Appendix 10-B

Terrain Stability, Hazard, and Constraint Mapping:
Murray River Coal Project

Terrain Stability, Hazard, and Constraint Mapping

Murray River Coal Project

Prepared for:

ERM Rescan

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SCL Project #14-998

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Attention: Mr. Jason Rempel

Subject: Terrain Stability, Hazard, and Constraint Mapping
Murray River Coal Project

At the request of ERM Rescan, Sitkum Consulting Ltd. has completed terrain hazard and constraint mapping with slope stability interpretations for a portion of the Murray River Coal Project study area near Tumbler Ridge, B.C. The terrain hazard and constraint mapping was completed for the Infrastructure Investigation Area (IIA) as well as the Extent of Underground Mining Area (EUMA). This was accomplished by applying ratings to previously mapped terrain polygons provided by ERM Rescan. Field work was carried out as a part of the project, with a Terrain Survey Intensity Level C (TSIL C) achieved in the IIA, and TSIL D achieved for the remainder of the study area.

The classification symbols used are consistent with *Terrain Classification System for British Columbia* (Howes and Kenk, 1997) where suitable, and where project specific symbols have been applied they are defined in the legend within this report. The slope stability classification system for the terrain stability mapping is consistent with the *Mapping and Assessing Terrain Stability Guidebook, Second Edition* (BCMoF 1999). The terrain hazard and constraint mapping classification system is defined within the attached report.

The discussions and recommendations presented in this report are based on digital air photo interpretation using PurView in ArcMap, selective field checking by means of foot and vehicle traverses, as well as additional background information. As slope stability is strongly influenced by subsurface conditions (e.g. subsurface hydrologic conditions) which may not be apparent from surface observations (air photo or ground inspections) and the timing/severity of natural events (e.g. extreme weather events, earthquakes, forest fires) which are unpredictable, it cannot be guaranteed that no landslides will result in areas affected by development activities or in areas mapped as low hazard. This report has been prepared for use by ERM Rescan, which includes distribution as required for purposes for which it was commissioned. The mapping has been carried out in accordance with generally accepted geoscience practice. No other warranty is made, either expressed or implied.

We trust that the information above meets your current requirements. If you have any questions, or require further information, please do not hesitate to contact the undersigned.

Respectfully submitted,

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1 INTRODUCTION

Sitkum Consulting Ltd. (SCL) was retained by ERM Rescan to conduct terrain hazard and constraint mapping including slope stability interpretations for the Infrastructure Investigation Area (IIA) and the Extent of Underground Mining Area (EUMA) for the Murray River Coal Project.

The primary project scope was to:

- provide interpretations for terrain hazards and constraints, as well as slope stability classes, and apply them to previously mapped terrain polygons provided by ERM Rescan, and
- prepare a brief report summarizing the methodology, limitations, and key aspects of the mapping.

An understanding of terrain stability is important in resource development in order to manage risks to environmental and economic values as well as human safety. This level of mapping can be a useful tool to provide guidance for locating where more detailed geotechnical works may be required during project planning and operations.

Assessment of other potential geotechnical related concerns such as subsidence, seismic hazards, acid rock drainage/metal leaching potential, and snow avalanche hazards is beyond the scope of this work.

2 METHODS

The following sections describe the general methodology used for this project. Terrain hazard and constraint mapping does not have any provincial standards that apply; project specific criteria and methods have been applied based on common practices and professional judgment. Where applicable, this project has adhered to standard procedures for Terrain Stability Mapping in British Columbia *(Mapping and Assessing Terrain Stability Guidebook, Second Edition*[1]*)*. Where practical, the hazard and constraint symbols used are consistent with the *Terrain Classification System for British Columbia*[2].

2.1 Study Area

The study area is situated approximately 12 km south of Tumbler Ridge, British Columbia in the Rocky Mountain Foothills (refer to Appendix A, Figure 1 and 2).The study area has been defined as the EUMA and the IIA combined and is approximately 8000 ha in area. It is located on TRIM sheets 093P.005, 006 and 93I.095, 096.

2.2 Background Information

Available background information was collected and reviewed. This included the existing terrain mapping completed by Rescan, research papers on landslides in the general area, bedrock geology mapping, slope themed mapping, and site plans and layout.

Additional background information such as climate data, geology, surficial geology, soil development and a historical background was provided by Rescan in the report *Murray River*

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[1] BCMoF, 1999

[2] Howes and Kenk, 1997

Coal Project:2012 Terrain and Soils Baseline Report[3]. As this information has already been compiled by Rescan, it has not been included in this report to avoid repetition.

2.3 Labelling Convention and Criteria Development

Prior to commencing preliminary air photo interpretation, a project specific labelling convention as well as preliminary hazard, constraint, and terrain stability criteria were established. The preliminary criteria were developed based on knowledge of the geomorphological processes common within the mountain ranges of the British Columbia interior gained through research and experience. The labelling convention and hazard rating criteria also generally followed established standards with respect to terrain stability mapping and resource based hazard and risk analysis wherever practical. These conventions and criteria were slightly modified throughout the mapping process to best reflect the local conditions as observed during field work and to meet the specific project requirements.

2.4 Preliminary Mapping

Preliminary hazard and stability interpretations were made by Jen Shypitka, P.Geo., using stereo colour imagery (2005) models with PurView 1.2 in ArcMap 9.3.1 for the IIA in 2013, and PurView 2.0.1 in ArcMap 10.2.2 for the EUMA in 2014 (refer to Section 3.1 for a list of imagery used). The existing terrain mapping layer, TRIM contours and water features, a slope themed layer, a bedrock geology layer, and infrastructure site plan were also reviewed at this stage.

The intended final scale of the mapping is 1:15,000. When mapping in PurView, the study area was generally viewed at a scale ranging from 1:5,000 to 1:20,000.

A range of polygons were flagged for field checking, but the steeper slopes and those with hazard processes were specifically targeted.

2.5 Field Work

Field work was completed by Jen Shypitka over five days on July 4th through July 8th, 2013. Field work was carried out using a combination of truck and foot traverses. Field site locations are indicated on the 1:20,000 scale Terrain Hazard and Constraints Map in Appendix A (Figure 3). The first three days were mostly spent in the IIA, and the remaining two days targeted the steeper areas within the EUMA.

Information collected at field sites varied depending on the site characteristics and site type but generally included positional data (Garmin GLO GPS receiver), a brief site description, photograph(s), applicable hazard processes and associated rating, indicators of instability, stability class rating, constraint(s) (if applicable), soil drainage, and a brief surficial material description.

A total of 39 field sites were recorded within the IIA. A total of 100 previously delineated polygons make up the approximately 1490 ha mapped area. This results in approximately 34% of all mapped polygons being field checked (some polygons had more than one field site). This relates to a Terrain Survey Intensity Level C (TSIL C; refer to BCMoF 1999 for TSIL

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[3] Rescan, 2013

definitions) within the IIA based on the percent of polygons field checked.

A total of 30 field sites were recorded in the additional EUMA. Three hundred and six previously delineated polygons make up the approximately 6510 ha of mapped area. This results in approximately 9% of all mapped polygons being field checked and relates to a TSIL D.

2.6 Final Mapping

After field work was completed, all polygons within the study area were reassessed for hazard process and ratings, constraints, and slope stability class using the field data. The finalizing of all mapping throughout the study area was completed by Jen Shypitka, P.Geo.

2.7 Digital Capture - General

A shape file of the existing terrain mapping with new attribute fields for hazard, constraint, and slope stability interpretations was created. The applicable new fields were populated during the mapping process, and polygons with field checks were indicated by a field number (e.g. JS21) in the *FLDNUM* field.

2.8 Quality Assurance

Quality assurance mechanisms were incorporated throughout both preliminary and final mapping stages. Jen Shypitka, P.Geo performed all of the preliminary site selection and field work, followed by the slope stability and hazard and constraint mapping for all terrain polygons within the study area. The mapping criteria and a selection of preliminary and final mapping was reviewed by Tedd Robertson, P.Geo., Eng.L. to ensure consistency and quality. Checking of the mapping to ensure consistency was also completed using various colour themed regimes in ArcMap.

3 RELIABILITY AND LIMITATIONS

The following sections outline the reliability and limitations typically associated with a mapping project.

3.1 Reliability

Factors influencing the overall accuracy of the map include:

- the accuracy of the base mapping used;
- the accuracy of the terrain mapping line work used;
- the skill and experience of the mapper;
- the scale and quality of the imagery used;
- the type and density of the vegetation;
- the type and complexity of the surficial material, terrain, and hazard processes;
- the extent of field work; and
- the extent of quality control and quality assurance measures taken.

The base mapping (1:20,000 TRIM) is assumed to be of reasonably good quality and is the provincial standard base map for terrain mapping projects.

The terrain mapping line work used as a polygon base for applying ratings in this project was not specifically intended for terrain hazard or slope stability mapping. However, as a base terrain layer the line work was accurately located on relevant terrain boundaries. Several practical efficiencies are gained by using this pre-existing terrain layer, and it is reasonable method for the purpose of this project; however, as a result the polygons are generally rated more conservatively with regards to slope stability, hazards and constraints. The reason for the more conservative ratings is that a polygon may contain a variety of stability classes, but the higher class is used in order to identify potentially hazardous or sensitive terrain. The comments column in the database was used to identify polygons in which a significant range of classes were present.

The interpretations were completed by Jen Shypitka, P.Geo, and reviewed by Tedd Robertson, P.Geo./Eng.L., both of whom are qualified and experienced terrain mappers, having worked on numerous terrain stability mapping projects throughout the province over the last 15 years.

The digital imagery used was derived from 2005 colour air photos (15BCC05089 Nos. 093-097, 146-151 and 15BCC05122 Nos. 052-056, 076-079). The nominal photo scale is 1:30,000 and the digital images were obtained by high resolution scans with a pixel size of 14 microns. In general, the imagery used was of good quality with no significant hindrance due to cloud cover or other reason.

The vegetation cover was typical for the area and did not present any difficulties in interpretation beyond the norm. The type and complexity of the terrain is also fairly typical for the area.

In the IIA, the level of field checking was appropriate for the size of the study area and scale of the mapping, with a TSIL C achieved. The additional EUMA was completed at a reconnaissance TSIL D. These field sites targeted the steeper, potentially unstable and unstable polygons. Refer to Section 2.5 for additional discussion regarding field checking.

Quality assurance was completed through a number of in-house reviews and quality assurance checks (refer to section 2.8).

3.2 Limitations

A number of limitations are inherent with terrain hazard and constraint mapping, with some of the key factors discussed below.

- **Scale:** The scale of the mapping generally dictates the minimum polygon size, which for this project was typically 1 ha. Some smaller polygons (0.5 ha) were mapped where important features were noted and would have otherwise not been captured.
- **Subsurface conditions:** During field work, shallow soil pits, overturned root wads, and resource road cut slopes were examined; no further subsurface investigations were carried out. Near surface conditions have been used to infer subsurface conditions for the most part as is standard practice in terrain mapping; however, subsurface conditions such as ground water flow and the thickness of material overlying bedrock cannot always be accurately assessed from these methods. As slope stability is strongly influenced by subsurface conditions (e.g. subsurface hydrologic conditions and subsurface material properties) which may not be apparent from surface observations

(air photo or ground inspections) as well as the timing of natural events (e.g. extreme weather events, earthquakes, forest fires) which cannot be predicted, the mapping cannot guarantee that no landslides will occur in or impact areas identified as low hazard.

- **Polygon Based Interpretations:** An inherent limitation to polygon based mapping of landscapes is the difficulty in capturing the variability within a polygon. Natural variability may be more than what can be captured by the standard practices of interpretation and data capture even in small polygons. The hazard and constraint interpretations identify key terrain conditions likely to occur within the polygon; however, this does not imply a spatial location within the polygon or reduce the need for detailed site investigations where the knowledge of specific terrain conditions is important. For example, a polygon identified as high hazard overall may have a much greater range of likelihood of landslides than is possible to indicate by the label. Some areas within the polygon may be subject to hazard events at an average frequency of 1 in 20 years, while other adjacent sites within the polygon may be subject to hazard events at a much lower frequency. This variability most often results in the most conservative hazard rating for a given area.
  An additional polygon based limitation to this project is that the terrain polygon base layer used was prepared by another terrain mapper without slope stability as a primary influencing factor for delineating polygons. This generally results in more hazard and stability variation within a polygon than if polygons are split or delineated for the intended purpose. However, the product can still provide useful overview information with respect to the extent, type, and frequency of terrain hazards, constraints, and slope stability
- **Access:** Access is a common limitation for field checking in mountainous terrain. Within the study area; however, good access to the project component areas was obtained by means of truck and foot traverses.

4 TERRAIN HAZARDS

In this project, hazard is defined as a harmful or potentially harmful mass wasting or fluvial related event[4]. The following sections discuss the hazard processes mapped within the study area and the hazard class rating system used.

4.1 Slow Mass Movement (F", F)

Slow mass movement refers to slope movement that occurs at a very slow rate and typically travels a relatively short distance. The double prime (F") indicates that the polygon contains the initiation zone for slow mass movement.

The slow mass movement subclass indicates the specific process that is present in the polygon. **Soil creep (F"c)** is the slow, down slope movement of soils. It has been mapped in 45 polygons where this process has been observed or suspected to occur. This was typically located on some of the steeper erosional slopes. **Slump in surficial material (-F"u)** is the sliding of surface material along a slip plane that is concave upward or planar. This process was observed during field work (JS26 and JS17; *TerrainID* 127) and has been identified in four polygons within the study area, all located within the IIA.

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[4] Adapted from Wise et al. 2004. Chapter 3, Section 3.2

4.2 Rapid Mass Movement (R”, R)

Rapid mass movement refers to the rapid, gravity induced down slope movement by sliding, falling, rolling, or flowing of either bedrock or surficial material. The double prime (e.g. R”) indicates that the polygon is considered an initiation zone for the mass movement process indicated. When no double prime is used (e.g. R) then the polygon is considered to include the transportation or run out zone of the mass movement process indicated. These areas are exposed to up slope hazards, but may not have significant likelihood of landslide initiation within that polygon.

The rapid mass movement subclass indicates the specific process that is likely to occur within the polygon. **Rock fall (R”b)** is located in a few of the steeper polygons adjacent to M17 Creek, M19 Creek, M20 Creek, and Murray River in the IIA. In the EUMA, R”b is located in some of the steeper polygons north of M20 Creek, to the east and west of the headwaters of Mast Creek, and some of the steeper slopes in the southern headwaters of M20 Creek. It is typically present where exposed rock bluffs with near vertical slopes are located. Blocky talus slopes are common below these cliffs and are subject to rock fall from above (Rb). **Debris fall (R”f)** refers to the rapid descent of a mass of surficial material by means of falling, bouncing, and rolling. Debris fall has been mapped in the study area in some of the same polygons that also contain rock fall adjacent to M20 Creek and Murray River (*TerrainID* 15, 174, 190, 195). Debris fall has only been mapped in one polygon in the EUMA adjacent to M20 Creek (*TerrianID*22). **Debris slides (R”s)** consist of a sliding mass of surficial material. They typically occur on steep gradient slopes at times when pore water pressures within the soil are elevated due to high levels of runoff or precipitation. The sliding surface (shear plane) of debris slides is commonly bedrock where materials are thin, or at the contact between weathered soils and unweathered parent material where surficial material thickness are greater (commonly near 1 m depth in till soils within the region). Eighty three polygons within the entire study area have been mapped with either R”s (initiation zone for debris slides) or Rs (receiving zone for debris slides). **Rockslide (R”r)** refers to the descent of large masses of disintegrating bedrock by sliding. Natural weakness in the bedrock layers often control the shape and location of rockslides. Within the EUMA, six polygons have been mapped with R”r (initiation zone for rockslides), and seven polygons mapped with Rr (receiving sites for rockslides). This is mapped in three different locations; two of which are located on the steep slopes to the east and west of the valley bottom just south of the proposed secondary shaft site (*TerrainID 543, 547, 563)*. Both of these areas mapped with rockslide were visited during field work. The other site where rockslide has been mapped is located near the crest of a steep east facing slope between M20 Creek and Murray River (*Terrain ID 484, 485).* In all of the polygons mapped with rockslide initiation, there are large tension cracks in bedrock indicating past movement.

4.3 Active Fluvial Processes (I)

Active fluvial processes (I) refers to hazards associated with **flooding, progressive bank erosion, and channel avulsion**. Subclasses for these processes have not been broken down; rather a polygon with an active fluvial process may be subject to one or more of the above hazards. **Flooding** is generally associated with overbank water flow and general flood plain inundation, as well as the potential for high suspended sediment load, mobile bed load, and large woody debris transport. **Progressive bank erosion** can be associated with elevated sediment input into creeks as well as unstable sidewalls adjacent to the creek. If the stream bank is high enough and the erosion significant it may result in debris slides (R"s) on the adjacent slope. **Channel avulsion** may result from partially blocked channels due to log/debris jams, landslide disturbance, or from progressive bank erosion. Where streams are well confined the potential for avulsion is limited, while if unconfined (e.g. on a fan or wide flood plain surface) the potential for avulsion is much greater. Within the IIA, active fluvial processes are predominantly situated along the Murray River floodplain and the M20 Creek fan. In the EUMA, active fluvial processes are located along Mast Creek, M20 Creek and their headwaters.

4.4 Non Classified (NC)

A "non classified" (NC) label has been applied to polygons that have been rated with a low hazard class for all considered hazard processes. An exception to this is where large rock slide features have been identified; in these cases the likelihood of occurrence may be low, but the process has still been mapped due to the potentially very large magnitude events.

5 Hazard Classes

A qualitative three class hazard rating system has been applied in this project (Low, Moderate, High). Criteria are project specific and are based on the likelihood of occurrence with no direct inference to potential magnitude (refer to Table 1). The class breaks used (annual likelihood of occurrences of 1/100 and 1/500) are common benchmarks used in landslide hazard analysis within British Columbia. These numeric values are intended to give the user a concept of the approximate annual likelihood of occurrence but do not represent exact values or infer a quantitative analysis. In comparison to example hazard rating tables presented in documents such as Land Management Handbook 56 Landslide Risk Case Studies in Forest Development Planning and Operations (Wise et al. 2004) and the Forest Road Engineering Guidebook, 2nd Ed. (BCMoF 2002), the three class system used in this project groups together the low and very low ratings as well as the high and very high ratings of their respective five class systems. Given the project scope this merging is considered appropriate. A more detailed analysis is beyond the scope of this work and something that could be undertaken as part of site specific assessments where necessary.

Table 1: Terrain Hazard Classes

HAZARD CLASSES†	
Hazard Class	**Interpretation**
L	Annual likelihood of occurrence is less than approximately 1/500. Evidence of past hazard events is generally either non-existent or may be difficult to identify.
M	Annual likelihood of occurrence ranges from approximately 1/100 to 1/500. Evidence of past hazard events is generally identifiable from scars and/or deposits but is often older than the mature forest and may not be easily identified by vegetation.
H	Annual likelihood of occurrence is greater than approximately 1/100. Evidence of recent hazard events within the lifetime of the mature forest is generally easily identifiable, but may not necessarily appear fresh.

6 TERRAIN CONSTRAINTS

In this project, terrain constraints are defined as terrain characteristics or features that are likely to pose a challenge to the construction, operation, or maintenance of project infrastructure including access structures. The following sections outline the terrain constraints that have been identified in this project. Terrain constraints have not been assigned hazard classes as they are considered to represent more of a difficulty with respect to construction or operation rather than a hazard; however, some constraint features may be sensitive to disturbance and could result in an increase in the likelihood of landslides resulting from resource development.

6.1 Gullying (v)

Gullies are ravines with a V-shaped cross section eroded into surficial material or bedrock by either water flow or mass movement processes. The symbol (v) is generally used to indicate that gullying is an active process within the polygon, whether there are many smaller gullies within the polygon or one large gully that makes up the entire polygon.

The presence of gullies indicates either active or formally active erosion. The presence of gullies has been identified as having a significant effect on landslide density[5]; therefore, the presence of significant or frequent gullies will typically result in a higher slope stability or hazard rating compared with an otherwise similar non-gullied polygon. The gully headwalls and sidewalls are areas especially sensitive to disturbance, and gully bottoms may channelize a small debris slide, which in turn can initiate a larger and more destructive debris flow. Within the study area, 30 polygons have been identified with gullying as a constraint; six of these polygons are within the IIA, and the remainder are within the EUMA.

6.2 Wet sites – poor drainage (w1)

This label has been applied to polygons that generally contain areas of substantial permanent or seasonal surface seepage. Soil drainage generally ranges from imperfect to very poor, with lesser areas of moderately well drained soils likely present as well. Thin (<1 m) organic veneers may also exist overlaying other surficial materials. In general, these sites may represent a construction or maintenance constraint due to the soil moisture content, elevated ground water tables, and associated pore water pressures. Wet sites on steeper ground are also commonly prone to a greater increase in hazard with respect to slope stability and erosion when impacted by development in comparison with similar drier sites. There are 31 polygons within the IIA labelled as w1 and 83 polygons identified as w1 within the EUMA.

6.3 Wet sites – wetlands (w2)

This category applies to areas of poorly to very poorly drained organics and floodplain deposits generally referred to as wetlands. Typically these areas are inundated for a significant portion of the year.

Organic materials are those resulting from the accumulation of vegetative matter, generally containing at least 30% organic matter by weight. These polygons contain areas that could present construction constraints due to high water tables. There are 12 polygons in the IIA labelled as w2; these are located mostly along the Murray River floodplain as well as the

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[5] Jordan, 2003

occasional upland location. Within the EUMA, 35 polygons have been identified as w2; these are located mainly in floodplain locations as well as the occasional upland location.

7 SLOPE STABILITY CLASSIFICATION

Slope stability classes were applied to the existing terrain polygons using the provincial standard five class system[6] (refer to Table 2). Local criteria were established based on a combination of the slope stability mapping experience of the author and reviewer throughout the province, taking into account results from landslide attribute studies carried out in the coastal and southern interior regions of BC[7]. No landslide attribute studies are known to exist in the specific region of the study area.

The criteria are based largely on: slope gradient; surficial material type; drainage; slope configuration; the presence of active geomorphological processes, and how terrain with similar attributes has responded to past resource development within the region (refer to Table 3). Not all surficial materials listed in the criteria table are necessarily found in the study area, but have been included as relevant examples.

Table 2: **Generalized Definitions and Management Implications of Terrain Stability Classes**

TERRAIN STABILITY CLASSES*†	
Detailed Terrain Stability Class	**Interpretation**
I	No significant stability problems exist.
II	There is a very low likelihood of landslides following timber harvesting or road construction. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction.
III	Minor stability problems can develop, with more significant problems possible in site specific areas if drainage or excavations are not properly managed. Timber harvesting should not significantly reduce terrain stability. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. Road and trail drainage should be carefully managed to avoid more significant stability problems. There is predominantly a low likelihood of landslide initiation following road construction or timber harvesting; however, the polygon may include small areas that are more susceptible to instability. A terrain stability assessment is usually not required, but may be warranted in some cases dependant on site specific conditions or if there are significant down slope elements at risk.
IV	Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. A terrain stability assessment is recommended for any resource development.
V	Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction. A terrain stability assessment is recommended for any resource development.

* adapted from Mapping and Assessing Terrain Stability Guidebook, 2nd edition, BC Ministry of Forests (1999) and Ryder, J. 2002. †The classification addresses clearcut timber harvesting and sidecast road construction. The considered landslide is greater than 0.05 ha in size.

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[6] B.C. Ministry of Forests, 1999

7 Jordan, 2003; Jordan et al. 2010

Table 3: Terrain Stability Criteria for Murray River Coal Project Area

Class I	
Terrain description	**Examples**
Till, fluvial (glacio, active, or inactive), colluvial, weathered bedrock, and organic deposits with slope gradients generally less than 25%. Soil drainage is generally moderately well or better, with minor areas of imperfect to poor drainage. Slope configuration may be uniform to irregular. Occasional small undulating bedrock outcrops may be present.	Mbw (F,C,D,O) m 0-25%
Glaciolacustrine and lacustrine deposits with slope gradients less than 10%. Soil drainage is generally moderately well or better, with minor areas of imperfect to poor drainage. Slope configuration may be uniform to irregular.	L$^{(G)}$tpu m 0-10%
Class II	
Terrain description	**Examples**
Till, fluvial (glacio, active, or inactive), and colluvial deposits with slope gradients generally between 25% and 45% and generally uniform slope configurations. Soil drainage is generally moderately well or better, with minor areas of imperfect drainage possible. Occasional small bedrock outcrops may be present.	Mbw (F,C) w-m 25-45%
Till and colluvium complexes on irregular or benchy rock controlled slopes with slope gradients predominantly between 20% and 55%. Occasional small bedrock outcrops may be steeper. Soil drainage is generally moderately well or better.	Mvw/Cvw//Rk w-m 20-55%
Constructional coarse textured colluvial deposits, well to rapidly drained, with slope gradients between 25% and 55%. May be a receiving site for rock fall and/or debris flows or snow avalanches.	Cca-R”b w-r 25-55%
(Glacio)lacustrine deposits with slope gradients between 10% and 30%. Soil drainage is generally moderately well or better, with minor areas of imperfect to poor drainage. Slope configuration may be uniform to irregular.	L^{G}ju m 10-30%
Class III	
Terrain description	**Examples**
Till and colluvial veneers or blankets on bedrock controlled slopes with a uniform slope configuration, moderately well or better drainage, and slope gradients predominantly between 45% and 60%. Minor or infrequent gullies may be present.	Mbv (Cvb) m-w 45-60%
Complexes of till and/or colluvial veneers or mantles of variable thickness on bedrock controlled slopes with an irregular surface configuration and/or benchy slope configuration with slope gradients generally less than 60% but up to 70% for short slope segments (typically less than 50 m long). Soil drainage is generally moderately well or better. Occasional steeper bedrock outcroppings may be present, as well as minor or infrequent gullies.	Mvw/Cvw//Rks m–r 50-70%
Thick glaciofluvial materials with generally well drained, uniform slopes (erosional or depositional), with slope gradients between 45% and 65%. Minor or infrequent gullies may be present.	F^{G}ak w 45-60%
Thick till materials with generally moderately well or better drainage, uniform slopes (erosional or depositional) with slope gradients generally ranging from 45% to 60%.	Mak m-w 45-60%
Glaciolacustrine deposits, generally moderately well drained, with slope gradients up to 45%.	L^{G}ja m-w <45%
Constructional coarse textured colluvial deposits (talus), well to rapidly drained, with slope gradients between 50% and 70%. May be a receiving site for rock fall.	xCk (-Rb) w-r 50-70%

Class IV – Potentially Unstable	
Terrain description	**Examples**
Till and colluvial veneers or blankets on bedrock controlled slopes with a uniform slope configuration, moderately well or better drainage, and slope gradients generally greater than 60%.	Mbv/Cvb w-m >60%
Till and colluvial veneers or mantles of variable thickness on bedrock controlled slopes with an irregular surface configuration and/ or benchy slope profile with slope gradients generally greater than 60% and frequent slope segments 70% or steeper. Soil drainage is generally well or better. Occasional to frequent steep bedrock outcroppings with minor rockfall may be present.	Cvw/Rs-R”b w-r >60%
Constructional coarse textured colluvial deposits (talus), well to rapidly drained, with slope gradients predominantly greater than 70%. May be a receiving site for rock fall.	xCs (-Rb) w-r >70%
Steep bedrock dominated slopes with lesser amounts of colluvial veneers. Slope gradients generally between 70% and 130%.	Rs//Cv-R”b w-r >70%
Glaciofluvial materials on generally well drained, uniform slopes (erosional or depositional) greater than 60%.	F^{G}ks w >60%
Glaciolacustrine deposits, generally moderately well drained, with slope gradients greater than 45%.	L^{G}ka m >45%
Thick till deposits with frequent gullies, soil drainage generally ranging from moderately well to imperfect, and slope gradients generally over 50%. Gullies are generally greater than 3 m deep and gully side wall gradients are commonly greater than 65 %.	Mb-V m-i >50%
Major gully sidewalls and stream scarps of thick material (till or glaciofluvial), generally well to moderately well drained with areas of imperfect drainage and possible seepage along the lower slope sections, with slope gradients greater than 55%.	Mks/F^{G}ks w-i >55%
Kame deposits of interbedded glaciofluvial, till, and/or glaciolacustrine or variable textured glaciofluvial, generally well to imperfectly drained, with slope gradients generally greater than 50%.	F^{G}ks/Mks/L^{G}ks w-i >50%

Class V - Unstable	
Terrain description	**Examples**
Any material, drainage, or slope gradients with significant indicators of instability or recent natural failures.	-R”sd; -F”
Steep bedrock dominated slopes which experience abundant and/or significant rock fall. Significant bedrock tension cracks or detached blocks are likely present.	Rs-R”b and/or -F”k

Notes:

- where soils are significantly wetter than described above, the assigned stability class may be higher or the typical slopes may be lower.
- where isolated natural active instabilities are present within an otherwise potentially unstable polygon (unstable area represents significantly less than 10% of the overall polygon area) then the polygon stability class may remain at IV and the instability present may be identified on the map with an on-site symbol if large enough.
- where slopes are significantly concave in profile, such as major gully headwall locations, slope gradients may be approximately 5% less steep than described above.
- where significant or frequent gullies are present in a polygon and not specifically addressed above, the assigned stability class may be higher or the typical slopes may be approximately 5% to 10% lower.

8 DISCUSSIONS AND RECOMMENDATIONS

The results of this mapping are represented in Appendix A, Figure 3 at scale of 1:20,000. Field site information including notes and photos has been provided to ERM Rescan in digital format only.

Slope stability and terrain hazard and constraint maps can be a useful tool in resource development planning, and are intended to provide a preliminary overview of the extent and spatial distribution of natural hazards present within a study area, along with an estimate of their frequency. The maps can also be useful for targeting areas where more site specific geotechnical work is warranted.

8.1 General Terrain Hazard Considerations

Terrain hazard polygons have been classified by both hazard process and hazard class ratings. It is important to take into account the hazard process when considering the hazard class rating. For example, a high hazard of rock fall run out may have a very different implication than a high hazard of debris slide initiation with respect to infrastructure placement and design.

The likely timing of natural hazard events may also be a factor to consider. While not predictable, there are common conditions that often result in specific hazard processes. For example, flooding is generally associated with high rates of snow melt during late spring or early summer, and occasionally during fall rain on snow events. Rock fall is commonly associated with freeze thaw processes as well as runoff periods that commonly occur between the fall and late spring. Debris slides and debris flows are most often associated with high runoff periods such as spring runoff, intense convective precipitation events during the summer months, or prolonged rains or rain on snow events in the fall.

In general, high hazard class terrain has been identified primarily relating to areas of soil creep, rock fall, debris fall, debris slides. These areas are mainly located in steeply sloping polygons which have been incised by the present day rivers and creeks.

In addition three isolated areas of rockslide hazard have been identified in the EUMA where large tension cracks in bedrock have been observed. Two of these tension cracks were visited during field work; however, detailed investigation regarding the potential activity and risks associated with these features is beyond the scope of the work. Within the province these types of instabilities are often relic features, many of which are associated with the unweighting of glacial ice at the end of the Fraser Glaciation and are not active under present day climatic conditions. However, there have also been cases of large catastrophic rock slides in recent B.C. history and these indicators of past movement should not be overlooked during resource development.

There are two polygons within the IIA in which slow mass movement in the form of slumping have been mapped. Where these sites were visited (site J17 and J26), the slumps occurred on a short steep slope in thick sandy glaciofluvial material.

8.2 Additional Geotechnical Investigations

As previously discussed in section 4.2, an inherent limitation to polygon based interpretations is the extent of spatial variability within a polygon. As a result, more detailed field investigations are important for determining the likelihood for destructive landslides at specific locations, as well as for the purpose of a more detailed risk analysis where appropriate.

Additional site specific geotechnical investigations may involve testing methods as simple as hand dug test pits and near surface investigations of existing road cuts and overturned root wads, or may include more detailed works such as rigorous sampling (machine excavated test pits and drill holes) and laboratory testing where more information is required with respect to subsurface conditions for large excavations or permanent infrastructure.

Additional investigation of the rockslide features mentioned in Sections 4.2 and 8.2, including an estimation of the extent and activity as well as the potential run out zones is warranted if these features may be affected by or could affect project infrastructure or human safety.

8.3 General Drainage Considerations

Since deglaciation, mountain slope drainage patterns have continuously evolved to their present day state and have become balanced with the amount and direction of water runoff. Disruption of this equilibrium can lead to instabilities even on terrain that would normally be considered stable. In the southern interior of British Columbia it has been documented that the majority (as high as 90% to 95%) of forest development related landslides are related to roads or machine trails as opposed to timber harvesting[8]. Relatively similar results could be expected in central and northern interior ranges of BC.

Road and trail related landslides can usually be at least partially attributed to drainage. Careful road/trail planning and construction including consideration of alignment, construction methods, drainage structures, maintenance, and deactivation or rehabilitation is important for reducing the likelihood of resource development related landslides.

8.4 Down slope Resources

Down slope resources, or elements at risk, which can be affected by landslides generally include:

- Human safety;
- Public and private property;
- Transportation systems/corridors;
- Utility and utility corridors;
- Domestic water supply;
- Fish Habitat;
- Wildlife (non-fish) habitat and migration;
- Visual resources in a scenic area; and
- Timber value (includes soil productivity).

Due consideration of the potential impact on down slope elements at risk is an important part of resource planning.

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[8] Jordan, 2003; Jordan et al. 2010.

9 CLOSURE

The discussions and recommendations presented in this report are based on digital air photo interpretation using PurView in ArcMap, selective field checking by means of foot and vehicle traverses, as well as additional background information. As slope stability is strongly influenced by subsurface conditions (e.g. subsurface hydrologic conditions) which may not be apparent from surface observations (air photo or ground inspections) and the timing/severity of natural events (e.g. extreme weather events, earthquakes, forest fires) which are unpredictable, it cannot be guaranteed that no landslides will result in areas affected by development activities or in areas mapped as low hazard. This report has been prepared for use by ERM Rescan, which includes distribution as required for purposes for which it was commissioned. The mapping has been carried out in accordance with generally accepted geoscience practice. No other warranty is made, either expressed or implied.

We trust that the information above meets your current requirements. If you have any questions, or require further information, please do not hesitate to contact the undersigned.

Respectfully submitted,
Sitkum Consulting Ltd.

Prepared by: Reviewed by:

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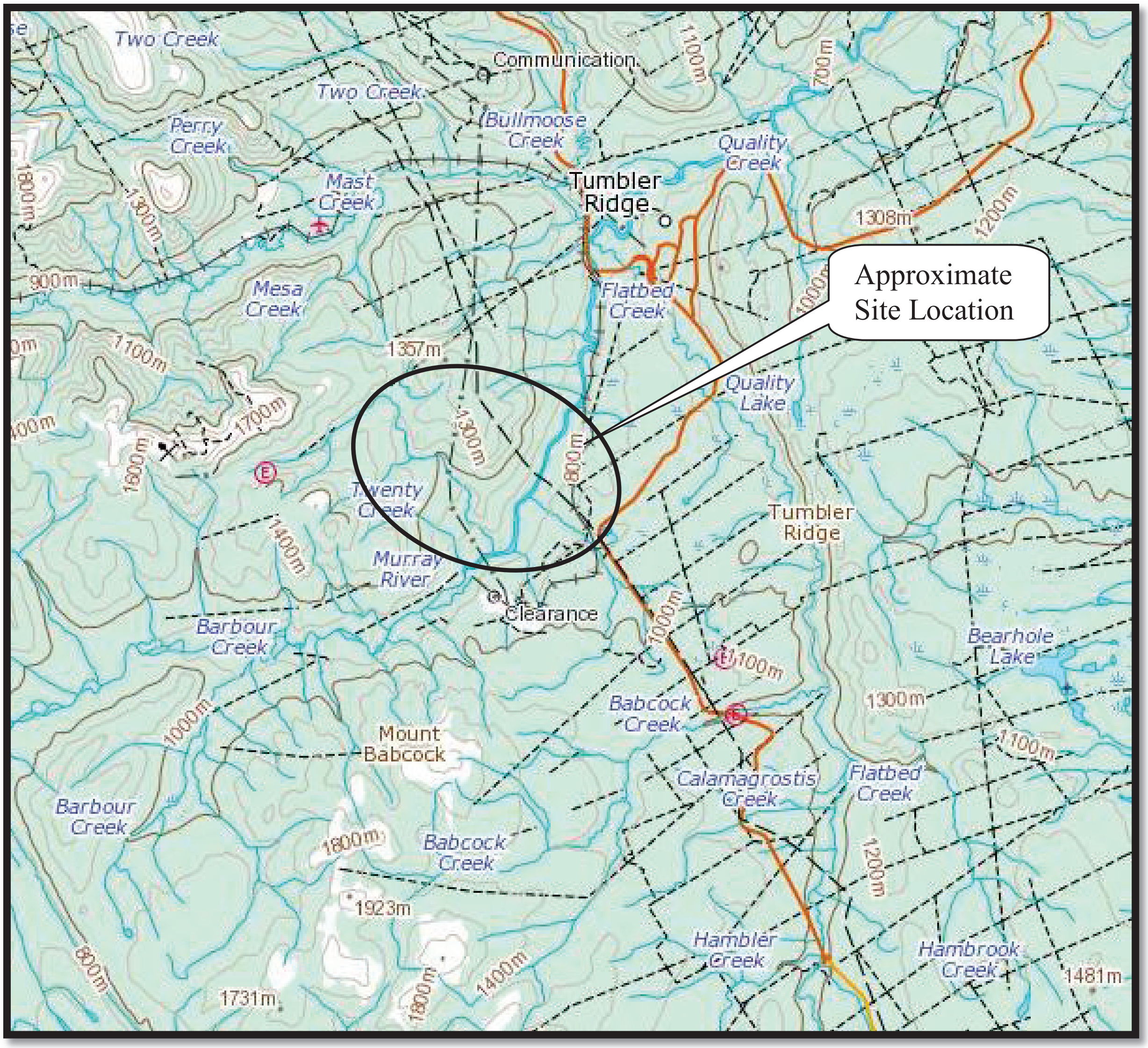
Appendix A

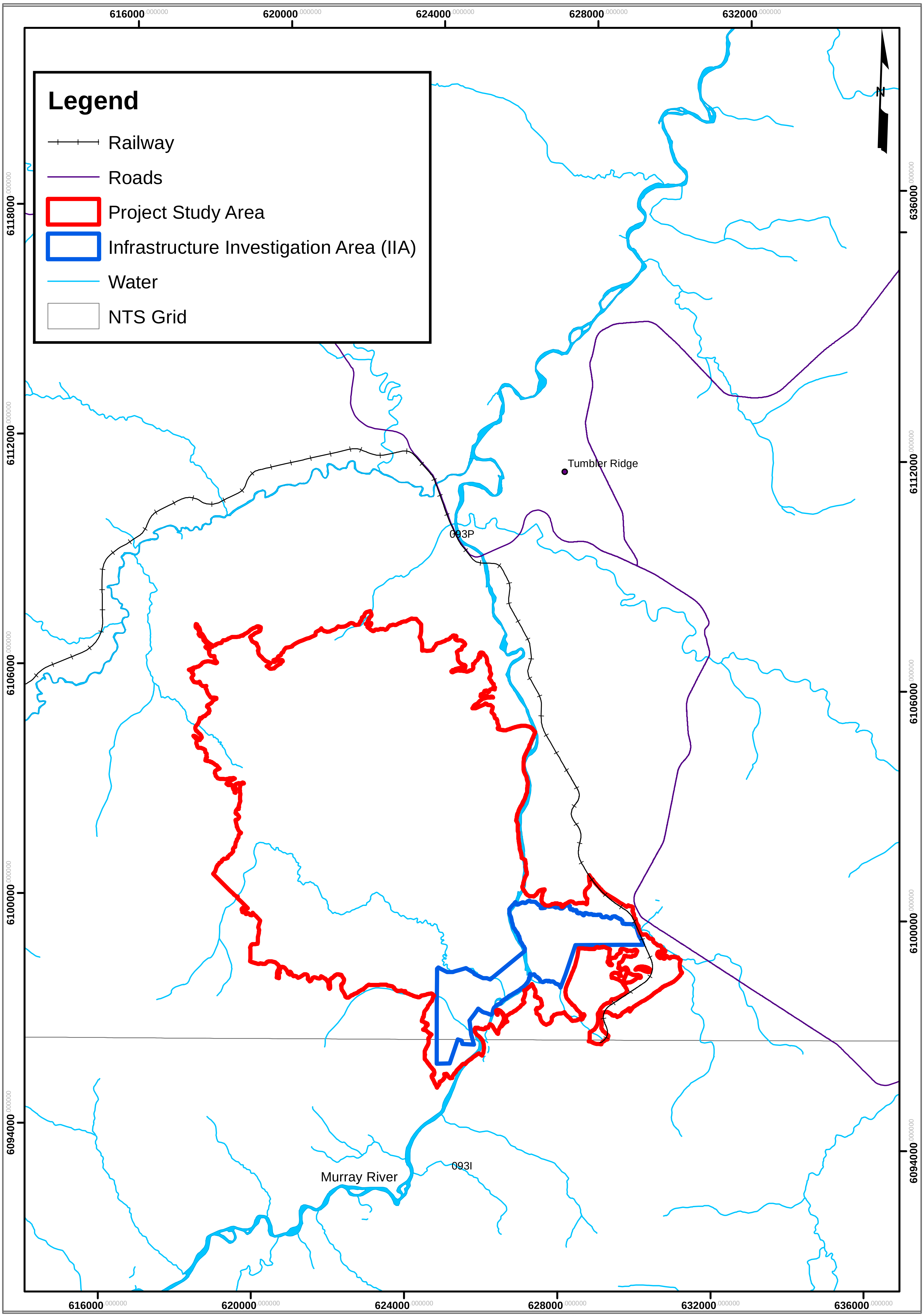
Figures



Approximate Site Location

Project **Murray River Coal Project**		Title **Location Map**
Client **ERM Rescan**		
Project Number **SCL 14-998**	Scale **Approx. 1:200,000**	Date **July 21, 2014**
	Base Map Source **Toporama web mapping application "© Her Majesty the Queen in Right of Canada, Department of Natural Resources. All rights reserved."**	Figure **Figure 1**

Murray River Coal Project
Slope Stabilty and Terrain Hazard Mapping
Study Area Location Map



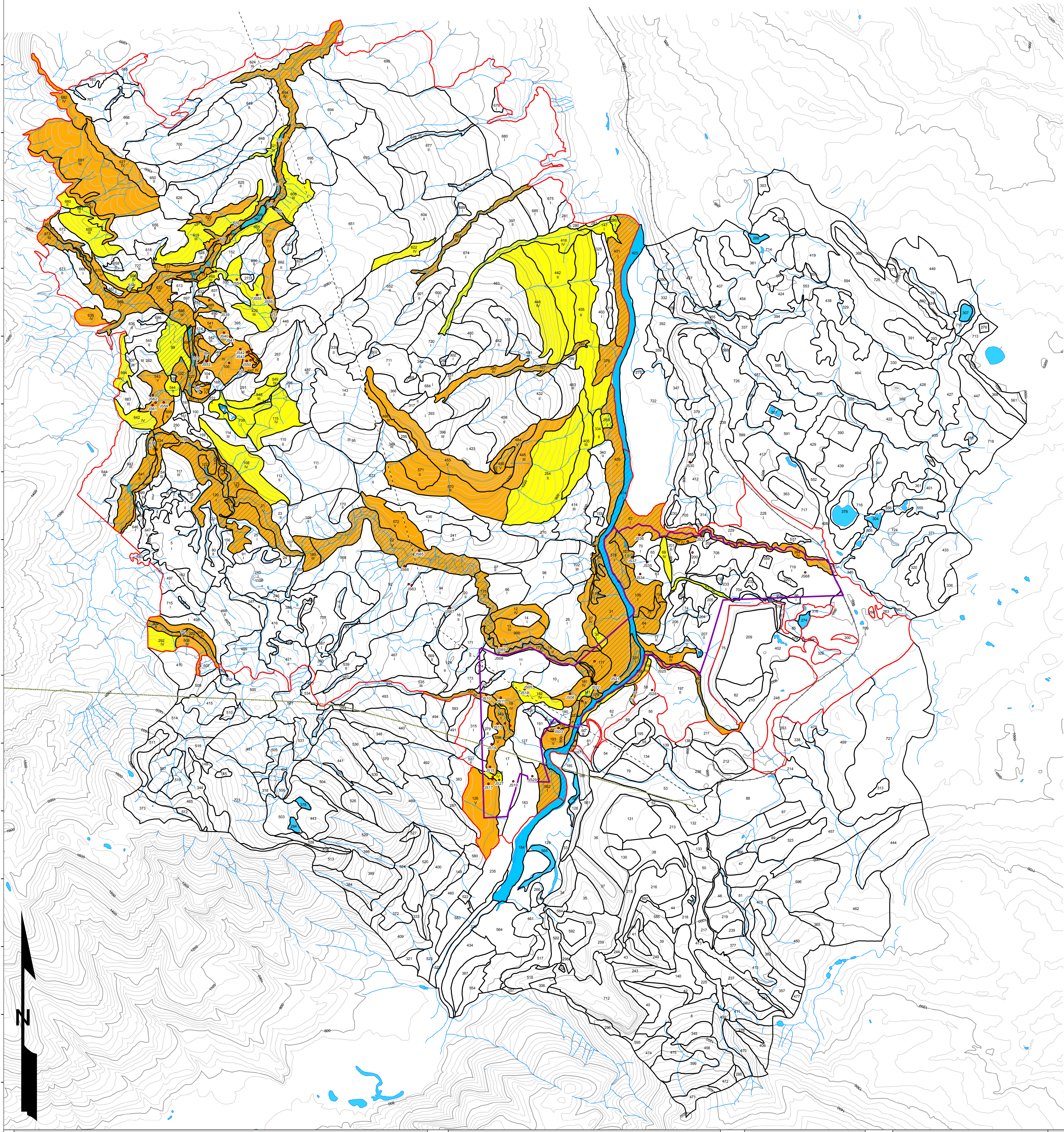
0 0.5 1 2 3 4 5 Kilometers

1:100,000

SCL# 14-998 Date: June 23, 2014
Drawn: T. Robertson

Figure 2
UTM Zone 10N, NAD83

TERRAIN HAZARD AND CONSTRAINT MAP WITH SLOPE STABILITY INTERPRETATIONS



TERRAIN HAZARD AND CONSTRAINT POLYGON ATTRIBUTE TABLE

Terrain ID	STABILITY	FIRST TERRAIN HAZARD PROCESS	FIRST TERRAIN HAZARD CLASS	SECOND TERRAIN HAZARD PROCESS	SECOND TERRAIN HAZARD CLASS	THIRD TERRAIN HAZARD PROCESS	THIRD TERRAIN HAZARD CLASS	FIRST CONSTRAINT	SECOND CONSTRAINT
1	II	NC	L					w2	
2	I	NC	L					w1	
3	II	NC	L						
4	I	NC	L					w2	
5	I	NC	L					w1	
6	III	NC	L					w1	
9	I	NC	L					w2	
10	I	NC	L						
11	I	NC	L						
12	IV	R"b	H						
13	IV	R"b	H	R"s	M				
14	I	NC	L						
15	V	R"sfb	H	I	H				
16	II	NC	L						
17	I	NC	L						
18	I	I	H					w2	
19	IV	F"c	H	R"s	M			v	
20	II	NC	L					w1	
21	V	R"s	H	F"c	H	I	H	w1	v
22	V	R"sbf	H	F"c	H	I	H	v	
23	II	NC	L					w1	
24	I	NC	L					w2	
25	I	NC	L					w2	
26	I	NC	L						
27	IV	F"c	H	R"s	M			v	
28	I	I	H					w1	
29	I	I	H						
30	I	I	M						
31	I	I	H						
57	IV	R"s	M					v	
60	II	NC	L						
61	II	NC	L						
62	II	NC	L						
63	I	NC	L					w1	
64	I	I	H					w2	
65	I	NC	L					w2	
66	II	NC	L					w1	
67	I	I	H					w1	
69	IV	R"s	M						
70	I	NC	L						
71	IV	R"s	M					w1	v
72	II	NC	L					w1	v
73	III	NC	L					w2	
74	II	NC	L					w1	
76	IV	NC	L						
77	II	NC	L						
78	I	I	H						
80	V	R"s	H	F"c	H			v	
84	III	F"u	H						
86	I	NC	L					w1	
90	II	NC	L					w1	
91	I	NC	L						
92	I	NC	L					v	w1
93	I	NC	L					w1	
94	I	NC	L						
95	III	NC	L					v	
96	I	NC	L						
97	II	NC	L						
98	I	NC	L						
99	I	I	M						
100	I	NC	L					w2	
101	I	I	H					w1	
102	I	I	H					w2	
103	II	I	H					w1	
104	II	NC	L						
105	III	Rr	L					v	w1
106	IV	R"r	L	R"b	H				
107	II	NC	L						
108	IV	R"s	M					v	
109	II	NC	L						
110	II	NC	L						
111	II	NC	L					w1	
112	II	NC	L						
113	I	NC	L					w2	
114	III	NC	L						
115	IV	NC	L						
116	IV	F"c	H						
117	III	NC	L					w1	
118	II	NC	L						
119	IV	I	H	F"c	H				
120	I	I	H						
121	I	I	H					w2	
122	I	I	H					w2	
123	IV	I	H						
124	II	NC	L						
125	II	NC	L						
126	V	F"uc	H						
127	I	NC	L					w1	
135	I	I	H					w1	
136	I	I	H					w2	
137	I	NC	L					w1	
141	I	I	M						
142	II	NC	L					w1	
143	II	NC	L						
144	I	NC	L					w2	
147	I	Rd	M					w1	
151	I	I	H					w2	
152	I	NC	L					w1	
153	I	NC	L						
154	III	NC	L						
155	II	NC	L						
156	I	NC	L						
157	III	NC	L					w1	v
158	I	I	H					w2	
159	I	NC	L					w2	
160	III	NC	L						
161	I	NC	L					w1	
162	I	NC	L					w1	
163	III	Rs	H					v	
164	V	R"s	H						
165	II	NC	L						
166	IV	F"c	H						
167	I	NC	L					w2	
168	I	Rr	L					w1	
169	III	I	H	R"s	M				
170	II	NC	L						
171	II	NC	L						
172	V	R"sfb	H	I	H				
173	I	NC	L					w1	
174	I	NC	L					w2	
175	V	F"c	H	R"s	H	I	H	w2	
176	I	I	H					w1	
177	I	I	H						
178	I	I	H						
179	I	I	H					w1	
180	I	NC	L					w2	
181	IV	F"c	H	R"s	M				
182	IV	R"s	M					v	
183	I	NC	L						
188	V	R"sbf	H	F"c	H				
189	IV	R"s	M						
190	I	NC	L					w2	
191	I	NC	L					w1	
192	IV	F"c	H						
193	V	R"sfb	H						
196	IV	R"s	M						
197	II	NC	L						
198	I	I	H					w1	
199	IV	F"c	H	R"s	M				
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201	II	NC	L						
202	II	NC	L					w1	
203	I	NC	L					w1	
204	I	NC	L					w1	
205	I	NC	L					w1	
206	I	NC	L						
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220	I	NC	L						
221	I	NC	L					w2	
222	II	NC	L						
223	I	I	H					w1	
224	I	I	H					w1	
226	I	NC	L					w1	
227	I	I	H					w2	
228	I	NC	L						
229	I	NC	L						
231	I	I	H					w2	
232	I	NC	L					w2	
233	I	NC	L						
234	II	I	H					w1	
240	V	R"s	H	F"c	H			v	
241	II	NC	L						
242	I	NC	L					w1	
245	I	NC	L						
246	I	NC	L						
247	II	NC	L						
250	I	Rr	L						
251	I	I	H					w2	
252	I	NC	L					w2	
254	II	Rs	M	Rr	M				
255	II	NC	L					w1	
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265	I	I	M						
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268	I	NC	L					w2	
270	II	NC	L					w1	
271	IV	R"s	H						
272	I	NC	L					w2	
273	I	NC	L						
279	II	NC	L						
280	III	NC	L						
281	I	NC	L						
282	III	NC	L						
283	I	NC	L						
289	I	I	M						
291	III	NC	L						
292	IV	R"s	M					w1	
295	II	NC	L					w1	
297	III	Rd	H						
299	I	NC	L						
302	I	NC	L						
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311	IV	F"c	H						
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317	II	NC	L						
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325	I	NC	L						
327	V	R"sd	H					v	
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342	II	NC	L						
343	I	I	H					w1	
349	III	NC	L					v	
354	IV	F"c	H	R"bs	H				
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358	I	NC	L						
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364	IV	F"c	H					w1	
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374	I	I	H					w2	
375	I	I	H					w1	
376	I	I	H						
380	IV	F"c	H	R"s	M				
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405	III	R"s	M						
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537	II	NC	L						
538	IV	R"s	M					w1	v
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541	IV	F"c	H						
542	III	NC	L						
543	V	R"r	H	R"bs	H			v	
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612	IV	F"c	H	R"s	H			w1	
613	I	NC	L						
614	IV	I	H	F"c	H	R"s	M	w1	
615	I	I	H	Rs	M			w2	
616	I	I	H					w2	
617	IV	R"s	H	F"c	H				
618	I	NC	L					w1	
619	III	Rsb	M					w1	
620	IV	R"sb	H	F"c	H				
621	IV	R"s	M						
622	IV	R"s	M						
623	I	NC	L					w1	
624	III	NC	L						
625	II	NC	L						
626	I	NC	L					w1	
627	IV	R"sb	H	F"c	H				
628	II	NC	L					w1	
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630	II	NC	L						
631	II	NC	L						
632	III	NC	L						
633	IV	F"c	H	I	H	R"s	M	v	
634	II	Rbs	M					w1	
635	IV	R"b	H						
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637	III	NC	L						
638	IV	F"c	H	R"b	H				
639	I	NC	L					w2	
640	I	NC	L					w2	
641	II	I	H					w2	
642	IV	NC	L						
643	III	NC	L					v	
644	III	NC	L						
645	IV	F"c	H	I	H				
646	I	NC	L						
647	II	NC	L						
648	I	NC	L					w1	
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652	II	NC	L						
653	III	F"c	H	I	H				
654	I	NC	L						
655	II	NC	L					w1	
656	IV	R"bs	M						
657	I	NC	L						
658	II	NC	L					w1	
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665	I	NC	L					w2	
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668	I	I	H					w1	
669	I	NC	L						
670	IV	R"b	H	F"c	H				
671	II	NC	L					w1	
672	I	NC	L						
673	III	F"c	H	I	H			w1	
674	I	NC	L						
675	I	NC	L						
676	III	NC	L					w1	v
677	II	NC	L					w1	
678	II	NC	L					w1	
679	I	NC	L					w2	
680	I	NC	L					w1	
681	III	Rsb	H					v	w1
682	IV	R"b	H	R"s	M	F"c	H		
683	I	NC						w1	w2
684	I	NC	L						
685	I	NC	L						
686	II	NC	L						
687	I	I	H						
688	III	I	H					w1	
689	I	NC	L					w1	
690	I	NC	L					w1	
691	I	NC	L					w1	
692	II	NC	L						
693	I	NC	L						
694	I	NC	L					w1	
695	II	NC	L					w1	
696	II	NC	L						
697	I	NC	L						
698	II	Rr	M	Rb	H				
699	II	NC	L						
700	I	NC	L					w1	
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706	I	NC	L					w1	
707	I	NC	L						
708	I	NC	L						
709	I	NC	L					w1	
711	I	NC	L						
715	I	NC	L					w1	
719	I	NC	L						
720	I	NC	L						
727	II	NC	L						

LEGEND

TERRAIN STABILITY CLASSES* †

Detailed Terrain Stability Class	Interpretation
I	No significant stability problems exist.
II	There is a very low likelihood of landslides following timber harvesting or road construction. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction.
III	Minor stability problems can develop, with more significant problems possible in site specific areas if drainage or excavations are not properly managed. Timber harvesting should not significantly reduce terrain stability. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. Road and trail drainage should be carefully managed to avoid more significant stability problems. There is predominately a low likelihood of landslide initiation following road construction for timber harvesting; however, the polygon may include small areas that are more susceptible to instability. A terrain stability assessment is usually not required, but may be warranted in some cases dependant on site specific conditions or if there are significant down slope elements at risk.
IV	Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction. A terrain stability assessment is recommended for any resource development.
V	Expected to contain areas with high likelihood of landslide initiation following timber harvesting or road construction. A terrain stability assessment is recommended for any resource development.

*Adapted from Mapping and Assessing Terrain Stability Guidebook, 2 nd edition, BC Ministry of Forests (1999) and Ryder, J. 2002.
† The classification addresses clearcut timber harvesting and sidecast road construction. The considered landslide is greater than 0.5 ha in size

TERRAIN CONSTRAINTS

v	Gullying	Slope affected by gully erosion. In general, these sites are prone to an increase in hazard with respect to slope stability and erosion when impacted by development.
w1	Wet Sites-Poor Drainage	Abundant surface seepage or evidence of substantial seasonal seepage. Thin (<1m) organic layers may be present. In general, these sites are prone to an increase in hazard with respect to slope stability and erosion when impacted by development.
w2	Wet Sites-Wetlands	Areas of poorly to very poorly drained organics and lacustrine deposits such as wetlands. Generally inundated for a significant portion of the year. In general, these sites are prone to an increase in hazard with respect to slope stability and erosion when impacted by development.

HAZARD PROCESSES

F	Slow Mass Movement	Slope experiencing slow mass movement, such as sliding or slumping.
I	Active Fluvial Process	Polygon is subject to active fluvial processes such as frequent flooding and/or the potential for progressive bank erosion or channel avulsion. Debris floods are also included within this process.
NC	Non-Classified	Polygons with low hazard ratings are generally non-classified with respect to the hazard process present, if any.
R	Rapid Mass Movement	Slope affected by processes such as debris flows, debris slides, and rockfall.

SUB-CLASSES AND SUB-TYPES FOR HAZARD

F"	Slow Mass Movement (Initiation Zone)	Polygon includes sites or zones of instability, such as the headscarps of earthflows or areas of active soil creep.
Fc	Soil Creep	Slow down slope movement of soil.
Fu	Slump in Surficial Material	Sliding of internally cohesive masses of surficial material along a slip plane that is concave, upward or planar.
R"	Rapid Mass Movement (Initiation Zone)	Polygon includes sites or zones of instability such as the headscarps of landslides or source areas of rock fall or debris flows.
Rb	Rockfall	Descent of masses of bedrock by falling, bouncing, and rolling.
Rf	Debris Fall	Descent of a mass of surficial material by falling, bouncing, and rolling.
Rs	Debris Slide	Sliding of disintegrating mass of surficial material.
Rr	Rock Slide	Descent of large masses of disintegrating bedrock by sliding.

MAP SYMBOLOGY

●	Field Site
□	Infrastructure Investigation Area (IIA)
□	Terrain polygon boundary (approx)
■	Open water primary terrain decile
▨	Hazard rating related to fluvial process
□	Study Area
19	Terrain Polygon Number
IV	Terrain Stability Class
- - - -	Teck Conveyor Corridor
– – – ·	BC Hydro Transmission Line

HAZARD CLASSES†

Hazard Class	Interpretation
L	Annual likelihood of occurrence is less then 1/500. Evidence of past hazard events is generally either non-existent or may be difficult to identify.
M	Annual likelihood of occurence ranges from 1/100 to 1/500. Evidence of past hazard events is generally identifiable from scars and/ or deposits but it is often older than the mature forest and may not by easily identified by vegeatation.
H	Annual likelihood of occurence is greater than 1/100. Evidence of recent hazard events within the lifetime of the mature forest is generally easily identifiable, but may not necessarily appear fresh.

† Refer to accompanying report for additional information with respect to hazard classes.

FIGURE 3

For use with report: Terrain Hazard and Constriant Mapping, Murray River Coal Project (SCL Project#14-998)

Air photo interpretation preformed on screen using PurView 1.2 in ArcMap 9.3.1 for the Infrastructure Investigation Area in 2013 and PurView 2.0.1 in ArcMap 10.2.2 for the Extent of Underground Mining Area in 2014. Stereo images are from 2005 colour air photos (15BCC05089 Nos. 093-097, 146-151 and 15BCC05122 Nos. 052-056, 076-079).
The nominal photo scale is 1:30,000 and the digital images were obtained by high resolution scans with a pixel size of 14 microns.

Infrastructure Investigation Area: A total of 39 field sites were recorded within the project study area. A total of 100 previously delineated polygons make up the approximately 1490 ha mapped area.
This results in approximately 34% of all mapped polygons being field checked.

Extent of Underground Mining Area: A total of 30 field sites were recorded in the additional area that contains the extent of underground mining. 306 previously delineated polygons make up the approximately 6510 ha of mapped area. This results in approximately 9% of all mapped polygons being field checked.

PREPARED FOR:

ERM
ERM Rescan

PREPARED BY:

consulting
sitkum
GEOTECHNICAL SERVICES

0 250 500 1,000 1,500 2,000 2,500 Meters

SCALE: 20,000

TERRAIN HAZARD AND CONSTRAINT MAP WITH SLOPE STABILITY

NTS MAPSHEET 93I AND 93P

TRIM SHEETS: 093I,095,.096; 093P.005,006

PROJECTION: UTM ZONE 10 N, NAD 83

Terrain Polygons provided by ERM Rescan Terrain Stability, Hazard, and Constraint Interpretations: J. Shypitka, P.Geo	Map Production: C.Randle Reviewed By: J. Shypitka, P.Geo Project Number: 14-988
Field Checking: J. Shypitka, July 4 through 8, 2013	Map Document: 14_988_MURRARY.mxd
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