaeological sites are not publicly available, and the site is not highly visible from the road which prevents damage from road users.

This project also addresses potential impacts to Aboriginal interests in the area by working to restore the natural drainage patterns to limit sedimentation affecting fish and the right to fish downstream (Beaudry & Associates, 2007; Elliot et al., 1996; Fisheries Target Committee, 1996). This project also supports the regrowth of native plants that may have cultural importance and is also helping to re-establish and protect wildlife habitat to support hunting and trapping interests (Govt of BC, 2019; Hanson, 2009).

5.0 Discussion and Recommendations for Monitoring and Additional Work

Limitations to Restoration

There were a few limitations to completing the Richmond Lake restoration work:

- I was restricted to the materials and budget available to me through my partner organization. If I had an independent budget, I may have chosen to purchase different trees or shrub species to plant at the site. However, I was impressed with the health and vigour of the whitebark pine seedlings.

- There is little baseline data for the stream or the area to make comparisons to for restoration work and monitoring.

- I would have liked to involve one of the local First Nation communities in the project. Although significant engagement occurred on the original road construction, there was no First Nation participation in the restoration project. Collaborative planning and decision-making about resource management is a step towards reconciliation and provides transparency around these types of activities that hopefully fosters trust and improved government to government relationships.

Expected Outcomes

Based on what I observed during my time at the project site, I expect that there will be more erosion during heavy rain events. The soil is very fine, and the slopes are unstable with seepage from upslope. There was a significant improvement in the amount of ongoing erosion occurring on the site over the year I worked on the project, but until it is fully vegetated, there is little stabilizing the soil (Chatwin, 1994). Provided there are no extreme weather events or prolonged drought, the vegetation should continue to grow, and I do not think additional seeding or planting will be necessary.

It will likely be necessary to continue to manage for invasive and noxious plant species until the acceptable vegetation can outcompete it (Haeussler, 2015). It may be necessary in future years to brush vegetation back from the road for visibility and public safety, with care taken not to impact the archaeological site.

This project was completed for the Ministry of Forests, Lands, Natural Resource Operations and Rural Development and, as such, some standard road engineering practices were employed to manage erosion in the project area prior to my participation in the project (personal communication, R. Phillips 2015). I expect the combined efforts on this project will improve the hydrology at the site and assist in the post-disturbance recovery of the ecosystem.

Since I am not able to monitor the effectiveness of the restoration work beyond the scope of this project, these are my recommendations, although operationally I understand not all may be feasible.

Monitoring	• Continue monitoring for erosion and sedimentation into the stream at minimum yearly after spring freshet
	  o Determine if other erosion methods should be employed to keep sediment out of stream:
	    ▪ More grass seeding, transplanting shrubs
	    ▪ Replacement of hay bales, fibre rolls or adding silt fences in riparian area
	    ▪ Consider adding root wads and boulders to strategic locations to slow and divert water from directly entering stream
	    ▪ If slopes and the stream bank continue to slump, consider wattle-fences and live stakes
	  o If additional work is required on the stream bank, consider live willow wattle fences, adding root wads or boulders to stream bank to prevent bank erosion during high flow times (SWC, n.d.).
	• Fill plant or seed in areas where vegetation is not well established
	• Address any new disturbances that occur to prevent damage to the site and stream
	• Target the site for Forest and Range Evaluation Program (FREP) effectiveness monitoring, if possible (FLNRORD, 2020)
	• Restrict any disturbance or brushing in the vicinity of the archaeological site
	• Monitor health and growth of whitebark pine seedlings for species conservation purposes
	• Brush roadsides as needed for visibility (avoiding work near the arch site)
	• Hire (paid or volunteer) First Nation and other community members for monitoring, where possible

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<tr><td>Invasive Plant and Weed Management and Disposal</td><td>Manually remove invasive/spreading plants on roadsides:
On a yearly basis before they go to seed, until site appropriate vegetation is well established (Ralph et al., 2017)
Dig around plants to remove roots (Haeussler, 2015, WCNWB, 2016)
Clean tools, vehicles, gear and pets before leaving site to limit spread
Limit soil disturbance as much as possible
Bag removed plants, plant parts and seeds and transport to a designated disposal site (Ralph et al., 2017)
For oxeye daisy, nitrogen fertilizers have been shown to significantly reduce growth; however, this can be harmful in watercourses and should be avoided where runoff will carry the fertilizer into the stream (Govt of Alberta, 2011)
Herbicides approved for use in and around water if spread is otherwise uncontrollable (Sarfaraz, 2017; WCNWB, 2016)
Plant native shrubs, sedges and trees if vegetation removed or disturbed
For visibility or budget reasons, if it is not possible to plant trees or shrubs, seed disturbed areas with native grasses or an approved seed mix in large areas of soil disturbance (Zuazo and Pleguezuela, 2008)</td></tr>
<tr><td>Communication and Engagement</td><td>Maintain communication between project partners as well as recreation and trails staff regarding all major project changes and milestones
Inform the larger community on project successes and significant updates to build support for restoration work and show accountability (Gann et al., 2019)
Communicate results of whitebark pine planting to the Bulkley Valley Research Centre and the research staff at Skeena FLNRORD
Involve the community in work bees for project components that need additional support
Install informative signage about the restoration area to discourage disturbance
Create information signage on invasive plants in the area and how to report and remove them from your vehicle or person to prevent spread</td></tr>
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Table 6- Recommendations for monitoring and further work

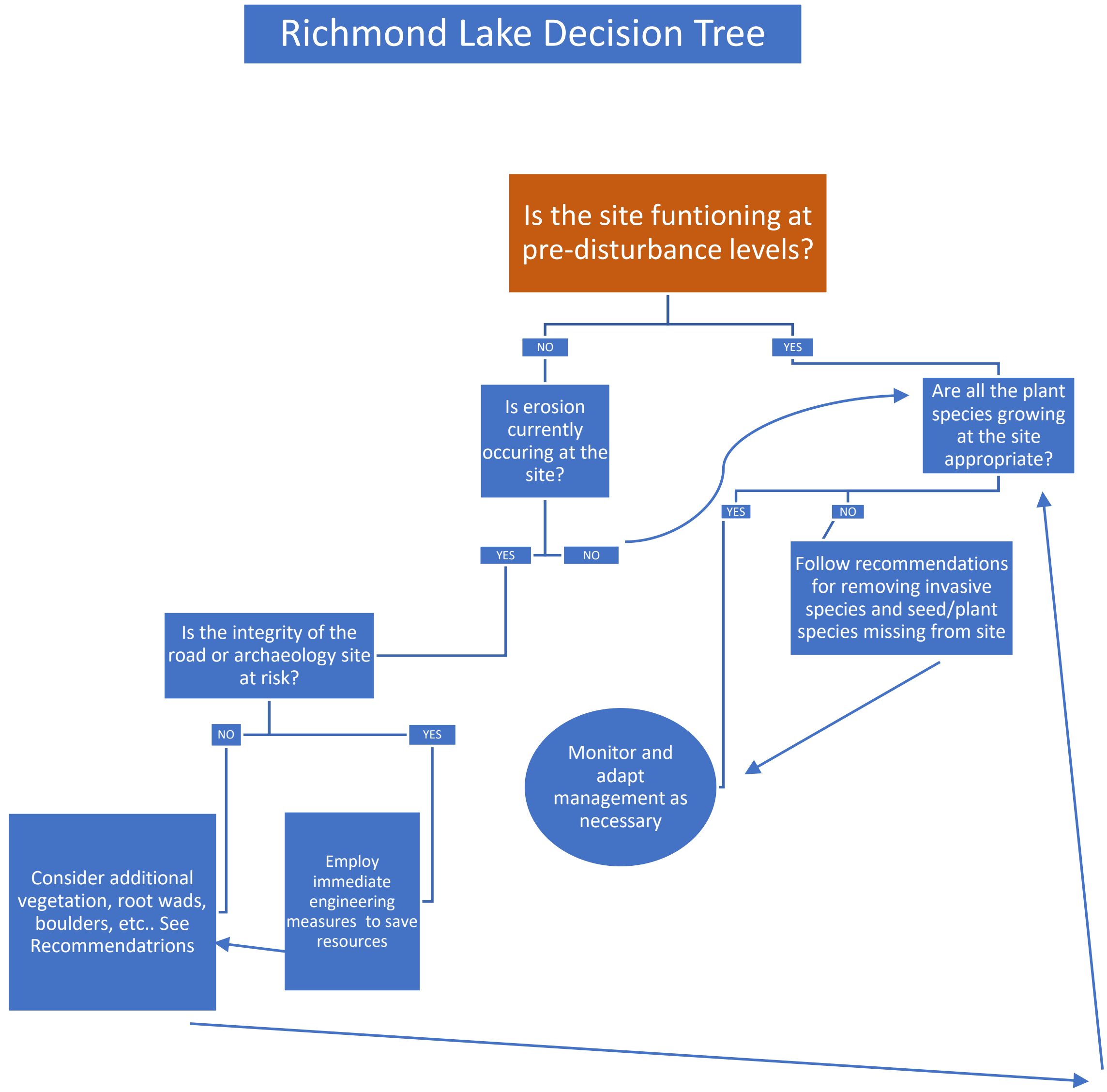

Figure 14- Management Response Decision Tree for Further Work

The above decision tree (Fig. 15) is meant as an aid for land managers and road licensees when considering whether the restoration site requires additional works. Some of the recommendations, such as brushing and road maintenance, are covered in a Professional Monitoring Plan developed by FLNRORD for every high-risk engineering project (R Phillips, personal communication, 2020). As an additional measure not normally completed for engineering works, I have requested ongoing targeted effectiveness monitoring be undertaken through the FREP program by staff at the Nadina District, beginning in 2021. I will communicate results of whitebark pine planting to the Bulkley Valley Research Centre and the research staff at Skeena FLNRORD so that they can continue to track the site and contribute to the monitoring of whitebark pine as a species at risk. I have also been given permission by FLNRORD District engineering staff to develop signage for the restoration site and adjacent recreation site to explain the project. In conclusion, my intention is to demonstrate that if considered in the development plan, simple restoration work can be undertaken with little extra budget or staff time by forest professionals and road crews, going above and beyond what is required by legislation, to significantly improve ecosystem function. This does not have to be a special project, it can and should be considered for regular operational work.

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Appendices

Appendix A- Project Site Map and Orthophoto

ArcGIS 2020


Apple Maps- https://satellites.pro/Canada_map#54.141197,-125.313964,15

Appendix B- Wildlife Surveys and Observed

Prior to road construction, wildlife surveys were conducted as the Ministry of Transportation and Infrastructure requested adherence to Skeena critical timing windows for wildlife during construction activities. Karen Grainger, RPBio conducted a pre-clearing nest and wildlife survey in July 2015. The survey showed a number of habitat features for nesting birds, waterfowl and raptors, including; old-growth spruce with broken tops, witches' broom, hollow trees as well as small wetlands dominated by willows (*Salix* spp.) surrounding the stream and river to the north (Grainger, 2015).

Species	**Critical Timing Windows**
• Wolverine	February 1 to April 30
• Osprey/eagles	April 1 to August 31
• Raptors	March 1 to July 31
• Owls (general)	February 15 to August 15
• Great Horned Owl	January 15 to September 15
• Northern Saw-whet Owl	February 1 to July 15
• Trumpeter Swan	April 1 to July 31
• American Bittern	May 1 to July 31
• Moose/Deer/Elk	April 15 to May 15 and July 15 to November 15
• Grizzly Bear	April 15 to May 15
• Black Bear	April 15 to May 15
• Passerines (songbirds)	May 1 to July 31
• Raptors	August 1 to September 30
• Trumpeter Swan	August 1 to September 30
• American Bittern	August 1 to September 30
• Sandhill Crane	critical period of April 1 to September 21
• Trumpeter Swan	critical period of April 1 to August 31
• Great Horned Owl	critical period is March 10 to September 6
• Northern Hawk Owl	critical period is March 21 to August 8
• Northern Pygmy Owl	critical period is March 15 to August 27
• Barred Owl	critical period is February 21 to August 14
• Great Grey Owl	critical period is February 27 to August 12
• Long-eared Owl	critical period is February 11 to August 1
• Boreal Owl	critical period is March 1 to July 15
• Northern Saw-whet Owl	critical period is February 1 to August 14
• Osprey	critical period is March 21 to September 5

• Bald Eagle	critical period is March 5 to August 31
• Sharp-shinned Hawk	critical period is April 30 to August 15
• Cooper's Hawk	critical period is April 1 to August 31
• Northern Goshawk	critical period is March 7 to August 21
• Red-tailed Hawk	critical period is January 26 to August 10
• Deer and moose	critical period is May 15 to July 15 and cautionary period is from November 15 to May 14.

Skeena Wildlife Timing Windows (Grainger, 2015)

Wildlife Observed 2015 Survey:
• Sandhill Crane • Ruffled Grouse • Winter Wren • Swainson's Thrush • Green-winged Teal • Red-tailed Hawk • Bald Eagle • Red Squirrel • Western Toad • Moose • Birch Sapsucker • Common Snipe • Chirping Sparrow • Dark-eyed Junco • Black-capped Chickadee • White-throated Sparrow • Yellow-rumped • Warbler • Nuthatch • Kinglet • Hairy Woodpecker • Crow • Raven • Robin

Other Species Identified Prior to Construction (Grainger, 2015)

Ecological Anchors/Habitat Features
- Witches brooms - Nurse logs - Hollow aspen and pine wildlife trees - Old growth spruce with broken tops - Game trails

- Trap boxes from trapline indicate presence of furbearers	
Wildlife Observed	
Common Name	**Latin Name**
Garter Snake	*Thamnophis sirtalis*
Mule Deer	*Odocoileus hemionus*
Moose (tracks)	*Alces*
Unidentified raptor	
Unidentified songbirds	*Passerines*
Rufous hummingbird	*Selasphorus rufus*
Ruffled Grouse	*Bonasa umbellus*
Bumblebees	*Bombus* ssp.
Dark-eyed Junco	*Junco hyemalis*

Wildlife and ecological anchors/habitat features observed

Appendix C- Regulatory Standards

The original road construction and related activities occurred in compliance with the applicable provincial legislation and regulations, including the Water Sustainability Act (2014), the Terms and Conditions for Changes in and About a Stream in the Water Regulation (2018), the Forest Act (1996) and the Forest and Range Practices Act (2002). The Heritage Conservation Act (1996) applies to archaeological resources. The federal Fisheries Act does not apply as the stream is not fish-bearing.

In addition, the objectives and strategies in the Lakes North Sustainable Resource Management Plan (Lakes North SRMP, 2009) and the Lakes District Land and Resource Management Plan (Lakes District LRMP, 2000), apply where legally required, directed through policy or are a requirement of obtaining a license for work.

Appendix D- Ground Inspection Form, Polygon 1

BRITISH COLUMBIA

GROUND INSPECTION FORM

G [X] vs V [ ]	PHOTO	X:	Y:
DATE June 23 / 19			
PROJECT ID. Richmond Lake R-O-W		SURV. AS	
MAP SHEET 093K014		PLOT # 1	POLY. # 1
UTM ZONE 10 M	LAT. / NORTH 54° 8' 16"	LONG. / EAST 125° 18' 36"	
ASPECT North °		ELEVATION 700 - 720 m	
SLOPE 67-133 %	SMR 3	SNR R	

MESO SLOPE POSITION: [ ] Crest [ ] Upper slope [X] Mid slope [ ] Lower slope [ ] Toe [ ] Depression [ ] Level

DRAINAGE - MINERAL SOILS: [ ] Very rapidly [ ] Rapidly [ ] Well [X] Mod. well [ ] Imperfectly [ ] Poorly [ ] Very poorly

MOISTURE SUBCLASSES - ORGANIC SOILS: [ ] Aqueous [ ] Peraquic [ ] Aquic [ ] Subaquic [ ] Perhumid [ ] Humid

MINERAL SOIL TEXTURE: [ ] Sandy (LS,S) [ ] Loamy (SL,L,SCL,FSL) [X] Silty (SiL,Si) [ ] Clayey (SiCL,CL,SC,SiC,C)

ORGANIC SOIL TEXTURE: [ ] Fibric [ ] Mesic [ ] Humic

SURF. ORGANIC HORIZON THICKNESS: [X] 0–40 cm [ ] > 40 cm

HUMUS FORM: [X] Mor [ ] Moder [ ] Mull

ROOT RESTRICTING LAYER: Depth 5 cm Type F

COARSE FRAGMENT CONTENT: [X] < 20% [ ] 20–35% [ ] 35–70% [ ] > 70%

TERRAIN

COMPONENT: TC1 [X] TC2 [ ] TC3 [ ]

	TERRAIN TEXTURE	SURFICIAL MATERIAL	SURFACE EXPRESSION	GEOMORPH PROCESS
1	S $	M L	k - S	E
2				

ECOSYSTEM

COMPONENT: EC1 [X] EC2 [ ] EC3 [ ]

BGC UNIT	SBSdk	ECOSECTION	BUB
SITE SERIES	05	SITE MODIFIERS	f
STRUCTURAL STAGE	2a / h	CROWN CLOSURE	/ %

ECOSYSTEM POLYGON SUMMARY

	%	SS	SM	ST
EC1	100	05	f	2a / h
EC2				
EC3				

TERRAIN POLYGON SUMMARY

	%	Classification
TC1	100	
TC2		
TC3		

DOMINANT / INDICATOR PLANT SPECIES

Total %	A: Trees 30%	B: Shrubs 5%	C: Herbs 50%	D: Mosses 2%

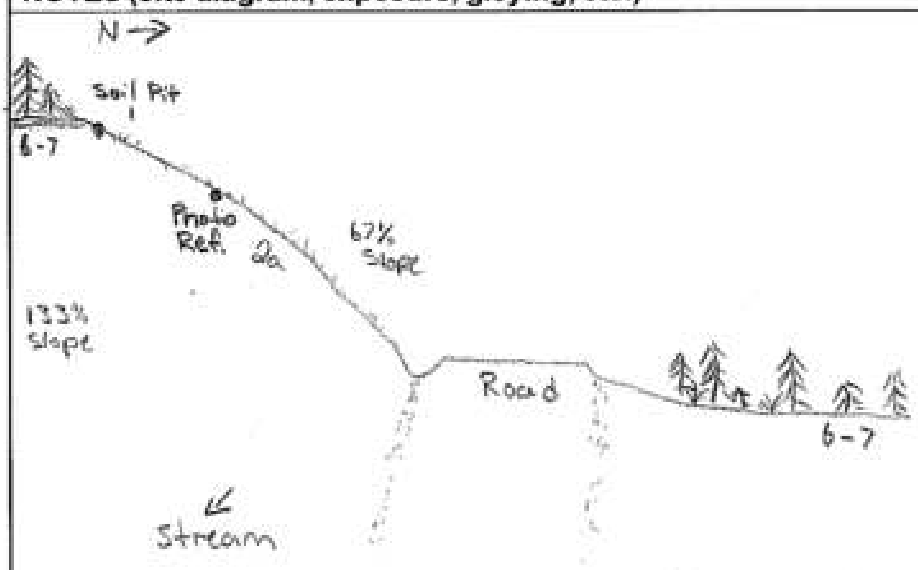
L.	Species	%	L.	Species	%	L.	Species	%
B	Red Raspberry	1	C	P. Rye	10	C	Spruce X	2
B	Prickly Rose	2	C	Timothy	5	C	Dandelion	2
B	Soopolallie	2	C	P. Brome	2	C	Oxeye daisy	3
B	Trembling Aspen	1	C	Pink Spirea	2	C	Yellow hawkweed	1
B	Black Twinberry	<1	C	Birch leaved Spirea	2	C	Bull thistle	1
B	Highbush Cran.	<1	C	Kinnickinik	1	C	Yarrow	<1
C	Fireweed	10	C	Bunchberry	1	D	Red Stemmed Feather	1
C	Little Buttercup	<1	C	P. Peavine	<1	D	Step Moss	1
C	Heart leaved Arnica	1	C	Vetch	<1	A	Sx	50
C	C. Red Fescue	10	C	Red Clover	5	A	Pl	20
C	Pine grass	20	C	Bedstraw	2	A	At	10
C	A. Rye	10	C	Whitebark Pine	1	A	Paper Birch	5

Complete ☐ Partial ☒

Tree Mensuration

Spp.	DBH	Ht. Calculation to DBH: Top	Bot	SD	SL	HD	HT	Ht. to DBH	Total HT	BH Age	Path Y/N

NOTES (site diagram, exposure, gleying, etc.)



Appendix E- Ground Inspection Form, Polygon 2

BRITISH COLUMBIA

GROUND INSPECTION FORM

G [X] vs V [ ]	PHOTO	X:	Y:	DATE June 23/19
PROJECT ID. Richmond Lake R-O-W		SURV. AS		
MAP SHEET 093K014		PLOT # 1		POLY.# 2
UTM ZONE 10M	LAT. / NORTH 54°8'16"		LONG. / EAST 125° 18' 36"	
ASPECT N °		ELEVATION 700 m		
SLOPE 5 %	SMR 7		SNR R-VR	

MESO SLOPE POSITION: [ ] Crest [ ] Upper slope [ ] Mid slope [X] Lower slope [ ] Toe [ ] Depression [ ] Level

DRAINAGE - MINERAL SOILS: [ ] Very rapidly [ ] Rapidly [ ] Well [ ] Mod. well [ ] Imperfectly [X] Poorly [ ] Very poorly

MOISTURE SUBCLASSES - ORGANIC SOILS: [ ] Aqueous [ ] Peraquic [X] Aquic [ ] Subaquic [ ] Perhumid [ ] Humid

MINERAL SOIL TEXTURE: [ ] Sandy (LS,S) [ ] Loamy (SL,L,SCL,FSL) [ ] Silty (SiL,Si) [X] Clayey (SiCL,CL,SC,SiC,C)

ORGANIC SOIL TEXTURE: [ ] Fibric [X] Mesic [ ] Humic

SURF. ORGANIC HORIZON THICKNESS: [X] 0–40 cm [ ] > 40 cm

HUMUS FORM: [ ] Mor [X] Moder [ ] Mull

ROOT RESTRICTING LAYER: Depth >30 cm Type F

COARSE FRAGMENT CONTENT: [X] < 20% [ ] 20–35% [ ] 35–70% [ ] > 70%

TERRAIN COMPONENT: TC1 [X] TC2 [ ] TC3 [ ]

	TERRAIN TEXTURE	SURFICIAL MATERIAL	SURFACE EXPRESSION	GEOMORPH PROCESS
1	$ C	L F	h	E
2				

ECOSYSTEM COMPONENT: EC1 [X] EC2 [ ] EC3 [ ]

BGC UNIT	SBS dk	ECOSECTION	BUB
SITE SERIES	10	SITE MODIFIERS	f
STRUCTURAL STAGE	2a/h	CROWN CLOSURE	25 %

ECOSYSTEM POLYGON SUMMARY

	%	SS	SM	ST
EC1	100	10	f	2a/h
EC2				
EC3				

TERRAIN POLYGON SUMMARY

	%	Classification
TC1	100	
TC2		
TC3		

DOMINANT / INDICATOR PLANT SPECIES

Total %	A: Trees 5%	B: Shrubs 25%	C: Herbs 50%	D: Mosses 50%

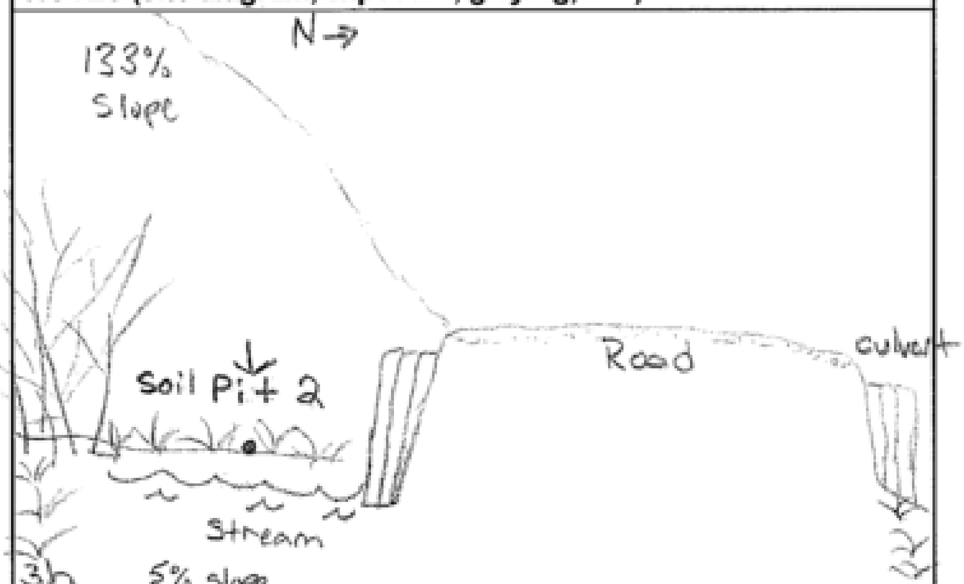
L.	Species	%	L.	Species	%	L.	Species	%
A	Hybrid Sx	5	C	A. Rye	5			
B	Willow	25	C	P. Rye	5			
B	Sitka Alder	2	C	Red clover	10			
C	Common Horsetail	30	C	Pink Spirea	2			
C	Skunk Cabbage	<1	D	R. Feather moss	25			
C	Fireweed	5	D	Step moss	25			
C	Crisp starwort	<1	C	Water Sedge	15			
C	Little Buttercup	<1						
C	Bedstraw	1						
C	N. Scouring Rush	10						
C	F. Solomons Seal	2						
C	Timothy	1						

Complete ☐ Partial ☒

Tree Mensuration

Spp.	DBH	Ht. Calculation to DBH: Top	Bot	SD	SL	HD	HT	Ht. to DBH	Total HT	BH Age	Path Y/N

NOTES (site diagram, exposure, gleying, etc.)



Appendix F- Slope Stability Forms, Polygon 1

Site Name: Richmond Lk. Polygon 1 Date: June 22/19
Map Sheet: 093K014 Photo Number:

1) Landform/Slope Data (Section 2.3.1, p. 41-48)

Slope Shape: Concave ☐ Convex ☐ Straight ☒
Surface Configuration: Uniform/smooth ☒ Irregular/benchy ☐
Slope Angle: (degrees) 67-133 % (percent)
Hillslope Profile

2) Overburden Characteristics (Section 2.3.1, p. 48-58)

Material Type: Till ☐ Colluvium ☐ Fluvial/Glaciofluvial ☐
Lacustrine/Marine ☒ Weathered rock (Residual Soil) ☐
Other:
Texture: Estimate %Gravel/rubble 2
%Sand 35
% Fines (silt/clay) 63
Coarse Fragment Shape: Rounded ☐ Angular ☒
Impermeable Layer: Yes ☐ Depth Below Surface (meters)
Overburden Profile: **Comments:** * most of top soil has been removed during construction

0-1 cm — grass, leaf litter, forbs
2-5 cm Ah — fine roots
6-20 cm E — SiL, very fine soils
— sand, small cobbles
21->30 cm B

(Note different layers and depth to bedrock and impermeable layer, seepage zones, etc.)

3) Geological Process Data (Section 2.3.1, p. 59-62)

Landslides:
Evidence of Past Landslides: Yes ☒ No ☐
Type: Fall ☐ Creep ☐ Slump ☒ Earthflow ☒ Debris Torrent ☐
Bedrock Slide/Slump ☐ Debris Avalanche/Flow ☐
Downslope Impact: Entered Stream Yes ☒ No ☐
Dimensions: Depth: (m) Width: (m) Length: (m)
Character of landslide initiation (starting) zone:
Material Type: Till ☐ Colluvium ☐ Fluvial/glaciofluvial ☐
Lacustrine/Marine ☒ Weathered Rock (residual soil) ☐
Other:
Texture: %Gravel/Rubble %Sand %Fine (silt/clay) 100
Slope angle: (degrees) 67-133 %
Slope Shape: Concave ☐ Convex ☐ Straight ☒
Surface Configuration: Uniform, Smooth ☒ Irregular, Benchy ☐
Drainage Features: Evidence of seepage ☒ (Yes)
Overall Drainage: Rapid-well ☐ Mod. well-Imperfect ☒ Poor-v. poor ☐
Landuse: Clearcut ☐ Natural ☐ Road ☒
Location: Open slope ☒ Gully ☐

Continued on next page

Field data card

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Box 3 continued

Other Features that Indicate Instability

Gully Erosion

Area Dissected by Gullies: ☒ Yes ☐ No

Number of Gullies in Area: Dozens

Landslide Evidence on Gully Slopes: ☒ Yes ☐ No

Termination Point of Gully: (describe) Base of hill / stream

Tension Fractures

Tension Fractures Evident in: Roadbed ☐ Overburden ☐

Landslide Deposits (indicate upslope landslide activity)

Debris Piles/Irregular Mounds at Base of Slope: ☐ Yes ☒ No

Upslope Location of Landslide: ______

Fans/Cones at Base of Slope: ☐ Yes ☒ No

Lobes/Leveeson Fan Surface: ☐ Yes ☒ No

Buried Landslide Deposits: ☐ Yes ☒ No

Upslope Location of Landslide: ______

4) Bedrock characteristics (Section 2.3.1, p. 62-66) None

Bedrock: Exposed (outcrops) ☐ Subsurface (buried) ☐

Bedrock Type: Volcanic ☐ Intrusive ☐ Sedimentary ☐

Metamorphic ☐ Specific Type: ______

Structure: Massive (nonbedded) ☐

Bedded ☐ Dip Downslope (parallel to slope) ☐

Jointed/Fractured ☐ Dip Downslope (parallel to slope) ☐

Stratigraphy that Promotes Landslides:

Massive Beds over Easily Eroded Beds ☐

Local Setting: Tension Fractures: ☐ Yes ☒ No

Cliffs: ☐ Yes ☒ No

Fresh rock exposed on cliff face: ☐ Yes ☒ No

Scattered boulder/blocks at base of cliff: ☐ Yes ☒ No

Talus at base of cliff: ☐ Yes ☒ No

Fresh rocks on talus/fresh blocks at base: ☐ Yes ☒ No

5) Hydrologic Characteristics (Section 2.3.1, p. 67-69)

Evidence of Wet Soils:

Mottles in Upper Meter of Soil: ☐ Yes ☒ No

Gleyed Soils: ☐ Yes ☒ No

Surface "Wet" Indicators:

Springs ☐ Sag Ponds ☐ Seepage/Damp Sites ☒

Shallow Linear Depressions

Drainage of Overburden: Rapid-Well ☐ Mod. Well-Imperfect ☒

Poor-v. Poor ☐

6) Vegetation (Section 2.3.1, p. 70-73)

Water tolerant Vegetation Present: ☒ Yes ☐ No

Identify species moss

Movement Indicators: Jackstrawed/Leaning Trees ☐ Split Trees ☐

Curved Trees ☐ Linear patches of uniform age forest oriented downslope that differ from surrounding forest ☐

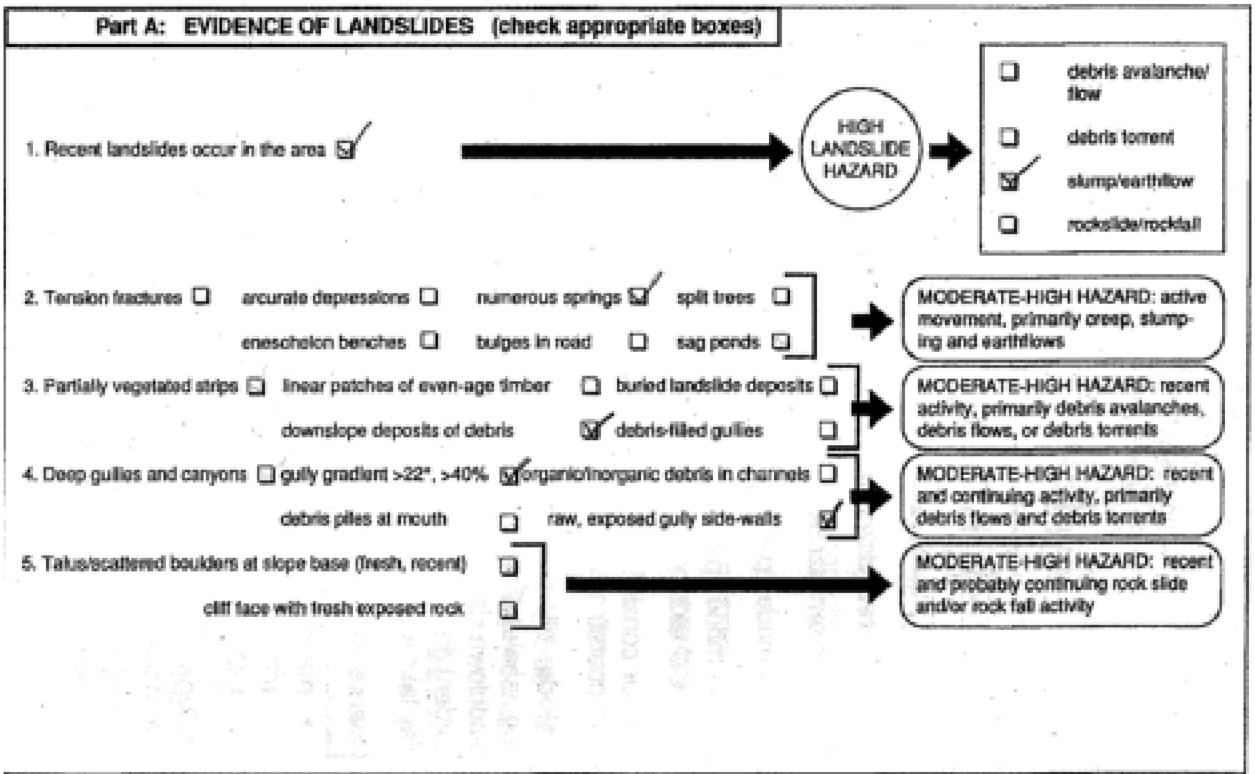
Evidence of Windthrow: ☐ Yes ☒ No

Site Conditions: Part of veg has been removed for road

Field data card

61

43



Part A: EVIDENCE OF LANDSLIDES (check appropriate boxes)

1. Recent landslides occur in the area ☑ → HIGH LANDSLIDE HAZARD → ☐ debris avalanche/flow ☐ debris torrent ☑ slump/earthflow ☐ rockslide/rockfall

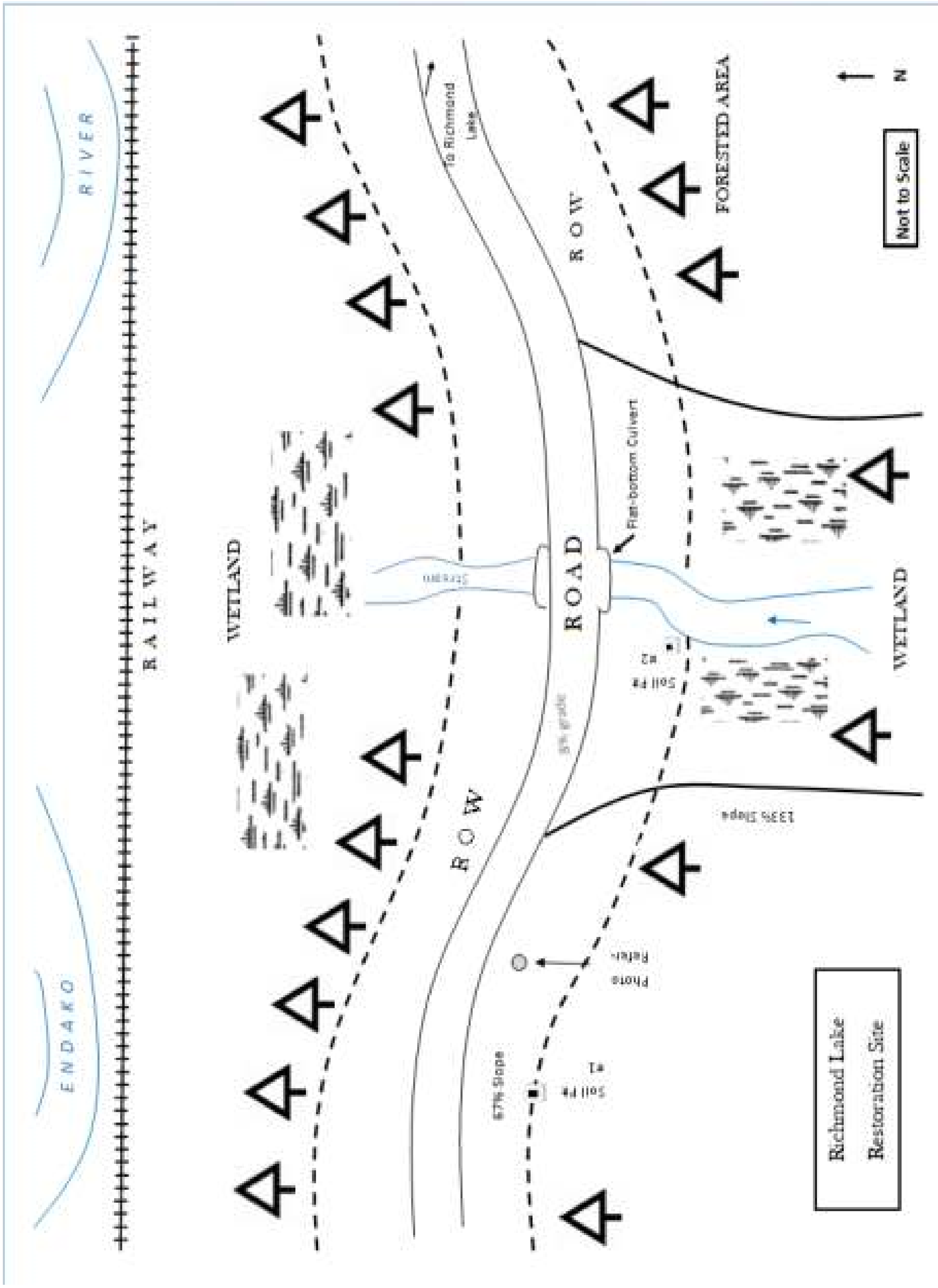
2. Tension fractures ☐ arcurate depressions ☐ numerous springs ☑ split trees ☐ eneschelon benches ☐ bulges in road ☐ sag ponds ☐ → MODERATE-HIGH HAZARD: active movement, primarily creep, slumping and earthflows

3. Partially vegetated strips ☐ linear patches of even-age timber ☐ buried landslide deposits ☐ downslope deposits of debris ☑ debris-filled gullies ☐ → MODERATE-HIGH HAZARD: recent activity, primarily debris avalanches, debris flows, or debris torrents

4. Deep gullies and canyons ☐ gully gradient >22°, >40% ☑ organic/inorganic debris in channels ☐ debris piles at mouth ☐ raw, exposed gully side-walls ☑ → MODERATE-HIGH HAZARD: recent and continuing activity, primarily debris flows and debris torrents

5. Talus/scattered boulders at slope base (fresh, recent) ☐ cliff face with fresh exposed rock ☐ → MODERATE-HIGH HAZARD: recent and probably continuing rock slide and/or rock fall activity

Appendix G- Site Diagram



Appendix H- Restoration Diagram