APEX GEOSCIENCE CONSULTANTS LTD.

Detailed Terrain Stability Field Review

Spur 1 and 2 and associated Block A080
Glade/Rover Area
For
Kalesnikoff Lumber Company Ltd.

W. Halleran P. Geo, L.Eng.

09/20/2019

1. Summary

If the recommendations contained within this report are implemented the proposed development will not significantly increase the low likelihood of landslide initiation. Partial Risk Analysis is reported in section 5.

2. Introduction

On October 18th, 2018, an email was sent to Mr. W. Halleran P. Geo L. Eng. (Civil) of Apex Geoscience Consultants Ltd. by Mr. Gerald Cordeiro of Kalesnikoff Lumber Company (KLC) requesting Detailed Terrain Stability Field Assessment of the proposed spurs 1 and 2 (A080) and associated block within the Glade operating area.

Mr. Cordiero noted that:

1. The upper access road (spur 2) crosses a steep gully with potentially unstable terrain identified.
2. This watercourse (which for the purposes of this report will be referred to as Stream A) requires several crossings on the lower road (Spur 1) which generally appear easier; however, these crossings should be assessed for hazards as well.
3. The harvest area is generally rocky without obvious signs of instability, however due to the steepness, identified potentially unstable terrain, and elements at risk below, a review of this area is requested to identify potential hazards,
4. Please determine if the number of culverts marked on the maps identified by the field crew is adequate to maintain natural drainage patterns. If additional culverts are required, please make recommendations for locations of additional culverts.

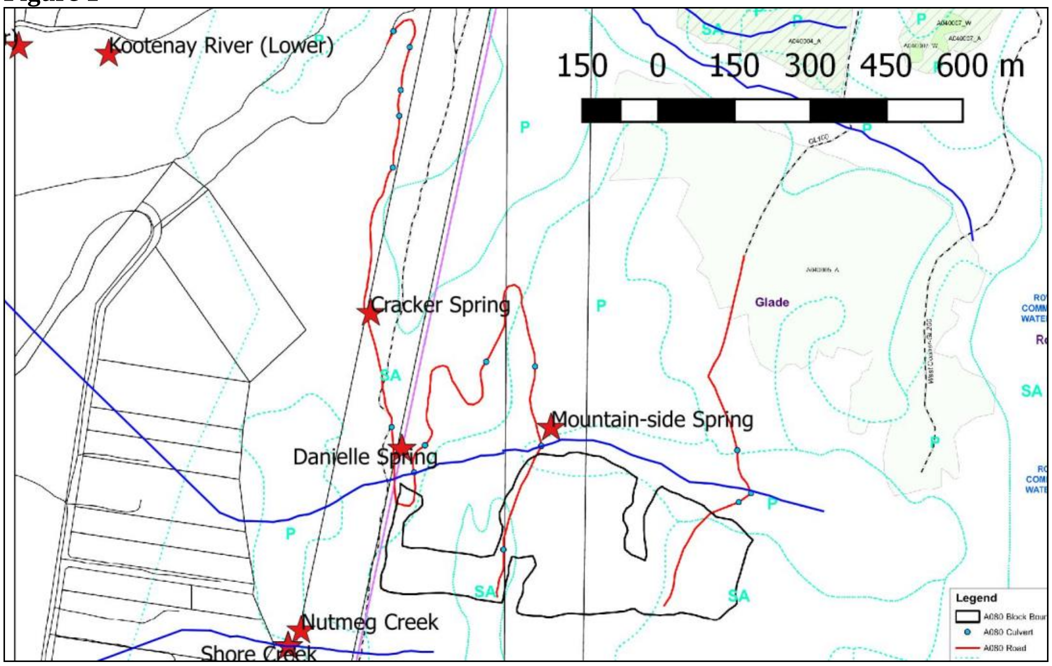
Elements considered for risk include:

a) Several licensed PoD's on and adjacent to the stream (Stream A) just north of the block. One of these is a spring. POD's include Mountain Side spring and Daniel Spring.
b) The power lines below the proposed development.
c) Private residences below the power lines.

Recommendations will include measures to ensure the road is left in a hydrological stable condition post operational use. This predominately involves recommendations for cross-ditch locations.

The proposed block, spurs, terrain polygons and pods are shown on Figure #1. The locations of the Springs marked on this map are downloaded from the government database, field observations indicate the locations may be misplotted. Field notes and observations are tabulated in Appendix I and shown on figure 11 in back.

Figure 1



3. Methods, Limitations and Reliability

Glade Hydrogeomorphic Risk analysis (Apex 2015), previous DTSFA reports (Apex Geoscience), Google earth imagery, Bing maps satellite imagery and historical airphotos were reviewed. KLC supplied development and hill shade maps with the roads, block, proposed culvert locations, and terrain stability polygons marked on it. A Samsung android tablet with the Avenza maps program with the imported hill shade map was used for navigation and note taking. QGIS slope drainage model was employed to delineate slope drainage patterns. Inferences are made from observations of materials in soil pits, road cuts, and tree churns within and adjacent to the proposed block and road during the field review.

The field assessment was completed by W. Halleran P. Geo L. Eng. on October 22nd, 24th and 30th 2018, weather was warm with occasional rain.

The terrain stability assessment made in this report is based on generally accepted practice described in "Guidelines for Terrain Stability Assessments in the Forest Sector-October 2010" published by APEG of BC. The risk assessment presented in this report follows the conventions outlined in Land Management Handbook 56 "Landslide Risk Case Studies in Forest Development Planning and Operations".

The partial risk analysis will be conducted on those portions of the roads and block that pose a hazard to the elements considered for risk. Areas and road sections assessed as having a low likelihood of landslide initiation and/or a low hazard will be omitted from the risk analysis.

This review assumes road good construction standards are met. Even if all standards are met there is still a possibility of landslides. Terrain assessment can reduce the likelihood of landslides, not eliminate it.

3.2 Likelihood of Landslide Determination

In this report the annual likelihood (Pa) of an event occurring is <u>estimated</u> by considering the age of the event (in this case, landslide). Slide reports and field observations are used to determine the age, cause, distribution, type, size and materials of both natural and development related landslides. In the absence of other information; for purposes of this report, the age of the landslide is assumed to equal to the return period of the conditions/climatic event that triggered the slide, i.e. a 500-yr. old event is associated with a 1 in 500-year return period (Pa). This will likely result in a higher estimate of the annual likelihood of an event occurring than is present.

For the natural terrain stability, field evidence for events that occurred less than 20 years ago, (Pa >0.05) will be obvious and likely appear relatively fresh (i.e. exposed mineral soil, broken and/or scarred timber, etc.). These areas are deemed to have a very high annual likelihood of landslides.

Field evidence for events that occurred between 20 and 100 years ago, (Pa = 0.05-0.01) should be obvious (i.e. change in vegetation, sharp slide scarps, scarred trees, buried soil horizons, absence of developed soil profile in the scar and scarp, etc.). These areas are deemed to have a high annual likelihood of landslides.

Field evidence associated with events that occurred between 100 and 500 years ago, (Pa=0.01-0.002) are usually more subdued (muted slide scars, multiple and/or thicker buried soil horizons, less developed soil profile within the scar compared to the adjacent slope, lack of burnt snags within the slide path if present on the adjacent slope). These areas are deemed to have a moderate annual likelihood of landslides.

Unless very large, field evidence for events associated with greater than 500-year-old events (Pa < 0.002) can be hard to notice (muted slide scars, old gullies, may have deep thick buried soils horizons). These areas are thought to have a low annual likelihood of landslides.

If a debris slide enters a "stream channel" a debris flow may result. The following assumptions are made[1]:

- A landslide entering a low-order channel of gradient less than 10^{o} (17.5%) stops
- A landslide entering a low-order channel of gradient greater than 10^{o} at an intersection angle of 45^{o} or less becomes a debris flow.
- Debris flows are erosive in channels of gradient greater than 10^{o}; they continue downstream but start depositing material at gradients less than 10^{o}.
- At channel junctions, if the gradient of the receiving channel is less than 20^{o} (36%), but greater than 3.5^{o} (6%), a debris flow continues if the junction angle is less than 70^{o}, otherwise it deposits on a fan.
- A debris flow entering a channel of gradient greater than 20^{o} will continue downstream, no matter what the junction angle.

Debris flow channels are most likely broadly U shaped. Trimlines (scoured side slopes), scarred trees adjacent to the channel, and buried soil horizons can indicate the age and frequency of events. Along lower gradient reaches and/or in unconfined sections, debris deposition often occurs as levees or debris lobes.

Observations of how previous development has influenced terrain stability, experience and professional judgment are used to determine how the proposed development will influence terrain stability.

The following formula is used to estimate the likelihood of an event occurring during the lifetime of a specific structure/element (long-term likelihood).

[1] From "A landscape-scale landslide model" ESI 2002.

$Px=1-[1-(Pa)]^x$

Where Pa is the annual probability, x is the lifespan of the "structure" and Px is the probability during the lifetime of the structure.

For this report the likelihood of an event occurring during the lifetime of the structure (Px) is defined as:

Greater than 50% is deemed Very High likelihood; from 50% to 20 % is a High likelihood; from 20% to 5% is a Moderate likelihood; less than 5% is a Low likelihood of landslide initiation.

3.3 Hazard Determination

For this report a hazard is a defined as a source for potential harm in terms of human injury, property, power line infrastructure, water quality or water intake infrastructure.

For this report, the hazard is a function of the likelihood of a landslide and the likelihood that the slide can materially adversely affect the elements considered for risk.

The relative rating for landslides is shown in Table 3.3.1

Table 3.3.1. Likelihood of a Debris slide or Sediment Reaching or Affecting elements considered for risk

Relative Rating of Likelihood of a Landslide Affecting elements	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect elements considered for risk.
Moderate	There is a run-out slope of<20º gradient and <200 m in length, or another terrain configuration which could possibly intercept or dissipate a potential landslide debris and/or sediment from erosion (e.g. irregular or benchy rock-controlled terrain) below and between the development and the elements considered for risk.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect the elements considered for risk at the time of an event. There is a run-out slope of <20º gradient for >200 m, or another terrain configuration which would likely intercept or dissipate sediment or landslide (e.g. irregular or benchy rock-controlled terrain), below and between the development and elements considered for risk.

The “Hazard” is determined via the matrix shown in Table 3.2

Table 3.2. Matrix for determining Hazard rating.

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Selected Elements		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

1) Modified from Wise et al (2004), Table 8, page 26.

3.4 Partial Risk Analysis Methodology

The risk analysis presented in this report is qualitative and is based on information gathered during this project and reviews of previous reports.

The elements assessed for risk for this project are:

a) water intakes (Cracker Spring Mountain Side Spring, Danielle Spring),
b) Power Lines,
c) and private land below the powerlines.

For this report, the risk is defined as hazard x consequence. Hazard has been defined in section 3.3, and consequence is the possible effect of the event. For the purposes of this report, due to uncertainty of vulnerability of private residences and private land, any impact is considered a high consequence, (i.e. the risk is hazard x high).
Consequences to POD and Powerline are defined in tables 3.4.1 and 3.4.2.

Table 3.4.1: Water quality and water supply infrastructure

Consequence	***Effect***
High	Long-term or permanent deterioration of water quantity/ quality. Complete destruction of water intake structures.
Moderate	Short-term deterioration of water qualityquantity, repairable damage (1 week) to water intake structures.
Low	Short-term (less then 1 week) deterioration of water quality/quantity, “damage” to water intake structures repairable during regular maintenance.

Table 3.4.2: Powerline

Consequence	Effect
High	Structural Damage to towers or extensive damage to access road (rebuild).
Moderate	Moderate damage to towers (i.e. debris impacts base and accumulates at base), moderate damage to access road (repairable).
Low	Minor damage to towers (i.e. debris flows past towers with no obvious impact). Minor erosion to/or deposition on the access road (minor repairs, still useable).

Partial risk is the product of the hazard and the consequence as shown in table 3.4.3

Table 3.4.3 Matrix for determining partial risk.

		Consequence		
		High	**Moderate**	**Low**
Hazard	**Very High**	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low
	Very Low	Low	Very Low	Very Low

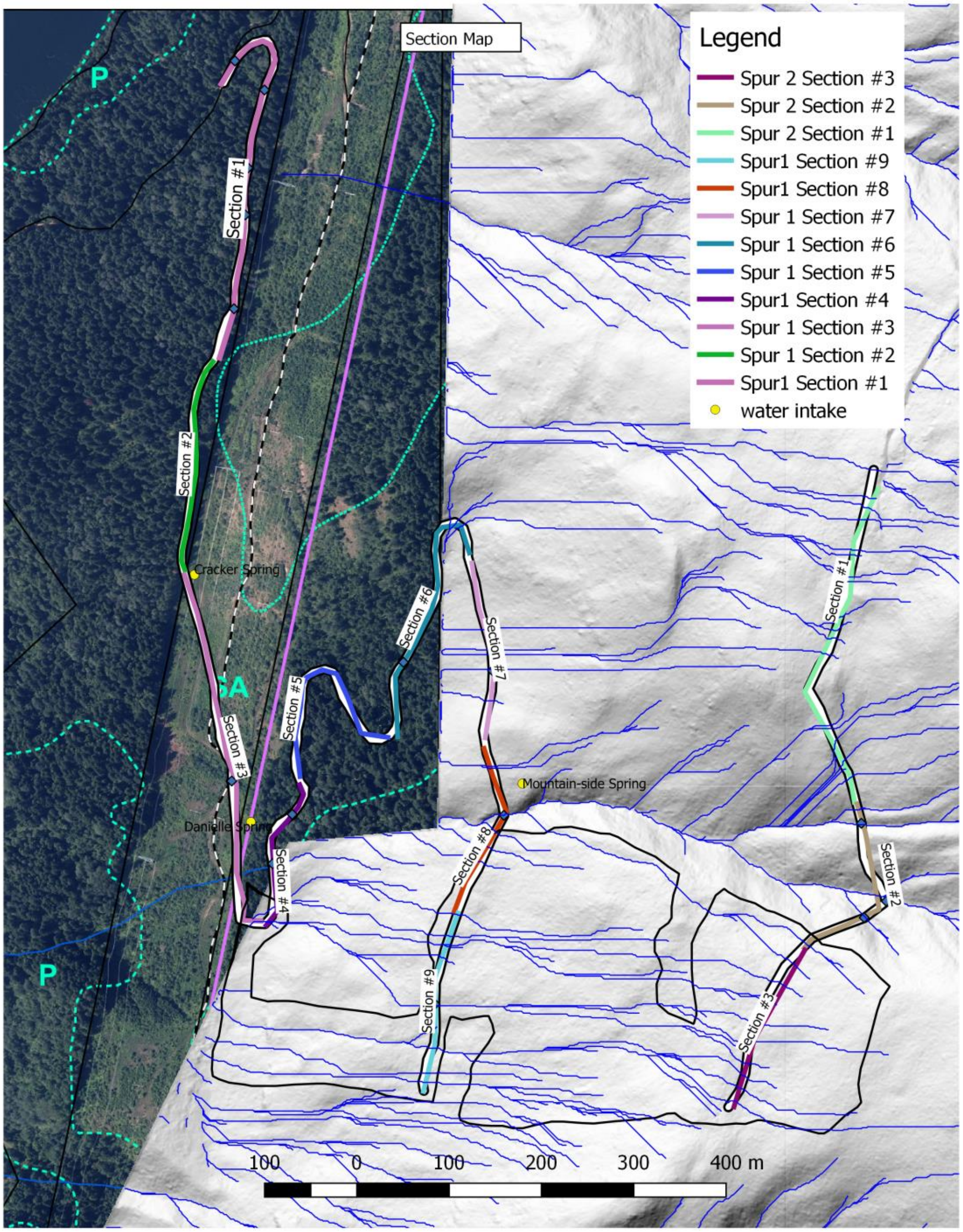
Table 3.4.3 Matrix for determining partial risk for private properties.

		Consequence
		High
Hazard	**Very High**	Very High
	High	Very High
	Moderate	High
	Low	Moderate
	Very Low	Low

4. Observations:

For the purposes of this report and for ease of discussions the spurs are divided into sections (figure #2).

Figure 2



Spur 1:

<u>Section #1</u>: (figure #3) This section of the road located below the Right of Way (ROW) for the powerline, there are at least four debris slide/flows crossing this section of the road. The slides range in age from 5 to 30 years old. Shallow gullies crossed by the road have hosted multiple debris flows. The initiation zones are between the powerline access road and the proposed road along a rock-controlled step just below the ROW. Access road, trails and push outs along the ROW likely concentrated and redirected slope drainage onto this slope. Recent cross-ditches along the road may have alleviated the likelihood of slides although some of the cross-ditches are too shallow to operate fully. In addition to the drainage diversions along the ROW, much of the headwater catchment of the stream that is upslope of the slides has been harvested (figure 4). The west aspect and elevation of the catchment may make it sensitive to harvesting which may have contributed to the instability, although the earliest slides pre-date the harvesting.

Figure 3

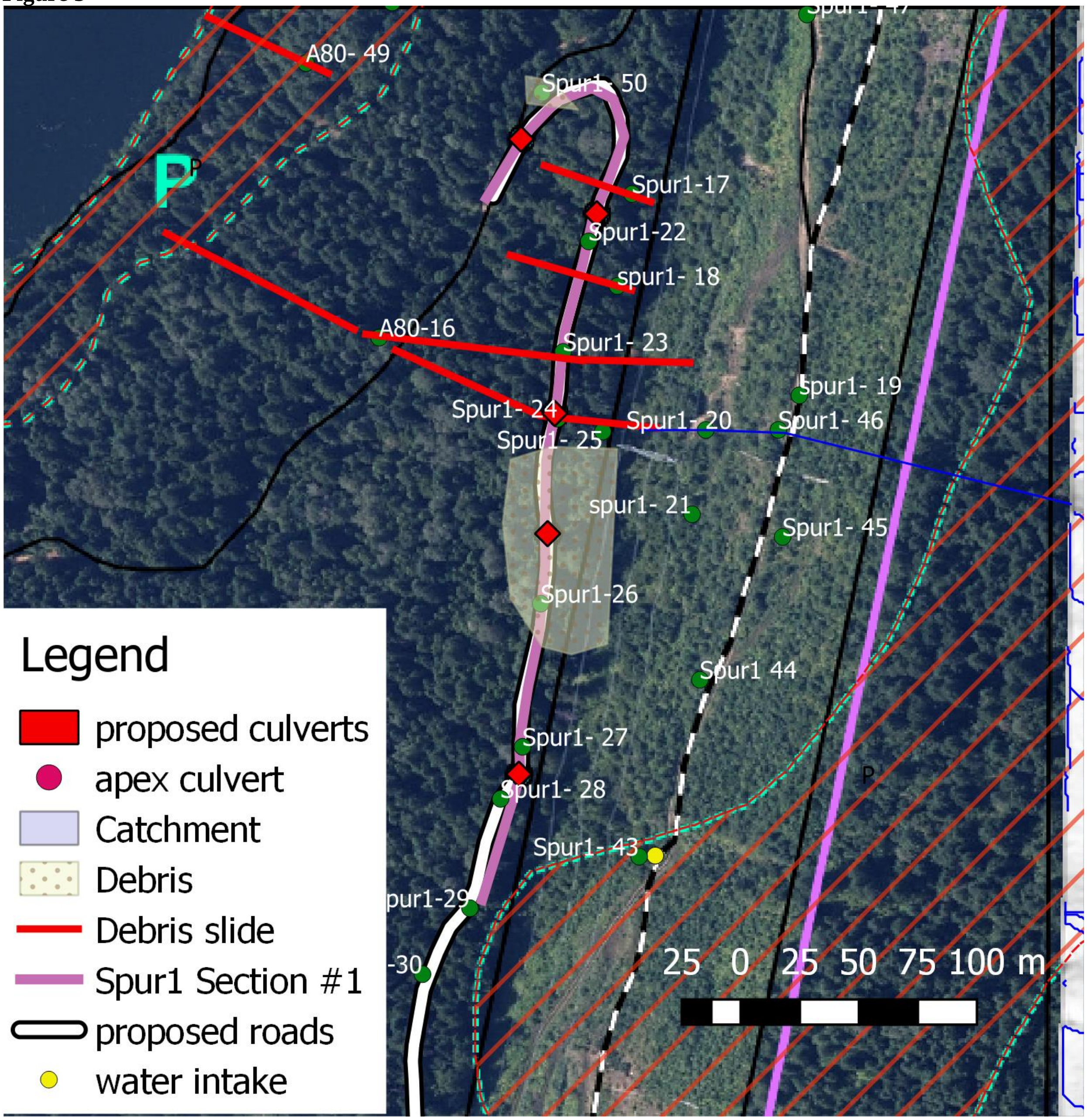
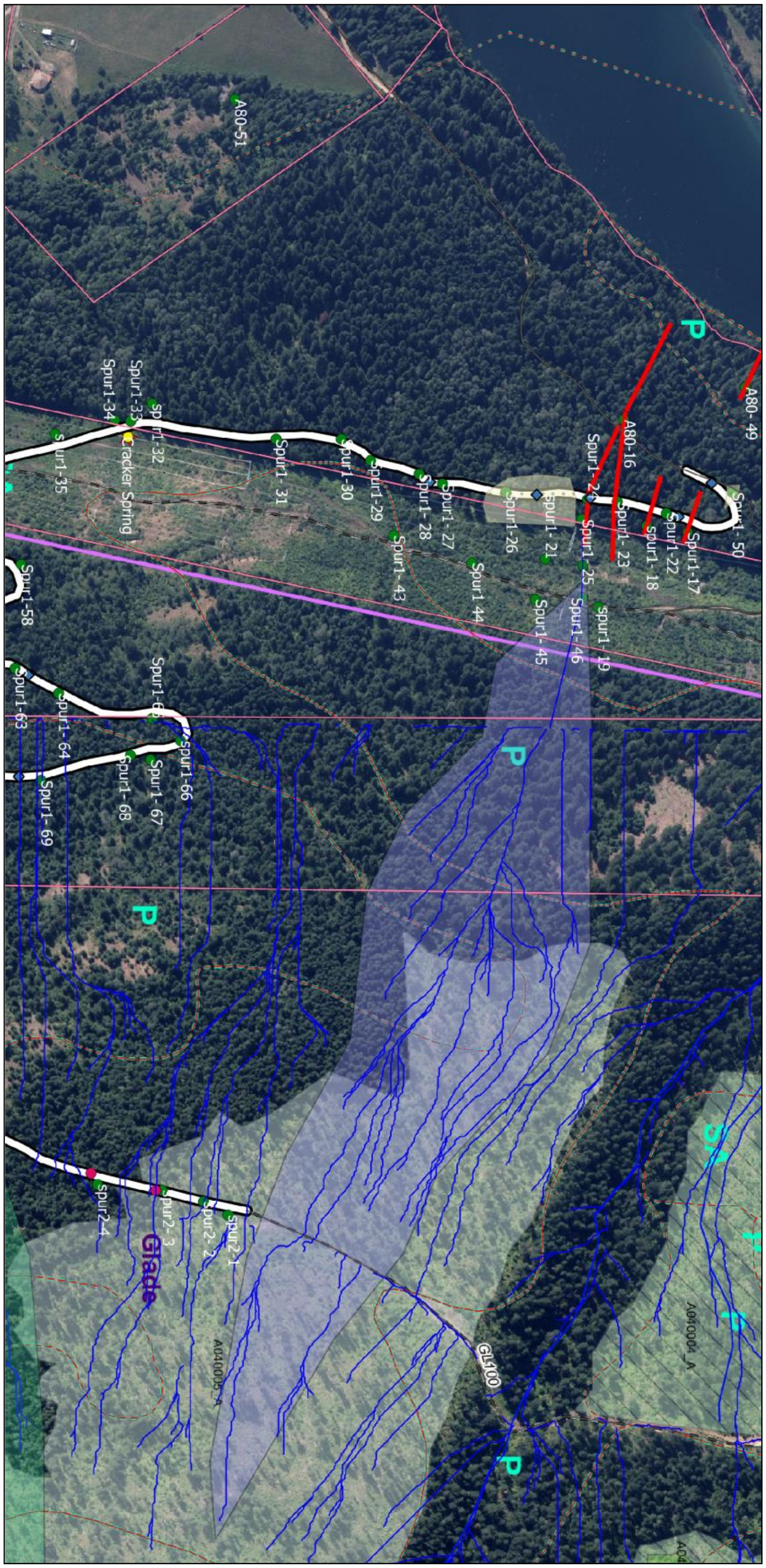
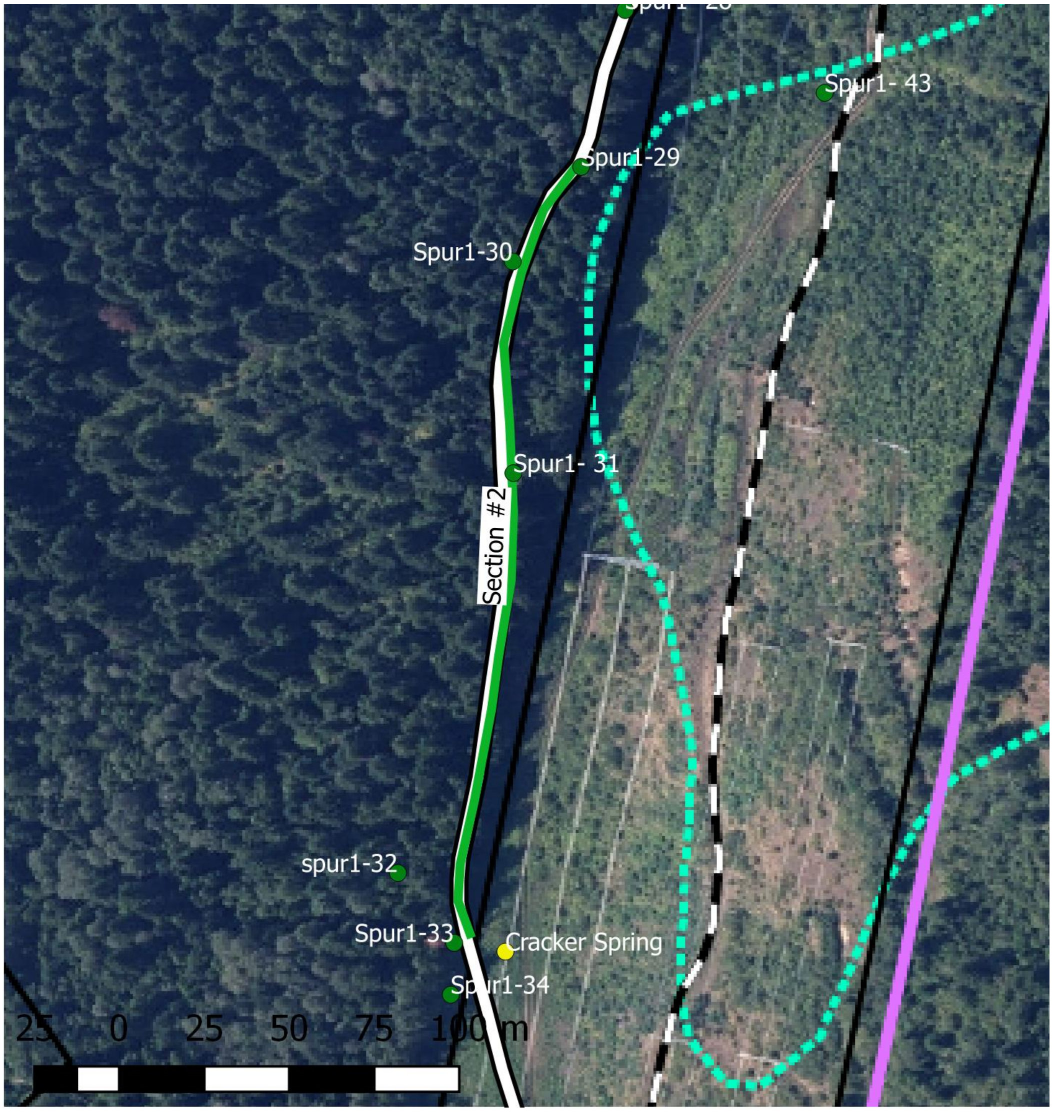

A80- 49
Spur1- 50
Spur1-17
Spur1-22
spur1- 18
A80-16
Spur1- 23
Spur1- 19
Spur1- 24
Spur1- 20
Spur1- 46
Spur1- 25
spur1- 21
Spur1- 45
Spur1-26
Spur1 44
Spur1- 27
Spur1- 28
Spur1- 43
pur1-29
-30
25 0 25 50 75 100 m
Legend
proposed culverts
apex culvert
Catchment
Debris
Debris slide
Spur1 Section #1
proposed roads
water intake

Figure 4


A80-51
A80-49
A80-16
P
Spur1-34
Spur1-33
spur1-32
Cracker Spring
Spur1-35
Spur1-31
Spur1-30
Spur1-29
Spur1-28
Spur1-27
Spur1-26
Spur1-21
Spur1-24
Spur1-25
Spur1-23
Spur1-18
Spur1-22
Spur1-17
Spur1-50
Spur1-43
Spur1-44
Spur1-45
Spur1-46
spur1-19
Spur1-58
Spur1-63
Spur1-64
Spur1-65
spur1-66
Spur1-67
Spur1-68
Spur1-69
spur2-4
spur2-3
spur2-2
spur2-1
Glade
GL100
A040005_A
A010004_A

<u>Section 2</u>: (Figure #5) This section of the road angles up through rock-controlled benches up onto a broad terrace which at this location is coincides with the ROW. The slope gradient does not exceed 65%. There is no evidence of instability.

Figure 5

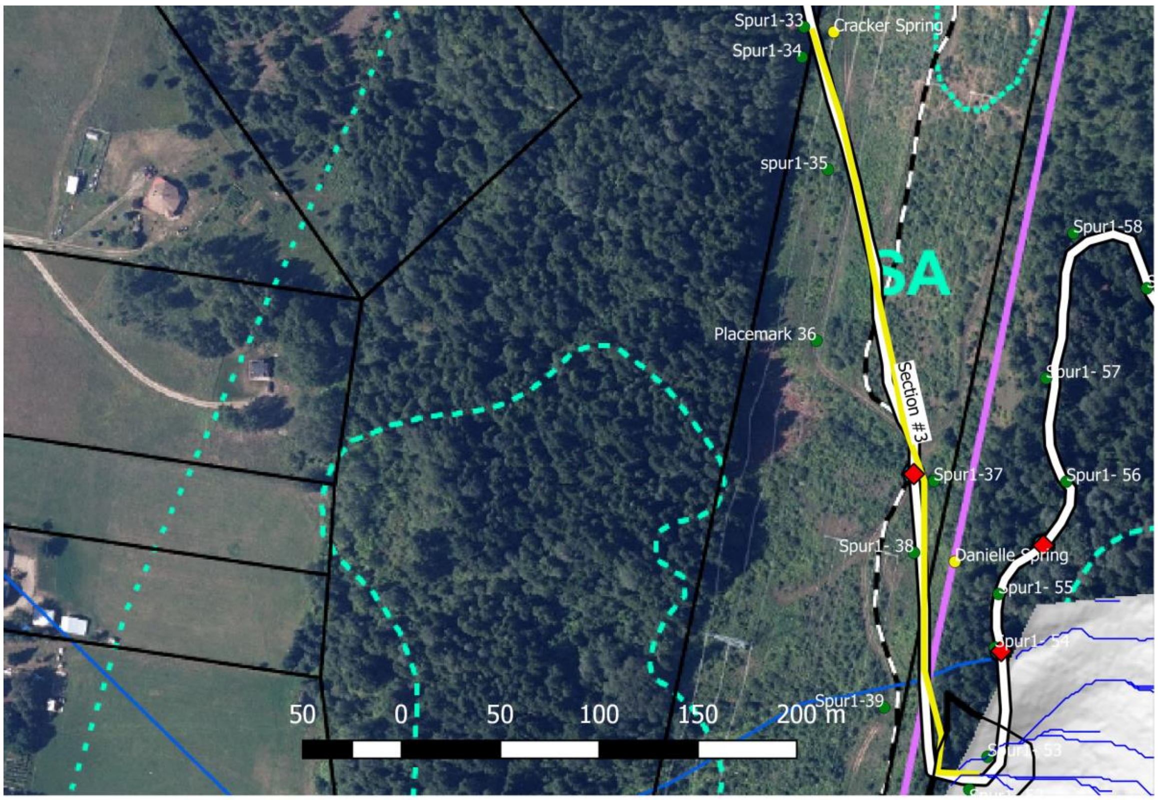


No PoD's are mapped along this section, there is, however, a constructed pond along the powerline access road at station Spur 1-43 (Cracker Spring?),

<u>Section 3:</u> This section of the road crosses the powerline ROW along a "terrace" top, crossing shallow gullies that feed deep ancient slumps and gullies. Most are dry with no evidence of erosion or flows crossing the existing road.

Cracker Spring is plotted at the north end of this section, but was not noted in the field. As stated previously, it may actually be located at station Spur 1-43. Danielle Spring is plotted along the southern end of this section but was not noted during the field review, it is likely that the spring location is actually upstream, water intake infrastructures was noted on the fan of Stream A.

Figure 6



Section 4: This section crosses the fan and stream associated with Danielle Spring and Mountain Side Spring. Currently the active stream is near the north edge of the fan, inactive (or overflow) channels occur along the southern portion. Between the active and inactive channels there is widespread forest floor wash and small levees. Concrete boxes and pipes occur on the fan upslope up stream of this section between stations 1-55 and 1-56 and are possibly the Danielle Springs, and at station 1-42 (likely Mountain Side Spring). The source of the “springs” is likely hyporheic flows associated stream flowing through the “fan” (figure 8). The approximate surface area catchment is shown in figure 9.

Figure 7

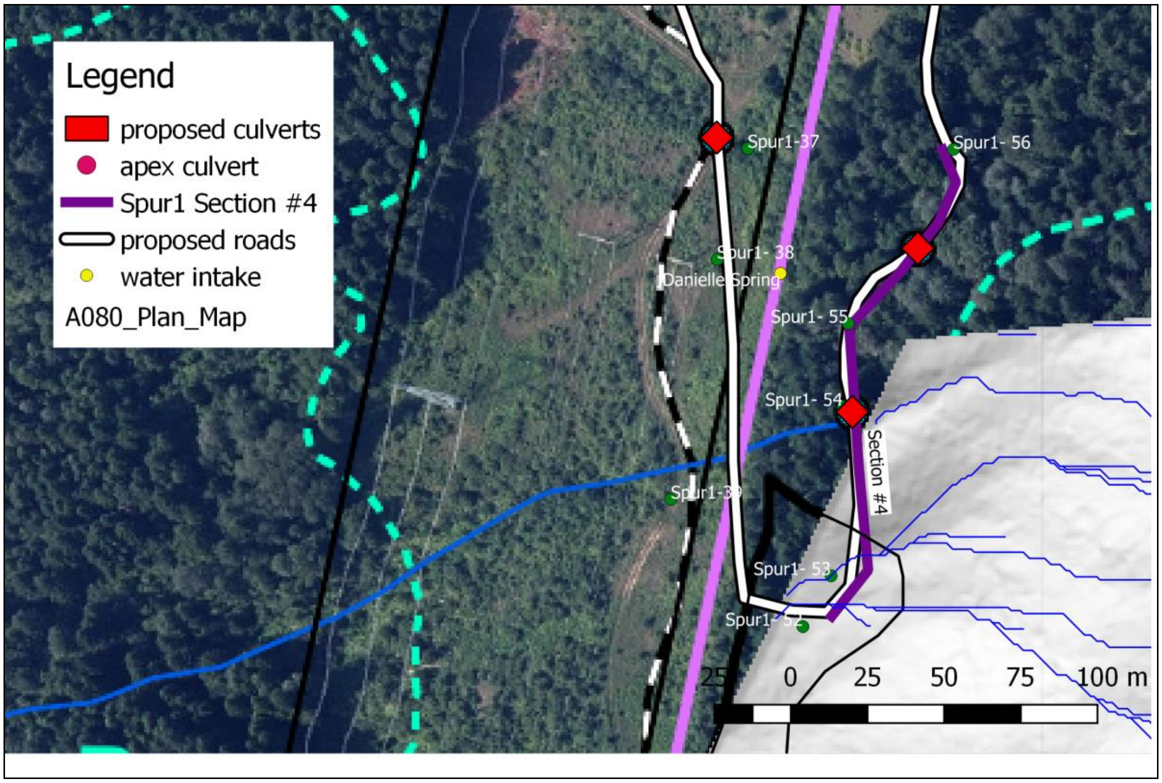


Figure 8

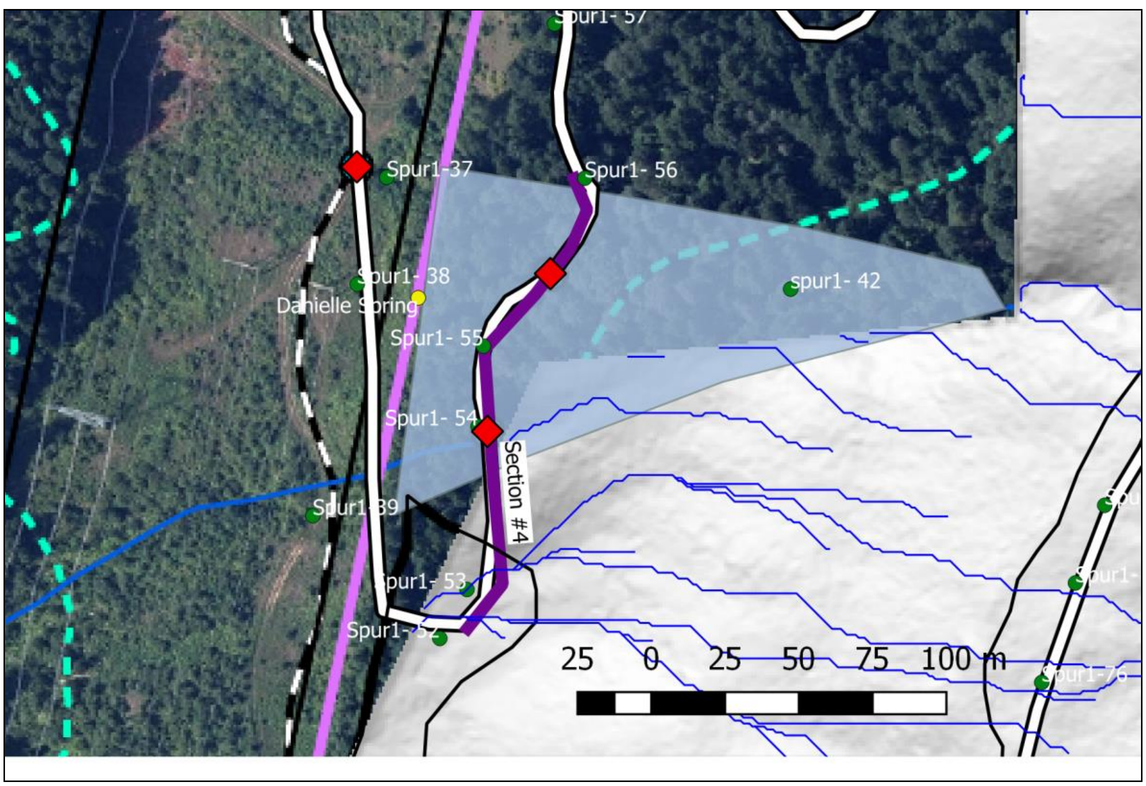
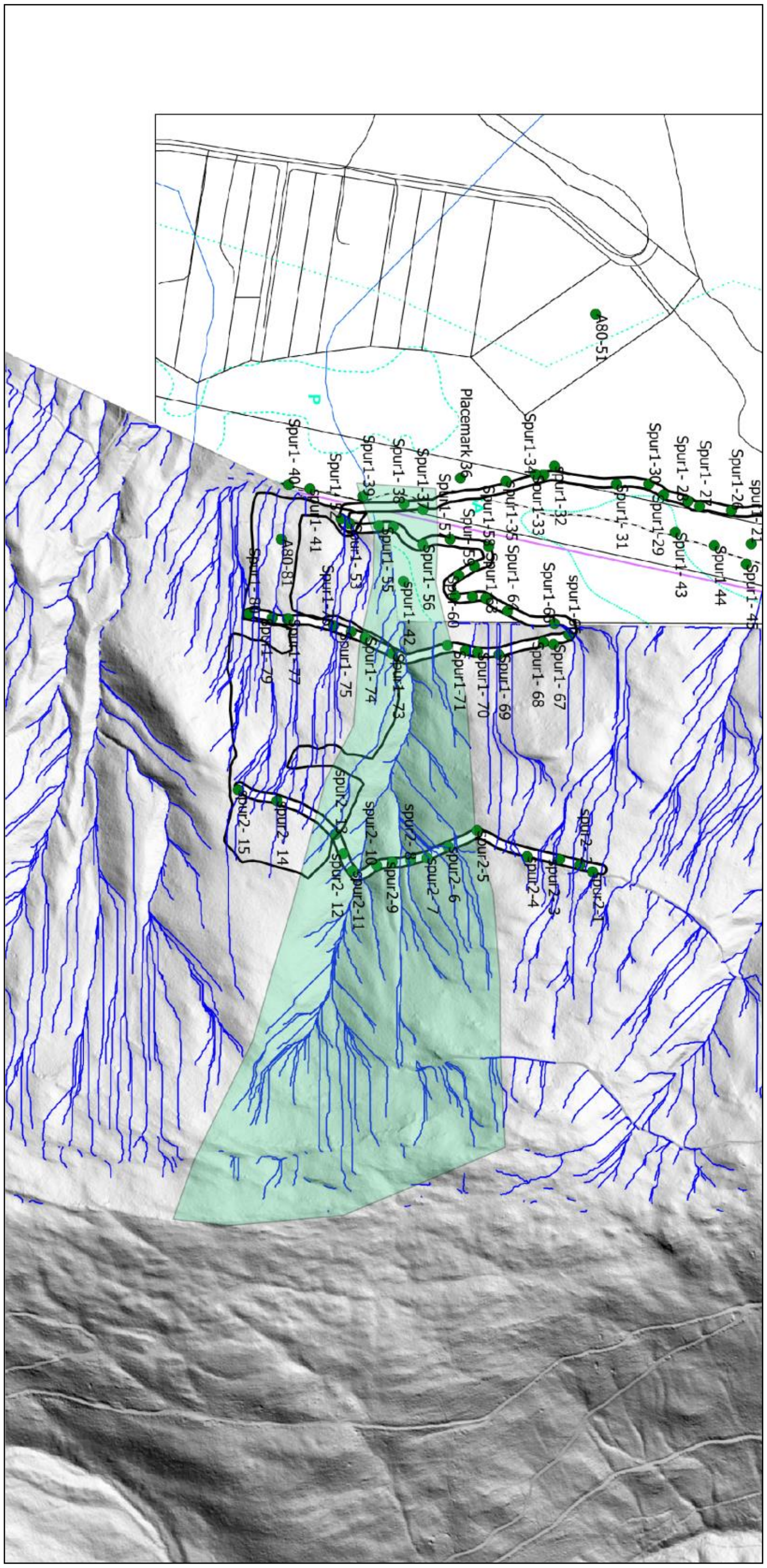
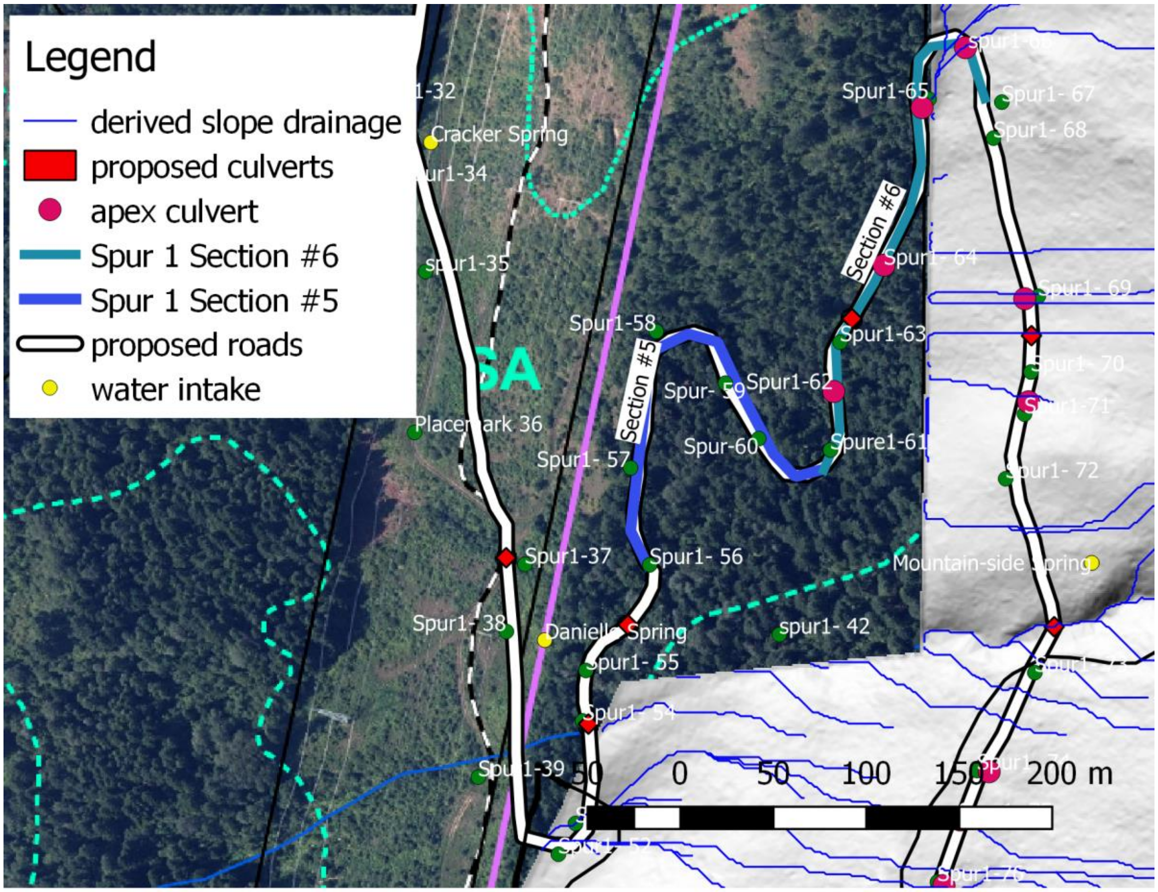


Figure 9



<u>Section 5:</u> (Figure 10) This section of the road crossed rock controlled benched terrain underlain by silty rubble and sandy gravel. There is no evidence of historic instability.

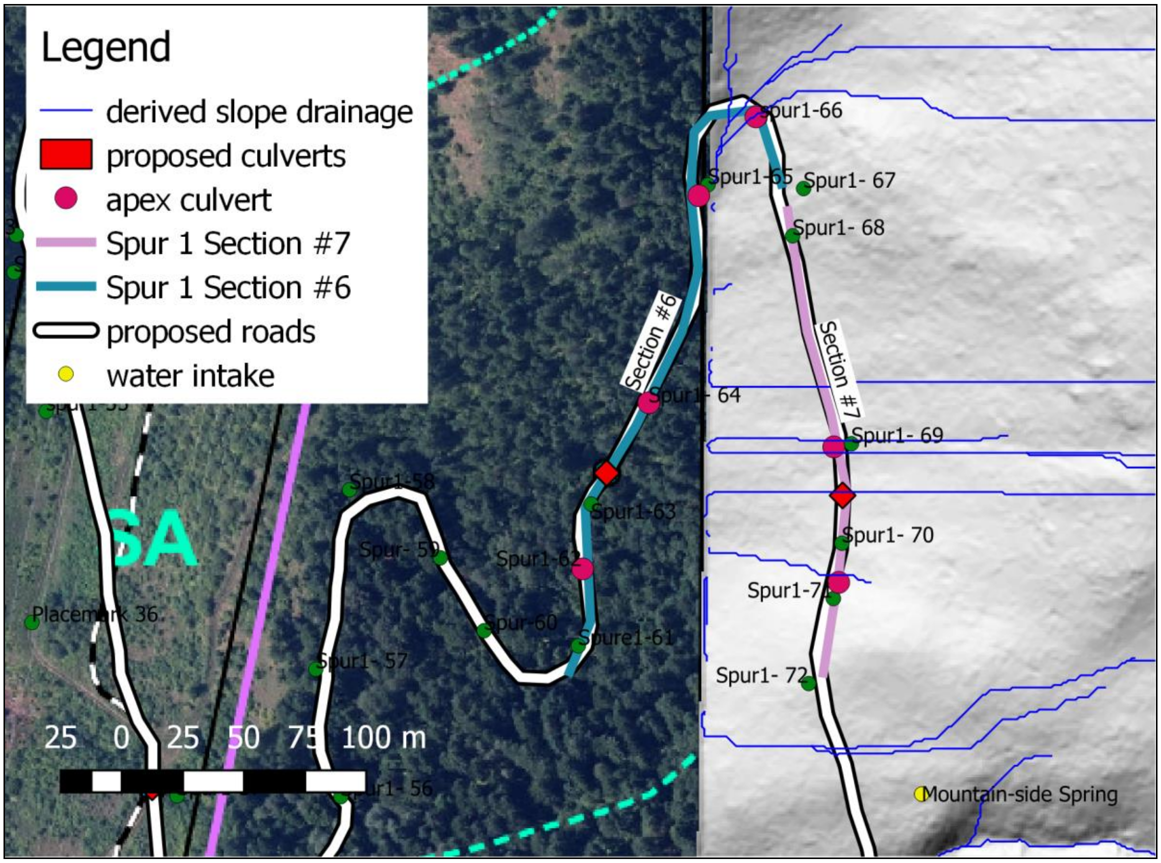
Figure 10



<u>Section 6:</u> (Figures 10 and 11) This section of the road crosses a 15 to 45% gradient silty rubble slope with swales. At station 1-64 there is a 50 to 75-year-old 0.7m high rubble levee, additional discontinuous levees and debris lobes are scattered across this fan like structure. The north end crosses, then heads up, a southerly trending rock draw, the switch is near the top of the draw, the road then crosses a short steep slope.

<u>Section 7</u>: (Figure 11) The road crosses a benched swaled slope (25 to 80%) underlain by veneer to blanket of silty angular rubble. At station 1-69 there is a 25 to 50-year-old 1m wide 0.5-meter-deep, stepped (rubble and blocks) eroded channel on a 65% slope. This channel is likely related to the levees noted at station 1-64.

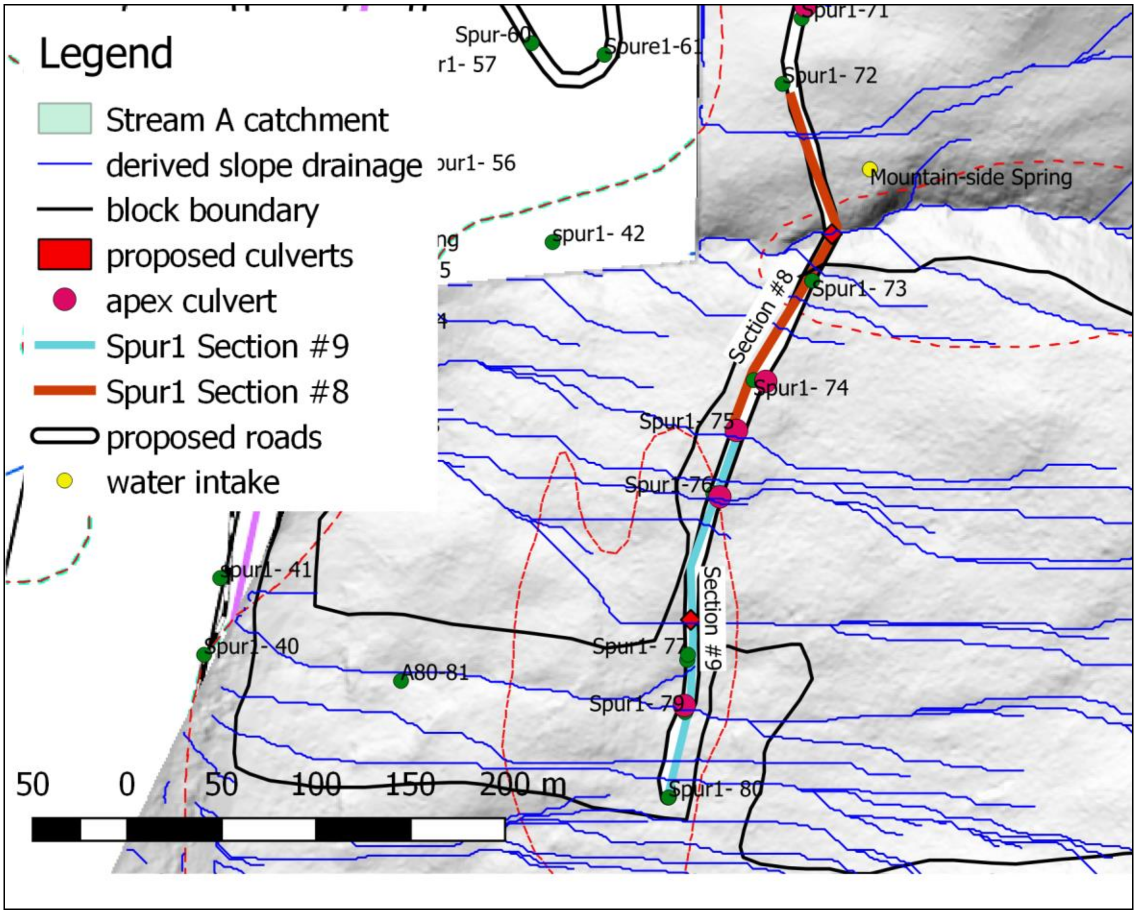
Figure 11



Section 8: (Figure 12) This portion of the road crosses the middle reach of Stream A, which is the likely source for the "springs". Mountain side spring is plotted here but was not noted during the field assessment and is likely downstream at station 1-42. The approach to the stream crossing is on 45% or less gradient slope underlain by silty rubble. The rubble gully side slopes are 75 to 85% 3m high and directly connected to the creek (V-shaped). The stream gradient is 30%, there is no evidence of recent or historic debris flows.

Section 9: (Figure 12) The proposed road crosses 45% slope with small shallow swales underlain by blocky rubble and decomposed (silt) rock.

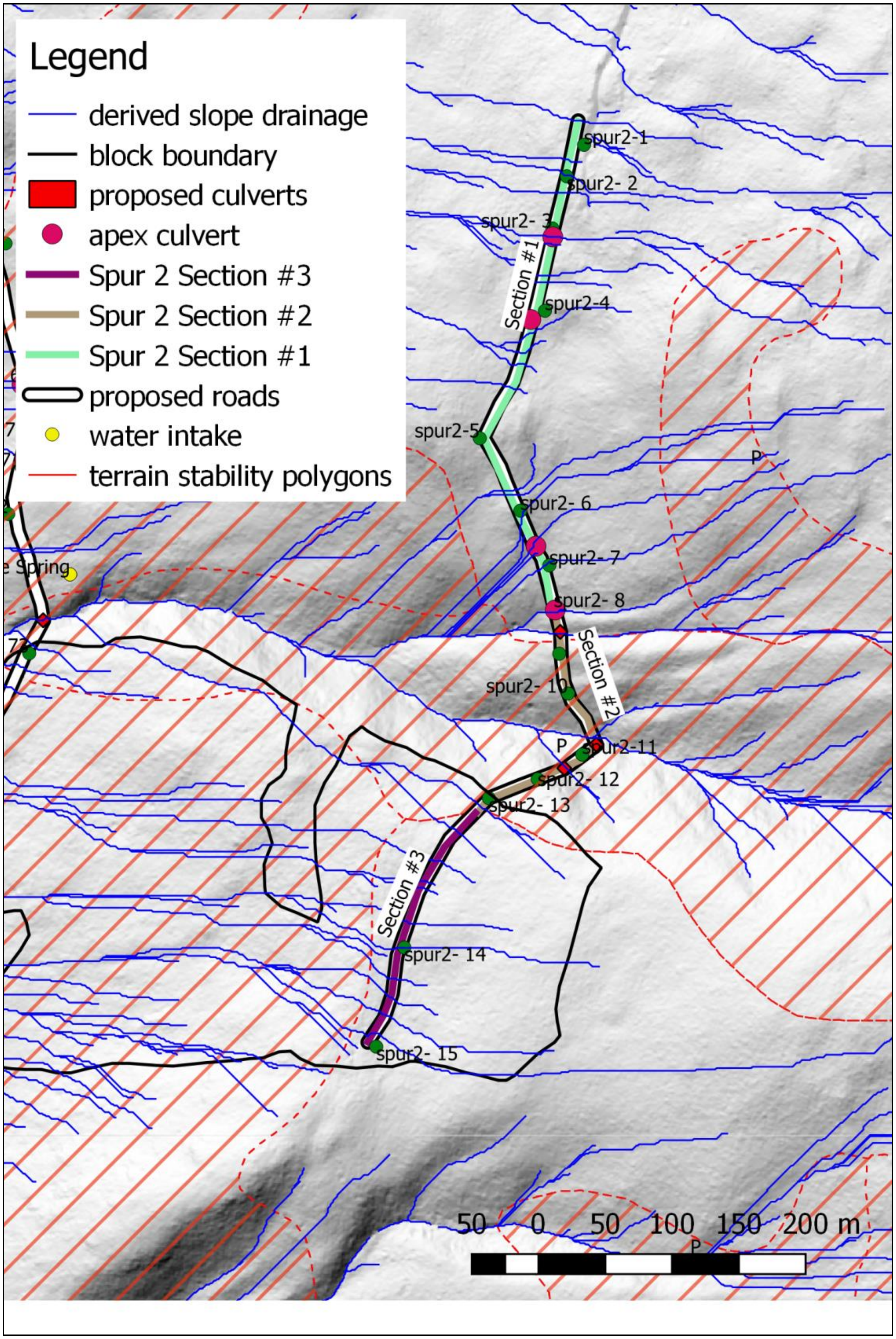
Figure 12



Spur 2:

<u>Section 1</u>: (Figure 13) This section of the proposed road is predominately underlain by a veneer to blanket of non-cohesive, loose, silty- sandy angular gravel (USCS GM) with occasional short rock steps. The angular to subangular gravel content ranges from 60 to 80%. It is likely that much of the road will be excavated at least partially into rock. The slope traversed by the proposed road has a slope gradient of 50% to 65%. There is no evidence of historical instability.

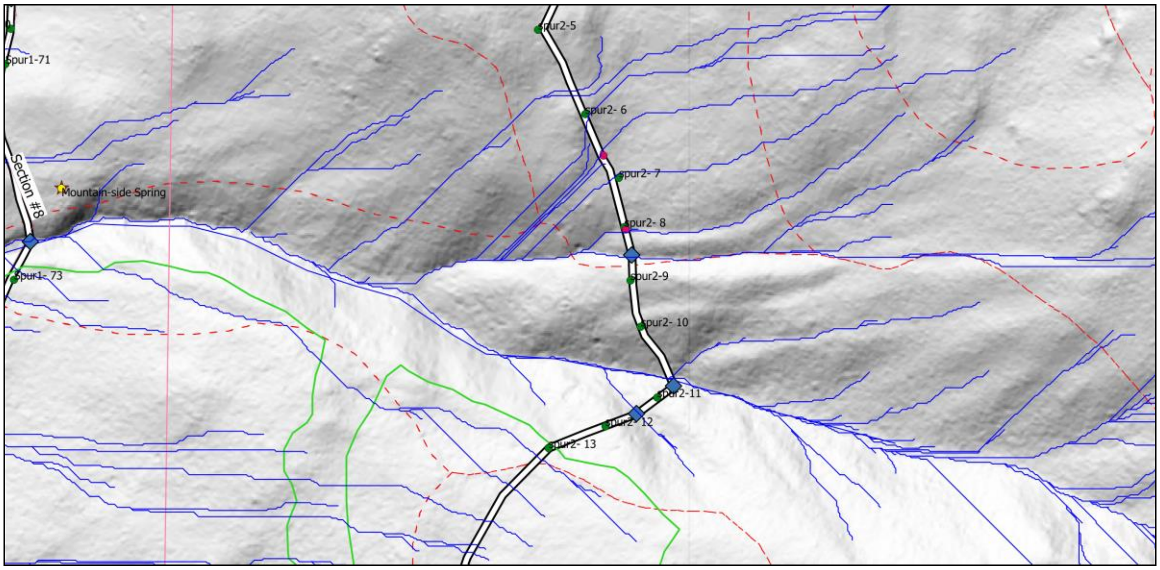
Figure 13


Legend
derived slope drainage
block boundary
proposed culverts
apex culvert
Spur 2 Section #3
Spur 2 Section #2
Spur 2 Section #1
proposed roads
water intake
terrain stability polygons
spur2-1
spur2- 2
spur2- 3
Section #1
spur2-4
spur2-5
spur2- 6
spur2-7
spur2- 8
Section #2
spur2- 10
spur2-11
spur2- 12
spur2- 13
Section #3
spur2- 14
spur2- 15
Spring
P
50 0 50 100 150 200 m

Section 2:

(Figures 13 and 14) The road crosses two main gullies and several secondary swales and associated interfluves. This results in a long section of road within the “gully system” crossing through interfluves and gullies.

Figure 14



Just prior to the northern gully, on 65% gradient slope, the proposed road crosses a small open swale (site spur 2-8) with rock exposed at the bottom. There is no evidence of recent surface flows. Just “downstream” the slope gradient increases to 90%.

The northern gully (spur2-9) has 3m high 85% gradient side slope underlain by silty sandy rubble. The gully gradient is 60%, there is no obvious stream channel and no evidence of debris flows.

The road than crosses an 85% gradient, wide interfluve (with a broad swale), soil pits give 95% coarse fragments, (rock is likely close).

The road then crosses just upstream of the junction of the main gully and a secondary swale just to the south. The gully side slopes are 85 to 90% and 3 to 4 meters high. The south side slope is underlain by silty sandy well graded sub angular gravel. The gully has a wide flat bottom, the gradient is 55% and there is no trim line. Rock is exposed near the top of the south side slope. The proposed road then crosses the nose of an interfluve (-

85%/+65%) underlain by subangular gravel and into the secondary swale then onto a 70% gradient slope underlain by sandy silty colluvium.

Section 3: (Figure 13) The proposed road exits the gully system (block boundary) onto an open 55 to 65% gradient slope underlain by silty sandy gravel.

5. Implications, Recommendation and Risk Analysis

Proposed Harvesting: Timber harvesting will likely result in a short-term increase in slope drainage. There is no evidence of historic instability on this slope. Timber harvesting will not significantly increase the low likelihood of landslide initiation.

Springs: The source of Danielle and Mountain Side "springs" is likely hyporheic flows associated with "Stream A". The proposed harvesting does not significantly overlap the surface catchment for the stream and should have a minimal impact on the quantity, quality and timing of the flows.

Roads: Unless otherwise specified, there is a low likelihood of landslide initiation with conventional road construction. Most of the slope is predominately underlain by a veneer to blanket of non-cohesive, loose, silty- sandy angular gravel (USCS GM) with occasional short rock steps. The angular to subangular gravel content ranges from 60 to 80%. The angularity of the gravel increases the soil strength, the long-term angle of stability is estimated to range between 38^o to 45^o depending on the percentage of coarse fragments and the soil moisture conditions.

Proposed additional culverts/drainage concerns:

Spur/section	Station	Culvert	note
Spur1/section 1	Spur 1-23	450	Recent forest floor scour
Spur 1/section 2	Spur 1-31		Sinuous path, check after road cut to see if sub surface flows
Spur 1/ section 2	Spur 1-32		Treat as GoS, check after cut to match drainage on ROW.
Spur 1/ section 4	Spur 1-53		Check after construction for intercepted subsurface water (deactivation).

Spur/section	Station	Culvert	note
Spur 1/ section 5	Spur 1-57		May require culvert, check after construction.
Spur 1/ section 5	Spur 1-60		Likely deeper sub-surface flows, check after construction (deactivation)
Spur 1/ section 6	Spur 1-62	450	Match lower lift of road
Spur 1/ section 6	Spur 1-64	450	Levee and debris.
Spur 1/ section 6	Spur 1-66	450	Top of draw.
Spur 1/section 7	Spur1-69	450	Eroded channel.
Spur 1/section 7	Spur 1-70	450	Swales
Spur 1/section 7	Spur 1-71	450	Swale
Spur 1/section 8	Spur 1-74	450	“wet” swale
Spur 1/section 9	Spur 1-75	450	Swale before gully slope.
Spur 1/section 9	Spur 1-76	450	swale
Spur 1/section 9	Spur 1-79	450	Swale, washed rock upslope.

Spur 1:

There is a low likelihood of landslide initiation along the proposed route, road will not significantly increase the low likelihood of landslide initiation.

Section #1: This section of the road traverses the transport/deposition zone of upslope-initiated debris slides/flows. There is no private lands downslope, the powerline is upslope, and there are no intakes in the vicinity. There is a low likelihood of landslide initiation along this section of road. This section of the road is very low hazard.

Table 5.2. Matrix for determining Hazard rating.

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Selected Elements		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

<u>Section #2:</u> South end of section (Spur 1-32) treat as GOS, check drainage after road cut or match cross-drains to ROW locations. There is a low likelihood of landslide initiation. There is no private land downslope and the powerline is upslope. This section of the road is a very low hazard.

Table 5.3. Matrix for determining Hazard rating.

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Selected Elements		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

<u>Section #3:</u> This section of the road is on a bench upslope of ancient slumps and deep gullies formed on a terrace scarp. This section is also downslope of the fan associated with stream A. Minor erosion of the ROW road and fill slope is the only indicator that flows from stream A cross the bench. Cracker Spring is mapped at the north end of this section but was not noted in the field, it is likely that the location is mis plotted and is actually at station spur1-43. Danielle spring is mapped at the south end but is likely at site upstream of section 4. Neither springs should be impacted by this section of the road.

Private land is located downslope of portions of this section at the base of the terrace scarp which for most of the slope has short a >20° apron along the toe. A slide off the terrace scarp below the road section could impact the private land but is not likely to reach structures which are isolated from the slope by flat ground. There are no reported debris slides related to the RoW along this portion of slope. This section of the road should be treated as Gentle over Steep (GoS), drainage control is the primary management strategy. Drainage control as recommended in this report will result in a low likelihood of road related landslide initiation.

Table 5.4 Likelihood of a Debris slide or Sediment Reaching or Affecting Private Land.

Relative Rating of Likelihood of a Landslide Affecting elements	Description of Activity and/or Geomorphic Conditions
High	Landslide debris and/or sediment delivery would reach or directly affect elements considered for risk.
Moderate	There is a run-out slope of<20° gradient and <200 m in length, or another terrain configuration which could possibly intercept or dissipate a potential landslide debris and/or sediment from erosion (e.g. irregular or benchy rock-controlled terrain) below and between the development and the elements considered for risk.
Low	Landslide debris and/or sediment from soil erosion is unlikely to reach or affect the elements considered for risk at the time of an event. There is a run-out slope of <20° gradient for >200 m, or another terrain configuration which would likely intercept or dissipate sediment or landslide (e.g. irregular or benchy rock-controlled terrain), below and between the development and elements considered for risk.

Table 5.5. Matrix for determining Hazard rating.

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Private Land		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

Table 5.6 Matrix for determining partial risk for private property.

		Consequence
		High
Hazard	**Very High**	Very High
	High	Very High
	Moderate	High
	Low	Moderate
	Very Low	Low

The powerline infrastructure coincides with the road location or is upslope of the road, this section of the road poses a low hazard to the powerline.

Section #4: This section of road crosses the fan, inactive channels (overflow) and the active channel of stream A. This section of the road should be checked after construction to see if sub surface water is intercepted and diverted. If evidence is noted, than cross-drain structures should be constructed at those sites. After operational use (hauling) cross-ditches should be constructed at the inactive channel sites. The PoD's are in the vicinity of this road section, the actual locations are not definitively known. It is assumed that Danielle Spring location is upslope of the road between sites 1-55 and 1-56 which is upstream of this section and should not be impacted. This section of road is upslope of a broad bench on which the powerline is located and separates this section from the slope to private land. The main objective is drainage control, if the recommendations contained in this report are implemented there is a low likelihood of landslide initiation and a very low hazard to elements at risk.

<u>Section #5</u>: This section of the road is located on moderate to gentle slopes upslope of a rock/gravel step to the powerline. There were no obvious surface flow features. After operational use (Hauling), cross-ditches should be constructed at swale locations. If these recommendations are followed there is a low likelihood of landslides and a very low hazard to elements at risk.

<u>Section #6</u>: There are several "swales" and rubble levees (50 to 75 years old) along the slope here. This is an erosion/deposition zone from upslope. There is a low likelihood of landslide initiation. This section of road is separated from the RoW and private land by low gradient slopes, there are no PoD's in the vicinity. The hazard to elements at risk is very low.

<u>Section #7</u>: There are several swales and eroded channels that require culverts. There is a low likelihood of landslide initiation. Similar to section 6, there is a very low hazard.

<u>Section 8</u>: This section includes the stream crossing. The side slopes are underlain by silty rubble with 75% angular fragments. The long-term angle of stability is likely around 45^o (100%), rock is likely within 1m of the surface. The fill slope should be ~ 85% (1.2:1), the cut can be 1:1 in colluvium and 0.25:1 in rock. Use coarse fill (>0.25m) to fill through bottom of gully (bottom subgrade), to reduce sedimentation use coarse fill (>0.25cm) on the outside of the fill. If these recommendations are implemented, road construction will not significantly increase the low likelihood of landslide initiation. If a slide were to occur the slide would enter "Stream A" gully at less than 45^o, the channel gradient here is 30%, it is likely that a slide would progress to a debris flow down the gully. Upstream of section 4, the gully discharges onto a broad fan with a gradient is less than 10^o, a debris flow would terminate on the fan. There is a moderate likelihood the debris would reach the PoD's on the fan. Although the vulnerability of the intakes on the fan is unknown, it is likely that they would sustain significant damage. The debris flow would not impact the powerline or private land.

For the PoD's the Risk analysis is as follows:

Table 5.7. Matrix for determining Hazard rating.

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Selected Elements		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

Table 5.8: Water quality and water supply infrastructure

Consequence	***Effect***
High	Long-term or permanent deterioration of water quantity/ quality. Complete destruction of water intake structures.
Moderate	Short-term deterioration of water qualityquantity, repairable damage (1 week) to water intake structures.
Low	Short-term (less then 1 week) deterioration of water quality/quantity, "damage" to water intake structures repairable during regular maintenance.

Table 5.9 Matrix for determining partial risk.

		Consequence		
		High	**Moderate**	**Low**
Hazard	**Very High**	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low
	Very Low	Low	Very Low	Very Low

There is a moderate risk to water infrastructure.

<u>Section 9</u>: This section of the road is underlain by blocky rubble and decomposed bedrock. After construction check swale locations to determine if water is intercepted, if water is noted, construct cross-ditches at those locations. The slope below this section is steep with rock steps to the bench where the powerline is located on the outer edge, the bench (~ 200 m > 15%) also separates the steep slope from private land. This section of road poses a very low hazard to elements at risk.

Spur 2:

The proposed road is located on stable terrain underlain by non-cohesive, loose, silty-sandy angular gravel (USCS GM (angular) Loose – Dr 20-40%). The internal angle of friction (the slope that is stable, Ø) is estimated to be 43^{o} (93%). The gully side slopes are 85% to 90%.

<u>Section 1</u>: The fill slope should be ~ 85% (1.2:1), the cut can be 1:1 in colluvium and 0.25:1 in rock. If these recommendations are implemented road construction will not significantly increase the low likelihood of landslide initiation. There are significant portions of the slope below this section that are less than 20^{o}, landslides would pose a low hazard to elements assessed for risk.

<u>Section 2</u>: For much of the road it is likely that that rock will be encountered within 1m of the surface. The cutslope can be 0.5:1 in rock, 1.1:1 in gravel. The fill slope should not exceed 1.2:1.

For the gully crossing Use ¾ bench to enter the “north” gully, push excess forward to fill gully. Push through interfluve to fill second main gully, ¾ bench out of gully, push through interfluve to fill secondary swale, use hoe to key fill into slope. If these recommendations are followed road construction will not significantly increase the low likelihood of landslide initiation. If a slide did occur it would enter the gully system at less than 45^{o}, the stream gradient exceeds 10^{o}, debris slides would transition into debris flows down the gully system. The debris flow would likely reach the lower fan below the upper lift of Spur 1. The Water PoD’s are located on the lower fan and may be damaged. The debris flow would likely terminate on the fan well above the power lines and private property.

For the PoD the Risk analysis is as follows:

Table 5.10. Matrix for determining Hazard rating Springs

		Likelihood that the Landslide and or Sediment Delivery Will Reach or Otherwise Affect Selected Elements		
		High	**Moderate**	**Low**
Likelihood of Occurrence of Landslide	**High**	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low

Table 5.10: Water quality and water supply infrastructure.

Consequence	*Effect*
High	Long-term or permanent deterioration of water quantity/ quality. Complete destruction of water intake structures.
Moderate	Short-term deterioration of water qualityquantity, repairable damage (1 week) to water intake structures.
Low	Short-term (less then 1 week) deterioration of water quality/quantity, “damage” to water intake structures repairable during regular maintenance.

Table 5.11 Matrix for determining partial risk Water Supply infrassructure.

		Consequence		
		High	**Moderate**	**Low**
Hazard	**Very High**	Very High	Very High	High
	High	Very High	High	Moderate
	Moderate	High	Moderate	Low
	Low	Moderate	Low	Very Low
	Very Low	Low	Very Low	Very Low

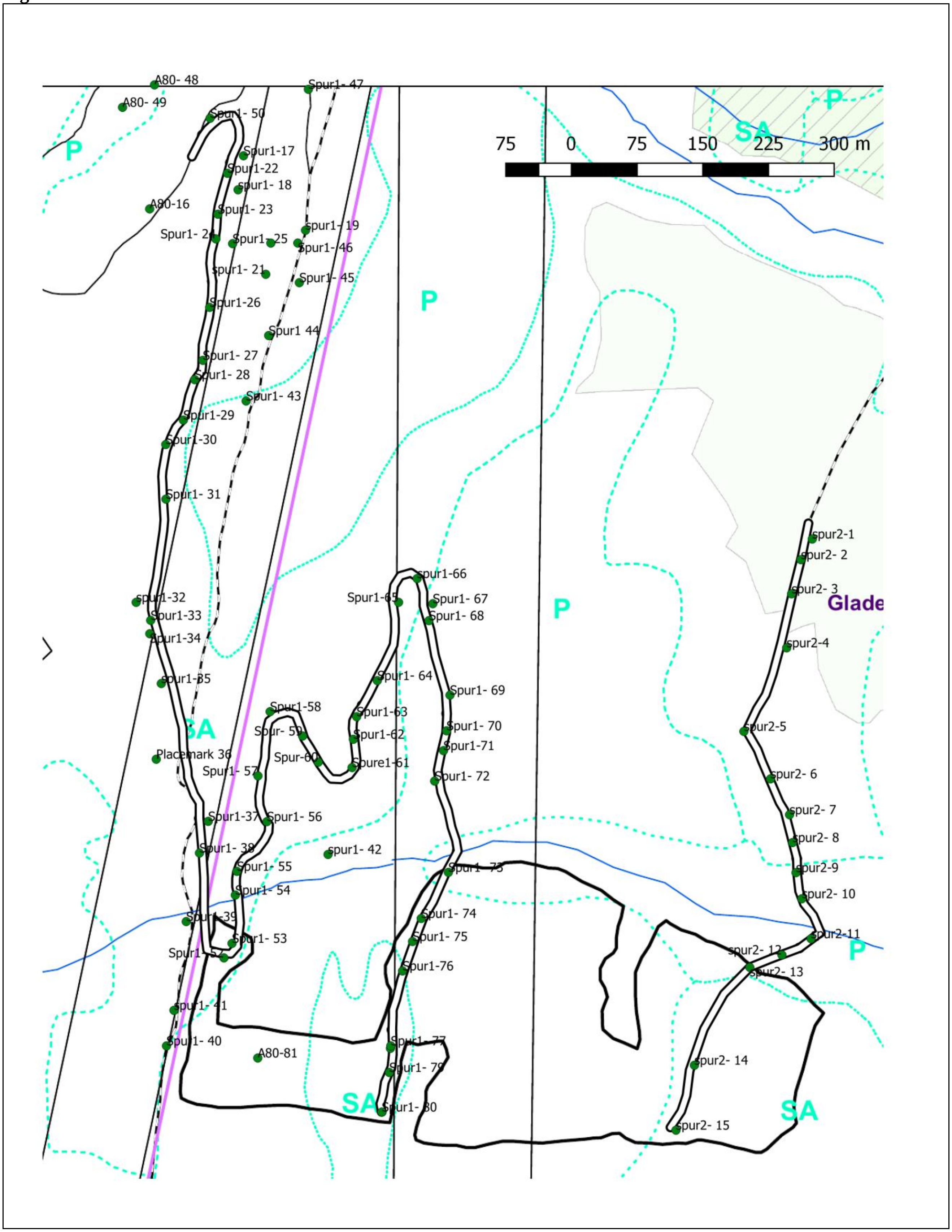
There is a moderate risk to Water Intke infrastructure.

Section 3: The proposed road exits the gully system (block boundary) onto an open 55 to 65% gradient slope underlain by silty sandy gravel. There are significant slope sections of less than 20^{o} downslope, there is a very low hazard.

Respectfully Submitted,
Apex Geoscience Consultants Ltd.

Will Halleran P.Geo.

Figure 15


75 0 75 150 225 300 m
P
SA
Glade
A80- 48
A80- 49
A80-16
A80-81
Spur1- 47
Spur1- 50
Spur1-17
Spur1-22
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Spur1- 23
Spur1- 19
Spur1- 25
Spur1- 46
Spur1- 21
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Placemark 36
Spur1- 57
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spur2- 3
spur2-4
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spur2- 6
spur2- 7
spur2- 8
spur2-9
spur2- 10
spur2-11
spur2- 12
spur2- 13
spur2- 14
spur2- 15

Appendix 1 notes.

Section	Title	Description
Section 1	spur2-1	poc, lots of rock on road to here, sections of fb, here55%.
	spur2- 2	+50/-65%, upslope of -80% small rock step, close to rock, angular rubble 75%, silty sand 25%. tuff outcrops.
	spur2- 3	small broad swale, bench below, +/-55%, blue flag culvert.
	spur2-4	just off short 75% rock step, large bench below, start on colluvial apron on bench 55%, blocky, rock swale here, culvert blue.
	spur2-5	near end of broad bench, rock benches, here back good spoil site, looks like small bluff about 40 m downslope, -30%+20%.
	spur2- 6	Crossed a short rock step 50 to 65% rubble veneer between benches, here pop up on bench.
	spur2- 7	start on 60% slope, just back bench seemed like ancient fan, there was a "swale" at start, followed to 60% break small outcrop, could have seasonal flow, bench underlain by veneer of sandy silty gravel, at edge here pit gives 15cm of silty sand then small angular fragments, likely rubble at depth, small sharp swale just ahead.
Section 2	spur2- 8	small open swale before deep, gully, bm soil throughout but no trees in bottom of swale but large vets beside rock in base, -65%+60%, just upslope of 90% gully side slope, go to gully.
	spur2-9	through gully, colluvium side slopes 85% 3m high, 60% gully gradient, large vets in bottom, into 60% interfluve, sand 25% silt 15%, sub angular frags 60%., fill through gully, will likely cut through interfluve, broad swale ahead as we head into broader draw.
	spur2- 10	crossed 55% swale onto 85% side slope, pits give 95% angular rubble well graded
	spur2-11	crossed gully, gully 60% gradient, north side slope 85%, mostly sandy silty colluvium, no trim, southside 90%, rock at lip, interfluve + 60/-85 (snout), pits give at least 20cm of silty sand than small sub angular frags 55%, likely deposit 9n rock minimize cut on south side, fill through gully, 3/4 bench on north side, use excess to push forward to fill gully.
	spur2- 12	onto 70% slope, another deep swale ahead, road crossed snout of interfluve, onto 85% side slope, gully was wide with 55% gradient, push snout to fill gully, depending on material may hit rock, otherwise sandy silty colluvium, construct pilot trail below grade to key fill into, depending on design may require significant fill. pit gives 20cm of silt 35% sand 25%, sub rounded c.f. 30% 20cm, bc sand 15%, silt 5%, sub angular packed rubble 80%.
	spur2- 13	at boundary off 75% slope onto 65% slope, so here back key in fill and 3/4 bench to fill through gullies, tree churns did not rip up rock so possible material is 65% c.f. silty sand. here 65% slope same material but looks like slope decreases ahead. ancient shallow debris slide scars, likely associated with the adjacent gully system prior to formation.
	spur2- 14	To here slope mostly 55% or less, silty sandy gravel, may hit subsurface water, here entering broad bench possible receiving site.

Section	Title	Description
	spur2- 15	pot, broad bench, yew

Section	Title	Description
	A80-16	eroded fill below gully. Erosion in gully below road, possible debris flow scour upstream
	A80- 48	70% slope, silty sandy gravel, deeply rutted old trail at top, old trail cuts slope about 20m down, wash here below silt fence at top. rock plot, to north grassy recontoured road? went below, small trail near foot of slope.
	A80- 49	just below break, +70/-85%, debris slide, 25 years old? recurved tree on crown, no obvious erosion to crown, on 80% slope. some kind of bench below, just before gully which is much more open here, so sandy to silty gravel. lots of trenches on flats.
	A80-51	rock
	A80-81	rock step swale. small bluffs adjacent
Section #1	Spur1-17	Debris slide scarp, on 80% slope just below powerline, at top washed gravel, 5m wide1m deep, enlarges to 7m wide 6m down on 70% slope, then scours to 50% slope (where proposed road is) at least 10 yrs. old, looks like lower gradient just up slope, no obvious recent scour, likely related to upslope power line access road. Developed in loose sandy gravel, silt 20%, sand 15%, sub rounded to angular well graded gravel 65%. Old eroded channel heads upslope. adjacent to larger older slide (25 to 30 yrs.) just to south. go upslope to see why.
	spur1- 18	older slide is here.
	spur1- 19	on upper road, just into rock, lower road less used, deeply cross ditched, here shallow reverse waterbed no ditch, some erosion here, but I think drainage has been altered since the slides.
	Spur1- 20	crossed a number of cross-ditches this ditch has recent erosion on fill and cut side, small rock face on uphill side, trail below deep cross ditch and eroded fill. cross-ditches appear to be just placed at regular intervals not at drainage locations.
	spur1- 21	Old eroded gully off fill.
	Spur1-22	back on proposed road, -35%/+45%, between slides, some scour but also deposition, noted old wash between slides, also old brushed trail directs down from roads to scarps, likely originally directed water to crowns and scarps.
	Spur1- 23	on 45% slope, lots of deposition piles, scour and erosion, here recent forest

Section	Title	Description
		floor scour and small debris piles, culvert.
	Spur1- 24	natural 3m deep v gully 75% side slopes, scoured to rock at bottom side slopes mix of silty gravel and angular colluvium, recently (5yrs) hosted a small debris flow, trim line 1.2 m, debris stuck behind trees, 2m rock face just up at head of gully on edge of power line cut, noticed broad, scour entering the gully just back. looks like slide scoured off rock at north side then entered top of gully, small amount of debris on trees up to 7m north of gully, coincides with noted scour. downstream rock shelves to lower road, 40% overall gradient but steps and shelves will complicate transport, mostly scour but most trees remained standing. Scars on trees indicate at least one earlier flow 25yrs? on other side, -65%/+35%, steep slope is gully side slope than 45%, fill through gully. more small debris deposits on slope, gully has cut through silty gravel to rock, may have to anticipate additional flows.
	Spur1- 25	rock face, scour over it and to north.
	Spur1-26	crossed 25% slope, multiple debris deposits and older slides off rock step just upslope at base of power cut, so material washed off rock, just past old debris flow swale/shallow gully, minor wash, no obvious trim line, carries up into power line row, here+/-45%, thin layer of rubble on silty gravel. on previous section there may be short term water flows due to rock not allowing water to go subsurface, review in freshet, culvert marked on map, but GPS doesn't align.
	Spur1- 27	to here generally less than 50% slope, "rock step" (or at least a steep convex slope) along bottom of row just ended, here on 55% slope, silty gravel, 4m V shaped gully, 80% side slopes, no evidence of debris flow.
Section 1	Spur1- 28	gully had 40% gradient, moderately compact silt 25%, sand 10%, sub angular gravel 65% inside slope, poor bm, on other side, +55%/-40%., steep road gradient from here I get about 20%.
Section 2	Spur1-29	just onto +65%/-50%, to here 60/45, silty gravel, strange feature just back may have been old trail.
	Spur1-30	onto small rock bench, +30%/-40%, 10m from -55% coarse colluvium, likely rock controlled careful of drainage, but coarser than where the slides occurred. station 9.
	Spur1- 31	here +/-25% foot of steeper rock face row, likely rapidly drained , just back along alignment -45% with strange shallow sinuous paths, could be old skid drags, no scarred trees or soil disturbance, might be shallow sub surface water due to rapidly drained slope above, check at pilot trail, pockets of silty sandy gravel and rock, here up 9n bench likely shallow to rock, drainage is difficult to determine, but slides before started on greater than 70% slopes. checked slope below, 55% step, pit gave 20cm of silt 60% sand 40%, then started to dig up small rounded pebbles, rock outcrop sticking out of slope, so step is rock controlled draped with sandy silt to silty gravel. careful of drainage, slope flattens out below.
	spur1-32	road is up on terrace top, pits give sandy silt, occasional rubble, likely rock controlled, walked along terrace scarp face, large flat below, slope increases to 65% in places, pits give mostly sandy silt with some gravel. likely ancient

Section	Title	Description
		wash, here ancient slump scarp, about 15m into terrace, 3m deep 75% scarp 10m across, at slope break (about 3m below top of terrace) bedrock is exposed in lip, slope below about 60%, so it appears to be about 3m of sandy silt to gravelly silt over rock, slope face likely rock controlled, treat as go's, lower slope sensitive to drainage, large bench below will limit run out, need to check for drainage after cut or match row road.
Section 3	Spur1-33	by slump, station 12. edge of powerline row, roadway up slope.
	Spur1-34	flags say jct with boundary, here on edge of second larger slump with trail running out of it.
	spur1-35	lower road skirts head of slump which is within the row. road in gravelly silt with rubble.
	Spur1-37	exiting road crosses shallow gully here, quickly deepens downslope, no culvert, cut side even with bottom of gully, some erosion of fill. minor erosion of road. Road went along side gully, major gully likely related to upslope draw on hill shade. possibly slumps occurred prior to gully formation due to saturated bench.
	Spur1- 38	surgical material has changed to fine as d 15%, silt 10% angular to rounded gravel 75%.
	Spur1-39	head of gully starts just below road, nothing upslope. exiting road constant grade through slightly out sloped no erosion.
	Spur1- 40	past north splat here head of gully just at road, no obvious erosi9n on road or feature upslope.
	spur1- 41	possible topo low point but no erosion, southern splat just below road, a tv trail down.
	spur1- 42	water intake.
	Spur1- 43	road crosses gully, wet,
	Spur1 44	low point, water has flowed off, cuts in silty gravel 90% dry.
	Spur1- 45	high point, shallow cross ditch minor erosion, swale upslope.
	Spur1- 46	rock swale, water crosses road in very shallow xd, only partially working, looks like it used to flow down road, now much of it flows, down road about 12m to second shallow xd, may be source of debris flow. steep road section. both feed cross-ditches on lower road so stay split, might be why debris slide from north, those lower cross-ditches were the ones noted to be eroded fill.
	Spur1- 47	road crosses face of snag gravel 100% cut, here eroded road.
	Spur1- 50	debris slide debris
Section 4	Spur1- 52	blocky rubble colluvial cone, steeper rock upslope, +/-45%
	Spur1- 53	small swale at edge of cone, then small levee (lobe) then broader swale, check after construction for evidence of flows, features likely paleo.
	Spur1- 54	dry swale, blocky colluvium over sandy gravel, ancient fan cone, abandoned channel off flats upslope, not the current stream channel. does run into current channel on flats above (apex of fan) so could take high flows, but no current evidence of flows.
	Spur1- 55	just crossed 45% rock nose onto broad zone, likely subsurface, note wash

Section	Title	Description
		zones, station r19 start of pod crossing, just slope concrete small water boxes and old metal drums, can hear water flowing in boxes, plastic pipes joining.
Section 4	Spur1- 56	crossed creek, no obvious channel. entrenched u shaped suggested debris flow or human work, lots of organics and sand silt deposited onto and behind small woody debris, all covered in leaf litter, fan is disturbed by humans hard to get natural profiles, 30% slope, here on cat trail to intake, broad swale, ancient debris slide upslope, silty sandy gravel, mostly sub angular well graded 75%, no evidence of flows on trial 55% slope.
Section 5	Spur1- 57	shallow sandy colluvium over rock, rock outcrops sticking out, +60%/-45% 5m -60%, outcrops at break. broad shallow swale. then up small swale parallel to slope, up into broad bench fan, swale on south side, likely ancient fan related to present creek, elevated, may need culvert check after construction.
	Spur1-58	switch, to here on 15% bench underlain by gravelly sand to sandy gravel, just past switch, excavated road along power line deep gravelly sand, downslope 70% slope cut by the road, gravelly sand likely draped on rock or fan/delta face into lake or against ice.
	Spur- 59	from top of switch along +70%/-55%slope above the fan, 8m up to flats, underlain by loose silt sand 20cm, then sandy silt with sub angular well graded gravel up to 65%, Kame terraces? likely variable.
	Spur-60	at station 24 the proposed road left the slope and started cross 25% gradient slope with old channels swales, off flats upslope, then into what appears to be broad fan with ancient channels. there may be sub surface flows through the flats, but likely very deep, so currently lots of complexity, need to make sure road doesn't concentrate and reroute (decrease downslope delivery time).
Section 6	Spur1-61	top of switch, +60% rubble colluvium apron at base of 80% likely rocky slope, -30% swales sandy gravel, from here steep slope eagles away, rock angles up colluvial apron to second "bench”. So likely rapidly drained upper slope made swales on gravel slope, but no sign of recent flows.
	Spur1-62	swale from upslope that seems to run along the base of the steeper slope, small rock ridge separates it from large bench ahead, apex culvert here matches lower road, likely dry. +/-45%. sta.26
	Spur1-63	around rock nose onto broad bench, + 35% 40m to upper steeper slope, bench is 10%.
	Spur1- 64	strange 0.7 m high rubble levee, shorter ones around on 15% fans, could be manmade, there are others subtle swale upslope, between 75 and 50 yrs. old, trails throughout as well, then onto base of 45% rubble apron, cougar or bear kill cannot wait around.
	Spur1-65	cross mouth then heads up north side of deep sub parallel draw, trail up middle, culvert mouth.
	spur1-66	crossed draw, up draw ends at small rock ridge 25m up, on this side very broad swale angles up, culvert here to direct flow into swale, in swale pockets of well washed coarse sand gravel and blocky colluvium, rock

Section	Title	Description
		controlled, cross blocky swale onto the hillslope.
	Spur1- 67	onto short 80% slope, just down from 65%, -60%, silt 10% angular rubble 90%, likely rock nose.
Section 7	Spur1- 68	off steep slope onto +/-65% slope, angular rubble 85% silt 15%.
	Spur1- 69	strange feature, eroded channel (bottom is small blocks large rubble no fines, lots of open spaces) or linear trench runs up hill just past swale on what appears to be a debris cone 65%, eroded channel stepped 0.5m deep 1m wide, rubble, may be relat3d to levees not3d below, culvert here, looks about 50 to 25 yrs. old.
	Spur1- 70	culvert just passed in middle of a couple swales, no obvious channels, here just off colluvial slope onto sandy gravel, loose, sand up to 25%, silt up to15%, slope,20m up to gentler slopes (bench) 20m down to bench, here +/-65%. broad swale ahead.
	Spur1-71	swale, to here rubble to blocks, scattered on surface, some against trees, loose gravelly sand, 65% slope, looks seasonally wet. culvert. tip of bench 12m upslope, head out into steeper slope. Bench may drain through the swales.
	Spur1- 72	off 75% slope of loose gravelly sand to sandy gravel, into 55% swales slope, break to bench angels away.
Section 8	Spur1- 73	approaching creek on mostly 45% or less slope, rubble content of soil increases to 75%, creek confined by 75 to 85% m high side slopes directly connected to creek, no evidence of recent debris flows, side slopes mostly rubble, but likely up to 25% silty sand, fill through. channel gradient 30%. to avoid sedimentation, use coarse fill as bottom subgrade. road is adverse from crossing so water will flow away, good for sedimentation, just on other side ancient shallow debris slide then swale. 45% to 50% slope.
	Spur1- 74	wet "swale", smaller semi arcuate rise on south, swale from upslope and sub parallel drains through here, elderberry, willow, here 45%, -60% downslope, rock outcrop at lip. culvert.
Section 9	Spur1- 75	second subtle swale +/-45%, also connected upslope and drains bench just upslope, culvert.
	Spur1-76	tree churns pullup angular blocky rubble and decomposed rock easily crumbled to silt. another feature, likely these features take upslope water as it shifts on the benches, culvert
	Spur1- 77	to here on rock bench with lip just below, here on to 50% to 45% swales silty rubble slope. after construction check swale locations. large flats below.
	Spur1- 79	swale, floored in rubble and blocks, washed outcrop upslope at slope break, here 45%, large bench below, culvert. slope is coarse rubble blocky colluvium.
	Spur1- 80	pot, +65%/-55%, rubble with rock lips.