Appendix 8-A

Baseline Soils Report

Baseline Soils Report

Crown Mountain Coking Coal Project

NWP Coal Canada Ltd

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1. INTRODUCTION

1.1. Project Description

The Crown Mountain Coking Coal Project (the Project) is a proposed 3.7 million run-of-mine tonnes per annum coal mine located approximately 25 kilometers (km) northeast of Sparwood, in southeastern British Columbia (BC) (Figure 1-1). Major components of the Project include three open pits and coal processing facilities, temporary and permanent waste rock storage areas, a rail line and rail loading loop, a natural gas pipeline, a new 12.7 km power line extension with associated substation to bring power to the site, and a conveyor to transport coal from the pit areas of the mine site. Most of the mine components will be located on Crown land within coal license areas held by Jameson Resources Ltd., east of the Elk River and encompassing Alexander and Grave Creek valleys. The rail line will be located on Crown land near the east bank of the Elk River, 25 km northeast of Sparwood. Current access to the proposed mine is via Highway 43, Line Creek Mine Road, and Valley Forest Service Road (FSR) to the Grave/Harmer FSR. The final 5 km of access road to Crown Mountain is along a mine exploration road. The Alexander Creek drainage is accessible from Highway 3 in the south via the Alexander Creek FSR.

1.2. Physical Setting

The Project and deposit are located within the north-south trending Elk River valley and the parallel Alexander Creek watershed. The deposit is centered on Crown Mountain between West Alexander and Alexander Creek drainages in mountainous terrain. The Project footprint, including all proposed mine infrastructure (see Figure 1-1, Figure 1-2), lies between 1,100-2,190 meters (m) elevation on the east side of the Elk River valley. The Elk River is a wide, extensively braided river with a large 200-300 m wide floodplain.

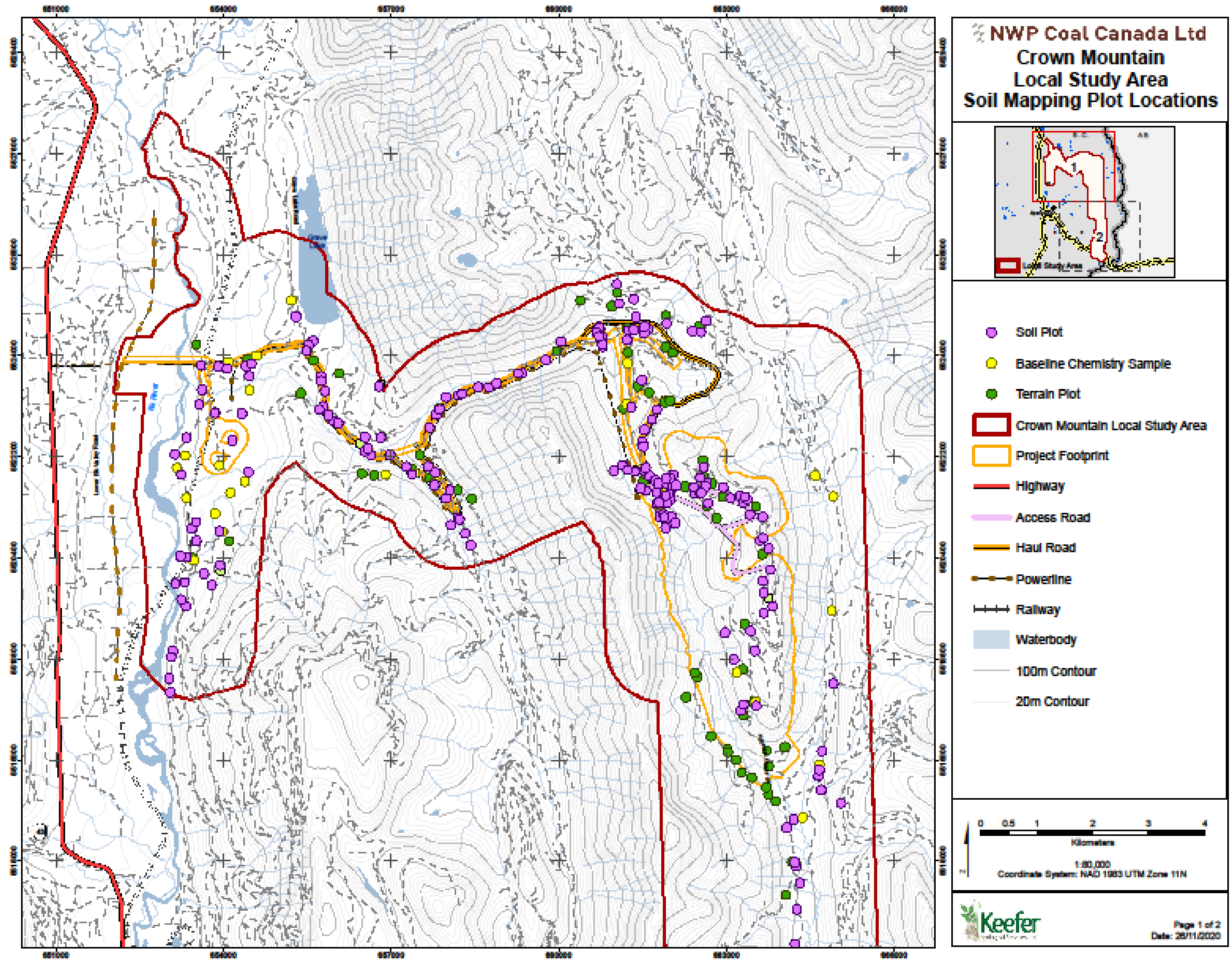

Figure 1-1 Crown Mountain Local Study Area (North Half) with Infrastructure Area and Ground Sample Locations

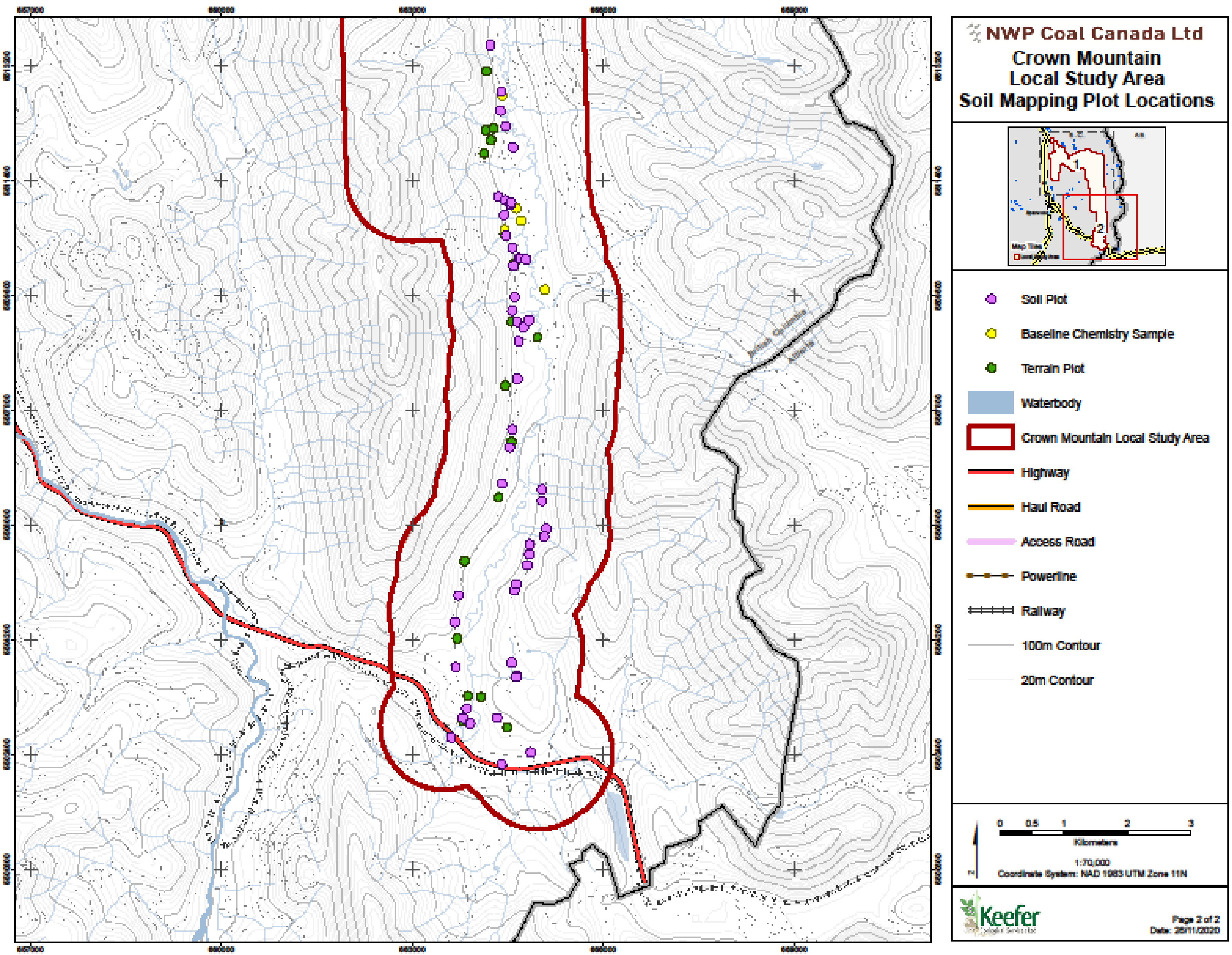

Figure 1-2. Crown Mountain Local Study Area (South Half) with Infrastructure Area and Ground Sample Locations

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The Project is crossed by several main tributaries that drain from the east into the Elk River, including Harmer, Grave, Alexander and West Alexander Creeks. In addition to these fluvial features, there are very few lakes, wetlands and reservoirs (totaling less than 0.3% of the local study area).

The study area exhibits a wide range of topography from relatively subdued terrain adjacent to the Elk River in the north western portion of the study area and along Alexander Creek south of the confluence with West Alexander Creek, through the very deeply incised Grave Creek canyon to moderately sloping terrain in the upper Grave Creek drainage. The Alexander and West Alexander Creek drainages are bounded by the steeply sloping Erickson Ridge on the west which rises to an elevation of 2,485 m. The eastern boundary of the study area ends at mid-elevation level on the mountains that form the Continental Divide. Crown Mountain, the focus of mine infrastructure, rises to an elevation of 2,260 m and is found between West Alexander and Alexander Creeks, in the north eastern portion of the study area. The lowest elevation within the study area is along the Elk River at about 1,160 m.

The following description of the geological setting for the study area is adapted from the Terrain Hazards and Geohazards Mapping for the study area (BGC Engineering Inc., 2019). The Project straddles the Fernie Basin and Front Ranges, which are subdivisions of the Rocky Mountains Physiographic Region (Holland, 1976). The Front Ranges are roughly north-south trending, rugged mountains that are structurally controlled (Ryder, 1981). Both areas are underlain by Mesozoic to Paleozoic-aged limestone, sandstone, shale and coal (Price, Grieve and Patenaude, 1992; Massey, MacIntyre, Desjardins and Cooney, 2005). The Fernie Basin is centered along the Elk River Valley and consists of bedrock that is more erodible, resulting in a more subdued landscape than the Front Ranges (Ryder, 1981). The Elk River floodplain near the study area ranges from 1,200 m to 1,100 m and makes up the lowest elevations in the Project. The regional bedrock geology described in this report is based on Massey et al. (2005) and Price et al. (1992). Bedrock outcrops are present on the highest slopes within the study area. Bedrock type determines the mineralogy, shape and texture of its weathered material. These characteristics influence the biological, chemical and physical properties that affect soil development. The Grave, Harmer and Alexander Creek valleys are largely underlain by Jurassic to Cretaceous, sandstone, siltstone and coal of the Kootenay Group and Jurassic sandstone, shale and limestone of the Fernie Formation. The central portion of the footprint is underlain by Carboniferous limestone of the Rundle Group, which forms a rocky ridge between the two valleys. Carboniferous to Permian Rocky Mountain Group siltstone, dolomite quartzite and limestone form the lower slopes of this ridge.

The variation in elevation found within the study area produces concomitant variation in climate that is reflected in the range of biogeoclimatic units found. Lower elevations to about 1,600 m are found within the Dry Warm Montane Spruce subzone (MSdw; MacKillop, Ehman, Iverson and McKenzie, 2018). Above the MSdw, to about 1,900 m, the Kootenay Dry Cool Engelmann Spruce-Subalpine fir variant (ESSFdk1) is found. The Dry Cool Engelmann Spruce woodland subzone (ESSFdkw) is found between about 1,900 and 2,200 m. The highest elevations of the study are classified as the Dry Cool Engelmann Spruce-Subalpine fir parkland subzone (ESSFdkp). This variation in climate results in different rates and types of soil forming processes.

1.3.Local Study Area (LSA)

The local study area (LSA) represents the geographic area that has the potential to experience direct effects associated with the Project. As such, the LSA includes the Project footprint and watercourses/waterbodies that intersect with the Project footprint and includes the area of potential southern extension along the Alexander Main FSR. The local study area for terrestrial and soil studies for the Project includes the mineral tenure areas and all proposed mine infrastructure buffered by 1 km, thus resulting in a 12,886-hectare (ha) LSA (see Figure 1-1, Figure 1-2). Preliminary Terrestrial Ecosystem Mapping (TEM) was completed for NWP Coal Canada Ltd. (NWP) by Keefer Ecological Services Ltd. (KES) in 2014 and was updated and resubmitted in 2018 following updates to the biogeoclimatic mapping for the East Kootenay. Additional ground sampling in 2019 as a result of changes to proposed Project infrastructure, led to minor revisions. The LSA for the soils baseline is identical to that used for the TEM, Listed Plants and Ecological Communities studies.

1.4.Soil Survey Objectives

The information collected during the soil survey was used to:

1) Prepare a soil inventory map at a detailed level (survey intensity level 2; Resources Inventory Committee, 1995) within the proposed infrastructure area and a reconnaissance level (survey intensity level 3) over the entire LSA;
2) Collect additional samples to aid in establishing baseline metal concentrations in soils of the LSA (this data is provided in the Baseline Metal and Polycyclic Aromatic Hydrocarbon (PAH) Report (KES, 2019));
3) Provide physical and chemical data to verify field identification as well as for land use interpretations such as soil salvage and erosion potential;
4) Interpret surface soil erosion potential; and,
5) Interpret soil salvage potential throughout the LSA.

The soil information presented in this report will support mine planning and can be used to facilitate reclamation prior to final mine closure. The soil inventory accomplishes this by identifying and mapping soil types and soil erosion and salvage potentials across the LSA.

2. METHODS

2.1. Plot Locations and General Concepts in Soil Sampling

Surficial soil materials were sampled over a range of terrain types and moisture/nutrient regimes to gain an understanding and to map the representative surficial soil materials that occur throughout the LSA. Priority for the soil inventory fieldwork was given to planned infrastructure areas and to representative forest ecosystems within the LSA (see Figure 1-1, Figure 1-2).

Prior to the field investigation, probable soil plot locations were identified by analyzing data from a combination of sources:

- Biophysical Resources of the East Kootenay Area: Soils (Lacelle, 1990);
- Soil Landscapes of British Columbia (BCMOE, 1986);
- preliminary TEM polygon line work by Keefer Ecological Services (2014, updated 2019);
- the provincial biogeoclimatic ecosystem classification (BEC) mapping products (BCMFLNRO, 2016);
- a badger survey in the LSA (Klafki, 2015);
- estimated soil type from slope position and contour lines overlain on LSA; and
- the mine plan and infrastructure layout maps current to 2017, when soil inventory fieldwork was initially undertaken.

Google Earth, existing ortho-imagery (dated 2014) and Project footprint maps provided by Dillon Consulting, up to and including the October 2019 revision to the rail loop (Laura Dilley, personal communication, October 2, 2019) were used to generate a base map that would be used in the field to determine appropriate soil plot/sampling locations. Other digital information used in preliminary soil field mapping included Terrain Resource Information Management (TRIM) contour lines and water features, active roads from Digital Road Atlas (Province of BC, 2017), and biogeoclimatic (BGC) mapping used by the TEM. Digital and paper maps were used during the 2017 field investigations. Avenza Maps™ software on an electronic tablet was used for recording terrain and soil notes associated with waypoints located throughout the LSA.

The priority areas for sampling included the proposed mine infrastructure components (e.g., mine pits, plant site, conveyor line, utility corridors and waste rock storage facility). Representative forest ecosystems spanning all biogeoclimatic (BGC) variants/subzones were also sampled.

The TEM was used to provide an initial stratification for the soils mapping. The TEM polygons were then modified to capture relatively consistent areas of soil map units (SMUs), and then attributed to proportion of SMU within each polygon (SMU; described in detail in Section 2.4). The Universe Transverse Mercator (UTM) coordinates (NAD 1983, Zone 11N) of each plot location described in the field were recorded for mapping purposes and to easily relocate the samples sites in the future. In addition to the field observations carried out specifically for the soil mapping, many field observations were recorded for the terrain baseline mapping for the Project (BGC Engineering Inc., 2019). Plot data gathered for the terrain mapping included many of the variables gathered for the soil mapping and was used as accessory information for soil map attribution.

2.2. Survey Intensity

The desired survey intensity within the LSA was a detailed level or Survey Intensity Level 2 (SIL2) (Resources Inventory Committee, 1995) for the Project footprint area[1] and a reconnaissance level (SIL3) for the entire LSA outside of the infrastructure area. This translates to one inspection for every 2 to 20 hectares for SIL2 and one inspection for every 20 to 200 hectares for SIL3. SIL2 is appropriate for creating a soil map at a scale between 1:5,000 to 1:40,000 that provides enough information for local planning of projects (Resources Inventory Committee, 1995). The final map provides reliable information on soil properties for a given soil polygon. Based on a project footprint area of 1,533[2] ha, a minimum target of 77 plots was planned for to meet the requirement of one inspection for every 20 ha or less. For the LSA outside the Project footprint, a minimum target of 54 additional plots was planned for to meet the Soil Inventory Methods suggestions for SIL3. This level of detail is adequate for describing simple and compound soil map units and is useful for planning, construction and operation phases of the mine development.

2.3.Field Survey Procedures

Detailed soil pit descriptions and associated samples were collected in areas near proposed mine infrastructure components (i.e., mine site buildings, coal pits, waste rock storage, transmission corridor, conveyor and access roads) and throughout the accessible LSA.

Each detailed plot entailed excavation and examination of soil material to depth of approximately 0.75 m to 1 m, or lithic contact, whichever came first. A pit was excavated and described for soil classification and physical features in order to characterize representative soil conditions. Where possible, soil pits were described along existing access roads (i.e., using road cuts or forested sites near the road edge) within the LSA, as road cuts can provide a deeper and wider inspection of the type(s) of parent material(s) present than is possible using hand excavation methods. Visual descriptions of terrain and soil type were also completed where no pit was excavated or in cases where it was unsafe to visit a certain location. In such situations, soil and terrain materials were assessed from a short distance away.

[1] The mapped infrastructure was buffered by 100m to create a 1,533 ha Project footprint area.
[2] This area is based on using a 100m buffer around all proposed mine infrastructure as of 2019 (Laura Dilley, personal communication, October 2, 2019).

2.3.1. Soil and Site Description

Detailed (i.e., excavation) and visual (i.e., no excavation) site, soil and vegetation descriptions were completed at soil pit locations using the methods outlined in Field Manual for Describing Terrestrial Ecosystems (BCMoFR & MOE, 2010) and recorded on Ecosystem and Soil Description Field Forms (FS882 Form) or Site Visit Forms (FS 1333). Soils were classified to the subgroup level according to the Canadian System of Soil Classification (see Table 2-1; Agriculture and Agri-Food Canada, 1998).

Table 2-1. Orders, Great Groups, and Subgroups of the Canadian System of Soil Classification identified within the LSA

Order	Great Group	Subgroup
Brunisolic	Melanic Brunisol	Orthic Melanic Brunisol, O.MB
		Gleyed Melanic Brunisol, GL.MB
	Eutric Brunisol	Orthic Eutric Brunisol, O.EB
		Eluviated Eutric Brunisol, E.EB
		Gleyed Eutric Brunisol, GL.EB
	Dystric Brunisol	Orthic Dystric Brunisol, O.DYB
		Eluviated Dystric Brunisol, E.DYB
Gleysolic	Humic Gleysol	Orthic Humic Gleysol, O.HG
Luvisolic	Gray Luvisol	Orthic Gray Luvisol, O.GL
		Brunisolic Grey Luvisol, BR.GL
		Gleyed Dark Gray Luvisol, GLD.GL
Organic	Mesisol	Terric Mesisol, T.M
	Humisol	Terric Humisol, T.H
Podzolic	Humo-Ferric Podzol	Orthic Humo-Ferric Podzol, O.HFP
Regosolic	Regosol	Orthic Regosol, O.R

All required information was collected at each site (Resource Inventory Committee, 1995) including but not limited to the following:

- horizon depth, colour, texture (see Table 2-2), coarse fragment volume (%) and size;
- soil structure of each horizon;
- main rooting zone depth;
- depth to root restricting layer;
- depth of seepage;
- drainage class;
- terrain classification;
- Canadian Soil Classification;
- humus form classification and depth of LFH; and,
- depth of Ah and Ae horizon to assist in fertility interpretation.

Table 2-2. Soil texture class abbreviations (BCMoFR & MOE, 2010)

Soil Texture	Abbreviation
Sand	S
Loamy sand	LS
Silt	Si
Sandy loam	SL
Sandy clay loam	SCL
Loam	L
Silt loam	SiL
Sandy clay	SCC
Clay loam	CL
Silty clay loam	SiCL
Silty clay	SiC
Clay	C
Heavy clay	HC

Biophysical attributes can also impact soil development and the supply of soil nutrient and moisture resources. Standard ecological (biogeoclimatic) site information (MacKillop et al., 2018) was collected at each soil plot location including some, or all, of the following:

- BEC to the site series level;
- moisture and nutrient regimes;
- slope gradient (%) and aspect;
- meso slope position;
- structural stage;
- surface topography;
- evidence of soil instability (e.g., erosion, tension cracks, buttressed trees).

Soil pH and alkalinity were measured in the field using pH test kits, as well as a visual effervescence field test for the presence of carbonates using 0.1N hydrochloric acid (HCl). Soil pH and the effervescence test are useful to confirm soil pH greater or less than 5.5 that is relevant to great group determination within the Brunisolic soil order (Agriculture and Agri-Food Canada, 1998); and to locate alkaline layers (i.e., pH >7.5), which is a common feature in limestone-rich bedrock types (i.e., soils that react to dilute HCl).

Alkaline soil types can have negative impacts on the availability of some soil nutrients (e.g., phosphorous, nitrogen and potassium); as such, this information can assist in reclamation interpretation for the LSA. In particular, Melanic and Eutric Brunisols in the drier climates of the East Kootenay often have high pH (greater than 5.5) and an accumulation of calcium carbonate ($CaCO_3$; from weathered limestone-rich bedrock types) that are leading contributing factors in reducing the availability of other plant nutrients (Kaya et al., 2009).

Soil type changes or unusual soil features, such as roadside slumps or mineral licks, were also noted.

Soil and site field data were entered into a database using the VENUS data capture application (BCMOE, 2004).

2.3.2. Soil Sampling for Chemical and Physical Analysis

At representative soil pit locations, soil samples from different depths (e.g., LFH, surface mineral (0-15 centimeter (cm)), subsurface mineral (often >40 cm depth), and/or a specific soil horizon) were collected using a small, clean stainless-steel trowel and placed directly into labelled plastic bags. The soil samples were stored in coolers with ice packs prior to shipment to ALS Environmental in Burnaby, BC. Methodology references are provided in Appendix 2.

Soil samples were collected from pit locations, primarily near infrastructure areas, within the LSA. The laboratory analysis aids in the establishment of baseline conditions of metal concentration (reported in Baseline Metal and Polycyclic Aromatic Hydrocarbon (PAH) Report (KES, 2019)), confirms field classifications and may be used to determine soil salvage and erosion potential. Samples analyzed for metal concentrations were collected to help establish baseline conditions throughout the LSA. These laboratory results are used to characterize ecological exposure for relevant receptor groups (AECOM, 2020). These samples were collected at an average depth of 0.3 m to capture the average rooting depth of associated tissue samples collected at these sites. Samples analyzed for nutrient concentrations were also collected from an average depth of 0.3 m to help inform soil salvage potential, management and reclamation for the purposes of reclamation and closure planning. Particle Size Analysis was performed on some of the samples to verify field classifications. Individual horizons (e.g., Bm for pH, and Ah for organic carbon content) were occasionally sampled to aid in soil classification.

2.4. Determination of Soil Map Units (SMU) – Soil Polygon Creation

Draft SMUs were defined once a pattern of major soil types in the LSA was established from examination of imagery and existing local information (Ryder, 1981; Yole and Lau, 2017). The SMUs were refined to better reflect important soils found during field sampling. The ecosystem polygons created by the TEM for the Project were used as a base polygon layer for soil mapping purposes. Soil attributes, slope gradient, slope position, aspect, terrain mapping and ground plot data were used to identify uniform soil types, or SMUs, on the landscape. The TEM polygon boundaries were modified to account for terrain and soil differences. Simple (single SMU) and complex (two or three SMUs) soil map units were assigned to each polygon as appropriate. Frequently, TEM polygons contain up to three ecosystem components and so soil variability in concert with site and vegetation is often seen. Where field plots were available and representative of significant portion of the polygon, soil texture, soil moisture, coarse fragments (%), moisture/nutrient regime, slope gradient (%), soil classification (Agriculture and Agri-Food, 1998) and slope position, were all used to assist in identifying soil type (i.e., SMU) and refining polygon line work. Where field plots were not available, imagery interpretation was relied on to determine the most appropriate SMU. Additionally, linework from the terrain mapping (BGC Engineering Inc., 2019) was used to assist in interpreting landforms.

Due to the soil and terrain variability on the landscape, many polygon labels are complexes to account for soil differences. Proportions of soil components are displayed using slashes separating components (modified from Newfoundland and Labrador Geological Survey, 2014). For example, a soil polygon label of SMU 1a/SMU 2a has between 60 to 80% soil characterised by the SMU 1a type and 20 to 40% soil characterized by the SMU 2a type (Table 2-3).

Table 2-3. Polygon Label Proportions

Sample Soil Polygon Label	Description
SMU1a	100% of polygon characterised by SMU1a
SMU1a/SMU2a	60-70% of polygon characterised by SMU1a; 30-40% of polygon characterised by SMU2a
SMU1a/SMU2a/SMU3a	50-70% of polygon is characterised by SMU1a; 20-40% of polygon is characterised by SMU2a; 10-20% of polygon is characterised by SMU3a
SMU1a//SMU2a	80-90% of polygon is characterised by SMU1a; 10-20% of polygon is characterised by SMU2a
SMU1a=SMU2a	The proportion of SMU1a and SMU2a are approximately equal

The lead SMU in a complex polygon determines the colour theme of the polygon on the display soil map (Appendix 1). Area of each SMU reported in the results section is calculated by calculating approximate percentage composition in complex polygons.

2.4.1. Soil Erosion Potential (SEP) and Soil Salvage Potential (SSP)

Soil erosion potential (SEP) is represented by a categorical value that indicates the erosional hazard associated with a soil type (Figure 2-1). These categorical values range from Low (L) to Very High (VH) and are determined by considering several factors including, topography (slope gradient), depth to restricting layer, texture (surface and subsurface soils) and coarse fragment content. In addition to those variables assessed above and presented in Figure 2-1, SEP rating was increased for polygons subject to avalanching and adjacent to creeks or rivers. SEP was assessed for each SMU; as numerous polygons contain more than one SMU component and/or site variation within an SMU, the SEP rating often contains a range (e.g., L-M). SEP was also adjusted upwards for polygons immediately adjacent to creeks or rivers. Two instances of note, where SEP can differ within an SMU due to variation in texture, are for SMUs 1a and 3. Some tills (SMU 1a) have sandy loam textures while others are siltier. The siltier tills are more erodible and as they tend to predominate, SEP was based on this texture. SMU 3 (fine-textured soils) can either be silt to silt loams or clayeyer textures (silty clay loams). SEP was based on the more erodible and widespread silty texture.

Soil Salvage Potential (SSP) is also represented by a categorical value that indicates the potential suitability of a soil for salvage (Table 2-4). These categorical values range from Very Low (VL) to High (H) and are determined by considering several factors including, organic matter, texture, coarse fragment content, pH, effervescence and consistence (i.e., friability). SSP was assessed for each SMU; as numerous polygons contain more than one SMU component and/or site variation within an SMU, the SSP rating often contains a range as well. The above-mentioned variation in texture within SMU 3 results in differing SSP within this SMU, with clayeyer soils being less desirable for salvage due to workability issues.

For both SEP and SSP, a value of N/A was assigned to anthropogenic soils.

Site factors	Degree of contribution of factors			
	Low	**Moderate**	**High**	**Very high**
Climate precipitation factor **(points)**	low **2**	moderate **4**	high **6**	very high **8**
Topography slope gradient (%) **(points)**	0-10 **1**	11-20 **3**	21-50 **6**	>50 **9**
length/uniformity **(points)**	short broken **1**	short uniform **2**	long broken **3**	long uniform **4**
Depth to water-restricting layer (cm) **(points)**	>90 **1**	61-90 **2**	30-60 **3**	<30 **4**
Surface soil detachability (0-15 cm)[a] **(points)**	SC,C,SiC **1**	SiCL,CL,SCL **2**	SL,L **4**	Si,SiL,fSL,LS,S **8**
Surface coarse fragments (0-15 cm)[a] **(points)**	>60 **1**	31-60 **2**	16-30 **3**	<16 **4**
Subsoil permeability (16-60 cm)[a] texture **(points)**	S,LS,SL,fSL **1**	L,SiL,Si **2**	CL,SCL,SiCL **3**	C,SC,SiC **4**

Soil erosion hazard rating[b] **(point total)**	**Low** <16	**Moderate** **16-22**	**High** **23-31**	**Very high** **>31**

[a] If two contrasting textures or coarse fragment contents occur in the depth, use the one with the highest point rating.
[b] Gently sloping areas with long, uniform slopes may rate as high soil erosion hazard. The reason is that substantial erosion can occur on these sites given the right conditions.

Figure 2-1 Soil erosion potential (SEP) classes (BCMoF & MOE, 1999)

Many of the factors in assessing SSP (Table 2-4) are difficult or impossible to assess from imagery; hence the assessment relies on field samples and relationships between these factors and SMUs established through the field sampling. A critical factor assessed in determining soil salvage potential, beyond those noted in Table 2-4 was slope steepness. Slope gradients >45% are impractical and unsafe to salvage soil from (Teck, 2015). So, regardless of other factors, polygons with slope gradients >45% were considered to have very low soil salvage potential. Soil salvage potential was reduced for sites that were >30% slope gradient from that determined from assessing factors in Table 2-4. Another issue in evaluating soil salvage potential when creating a soil salvage plan will be accessibility. This factor was not evaluated in the ratings given each soil polygon.

Table 2-4. Soil salvage potential (SSP) ratings

Criteria	High (H)	Medium (M)	Low (L)	V Low or Nil (VL-Nil)
Ah depth (cm)	> 3	1-3	0	0
Mineral texture	SiL, L, SL	LS, SiCL, SCL CL	S, C, Si, SC, HC	HC, bedrock
Root zone depth	> 40	25-40	<10-25	<10
Coarse fragment content (%)	<50	50-75	70-90	>90
Reaction (pH)	6.5-7.5	5.5-6.4	4.5-5.4	<4.5->9
Calcareous subsurface	Nil to minor fizz	Moderate fizz	Strong fizz; visible salt crystals	Very strong fizz
Consistence (moisture)	Friable	Loose, firm	Very firm, sticky (wet)	Extremely firm

Source: Yole and Lau 2017; MacCallister, personal communication, 2016.

2.4.2. Organic Carbon Content

Commonly, for the purposes of soil salvage there are two major components for evaluating soil suitability; topsoil or upper lift (the surface A horizon(s) of the soil profile) and subsoil or lower lift (the B horizon(s) and upper portion of the parent material, where suitable given site-specific conditions). Salvaging of the top lift as a separate unit is important in that organic matter levels as well as important macro and microorganisms are less diluted, it generally has better growth support capability and it may serve as an excellent seed source for native species. Typically, soils that develop under coniferous forests are relatively nutrient poor and have poorly decomposed litter layers, either resulting in no or a thin Ah (<5 cm). The soils observed throughout the LSA typically have thin A horizons which will result in one lift that combines both A and B horizons, as is common the local area (Teck, 2015). Soil organic carbon content was not tested for all soil samples collected throughout the LSA, rather this important aspect can be inferred from the presence and depth of the Ah horizon.

2.4.3. Soil Reaction (pH) and Free Carbonates ($CaCO_3$)

Soil pH can change the availability of some minerals and nutrients within the soil profile. In strongly acid soils, the availability of soil macronutrients (e.g., potassium (K), phosphorus (P), nitrogen (N) and sulphur (S)) is curtailed. In contrast, the availability of micronutrients is increased by low soil pH. In slightly to moderately alkaline soils, macronutrients are amply available (except P) but micronutrient levels are so low that plant growth is constrained. Generally, pH ranges between 5.5-6.5 provide the most satisfactory plant nutrient levels (Brady & Weil, 2004). The effects of soil pH on plant nutrient availability are further complicated on limestone-rich bedrock types, where free calcium carbonates in the soil result in serious micronutrient and phosphorous deficiencies. Calcareous soils are also prone to cementation, thereby restricting root penetration deeper into the soil profile.

2.4.4. Texture and Coarse Fragment Content

Suitable soil textures for salvage and reclamation are among the most moderate or loamy textures, often ranging from fine sandy loams to silt loams, excluding the largest and smallest extreme texture classes (i.e., sand and [heavy] clay). This is due to their moisture and nutrient holding capacities and favourable physical properties. Percent coarse fragments by volume ideally ranges between 0 to 30% for all suitable textures.

2.5. Laboratory Analysis of Soil Samples

Laboratory analyses performed by ALS Environmental, an accredited laboratory located in Burnaby and Saskatoon, include soil fertility parameters such as available cations (calcium (Ca), magnesium (Mg), sodium (Na)), available N, P, K and S, pH (2:1 water:soil to determine soil acidity) and total Kjeldahl Nitrogen (%; TotN), as well as particle size analysis. Test methods used are provided in the Certificate of Analysis (Appendix 2). All chemical results are reported in milligrams per kilogram (mg/kg).

No soil samples were collected for laboratory analysis in the rail loop area proposed prior to October 2019 (Grave Prairie Access Management Area) as this area falls within in a high value area (Ktunaxa Nation, personal communication, 2018) for significant archaeological features of importance to the Ktunaxa Nation. In addition, some soil samples were collected in representative soil types throughout the LSA that are not expected to be disturbed during mining operations. These samples located away from planned infrastructure, provide a record of undisturbed baseline conditions for long-term soil monitoring and characterization of soil materials well away from possible sources of disturbance.

3. RESULTS

3.1. Plot Location and Site Information

In 2017, a total of 101 detailed soil pits, with full horizon descriptions and classification contributed to the creation of the interpretive soil map for the LSA. In addition, 108 visual plots, which include notes on basic site, terrain and soil classification, helped to confirm SMUs and to refine soil polygon boundaries (see Figure 1-1, Figure 1-2). Jessica Lowey from KES completed soil descriptions in nine additional locations throughout the proposed rail loop infrastructure area in October 2017 (Grave Prairie). This protected area has special significance to the Ktunaxa Nations and requires special permission to excavate soils; as such, Ms. Lowey was accompanied by a member of the Ktunaxa Nation during the fieldwork.

Thirteen additional soil descriptions were completed in 2018 in other infrastructure sites not previously captured, specifically relating to the 2018 mineral exploration program and aimed to capture deeper soil information at 13 drill pads across the Crown Mountain ridge in the LSA. In 2019, an additional 50 observations were made comprising 8 detailed plots and 42 visual observations. Detailed soil, environment and vegetation data were entered into VENUS (BCMOE, 2004) in 2017, with additional field plots from 2018 and 2019 added in 2019.

In total, 276 soil plots were examined, of which 138 were considered visual in nature (i.e., contain less detailed descriptions and often are not associated with an excavation). Soil inspections were focused on areas largely inside or near planned infrastructure areas and along planned transportation corridor options. The minimum target to achieve a detailed level sample intensity (SIL2) within the Project footprint was attained, with 123 plots being assessed, while the target was 97. For the remainder of the LSA, a minimum target of 52 plots to attain a reconnaissance level sample intensity (SIL3) was also exceeded, as 153 plots were assessed in the remainder of the LSA. These numbers of plots do not consider the terrain plots that were also used to assist in the mapping.

Terrain mapping conducted in 2017 (BGC Engineering Inc., 2019), also gathered valuable data to aid soil mapping (e.g., terrain classification, soil texture and coarse fragment content). A total of 214 terrain observations were made including 79 detailed plots, 35 visual observations (see Figure 1-1, Figure 1-2) and 100 photo points. The terrain mapping linework was also examined while delineating SMU polygons. Furthermore, 2017 and 2019 baseline soil chemistry data that was collected to inform the human and wildlife health assessment for the Project was used when considering the soil chemistry across the LSA. A total of 38 additional samples (see Figure 1-1, Figure 1-2) were submitted to ALS Environmental for the chemistry baseline assessment.

Twelve (12) soil samples were also analyzed for particle size. These samples were collected in areas that could be viewed as sensitive to soil erosion, often being adjacent to water features or in areas where unstable surficial materials were evident.

3.2. Soil Map Units

Seventeen (17) SMUs were described. The SMUs are repeatable soil types on the landscape and have soil characteristics that could have significant management implications for construction and reclamation activities.

3.2.1 Description of SMUs in the Study Area

Soil map units were finalized once a pattern of main soil types in the LSA was established through field sampling and image analysis. SMU descriptions characterize the most common soil characteristics such as parent material, soil texture, drainage, soil nutrient and moisture regime, depth to water table or seepage, soil colour, percent coarse fragment volume (%). Soil classification common to each SMU follows the Canadian System of Soil Classification (Agriculture and Agri-Food Canada, 1998). Table 3-1 presents typical characteristics of the SMUs based on local field sampling; there may be instances where the descriptions do not describe all possible examples of the SMU. Their percentage contribution to the LSA and Project footprint is also presented. SMU's are grouped by number, as presented in Table 3-2. More detailed characteristics are noted below and in

Table 3-2.

In steep terrain, colluvial veneers (circa 50 cm deep) of loose soil and angular coarse fragments overlying other SMUs are frequently found.

Table 3-1. Soil Map Unit group definitions

SMU Number	Basic Soil Characteristics (Parent Material Identifier)
1	Till (morainal) soils (M)
2	Shallow soils, less than 0.1 m (veneer(v))
3	Glacio-lacustrine soils (LG)
4	Colluvial soils (C)
5	Glacio-fluvial soils (FG)
6	Fluvial soils (F)
7	Wetland soils

SMU 1a: Circum-mesic glacial till (3,490 ha, 27% LSA; 377 ha, 25% Project footprint)

These soils are generally deep tills (occasionally colluvium) >1.0 m to bedrock; blankets of sandy loam and minor silty glacial till, largely found on moderately steep terrain (10-60% gradient). Coarse fragment content is generally quite low for tills, often around 30%. They are often found in mid-to upper slope position and can occur in steeper terrain (i.e., >50% slope gradient) and include colluviated till materials showing some signs of water worked clasts and downslope movement. These soils (O.EB, E.EB, (BR.GL less commonly)) form in mesic and or slightly drier ecosystems within the MSdkw, ESSFdk1 and ESSFdkw (MacKillop et al., 2018). Seepage and mottles are uncommon in this SMU. A root restricting calcic layer is common in this SMU at an average depth of approximately 30 cm across 25% of sites. Where slopes are not excessive and root restricting layers are not present, these soils are well suited to salvage operations and are often moderately fertile. This SMU is the second most prevalent SMU in both the LSA and Project footprint.

SMU 1b: Lower slope position till (and colluvium) (289 ha, 2% LSA; 74ha, 5% Project footprint)

Deep soils forming in lower and toe slope positions often with subsurface seepage water (imperfectly drained). Ecosystems and plant vigour indicate higher available nutrients and productivity. Soil texture is mainly loamy (L, SL, SiL). Parent materials are generally till or less commonly colluvium on 10-30% slope gradient. These soils often have slightly higher organic matter content accumulating near the upper horizons. SMU 1b generally has darker surface mineral horizons or intermixed surficial soil materials (e.g., Ah). Soils are moist but not saturated for significant periods in the growing seasons, thus gleying and prominent mottling is not a common soil feature of this SMU. Typical soil classification for this SMU include O.EB, GL.EB and O. MB. This relatively uncommon SMU is found in the MSdw and ESSFdk1 biogeoclimatic units. Where accessible and the proximity to water bodies does not create unacceptable sedimentation risk, these soils are highly desirable for salvage.

SMU 2a: Moderately shallow soil (2,298 ha, 18% LSA; 354 ha, 23% Project footprint)

These moderately shallow soils (50-100 cm to bedrock) are found on a variety of parent materials, till, colluvium and saprolite (weathered-in-place bedrock). Soils are drier than the SMU 1a type owing to shallower soil depth, slope position (i.e., upper to crest position) and/or soil texture. Soil drainage is well to rapidly drained, while soil moisture regime is submesic to subxeric (MacKillop et al., 2018). Sandy or loamy textures and moderate to high coarse fragment content (30-70%) and shallow soil depth result in slightly nutrient poor soils, supporting average to lower productivity forests, depending on position on the landscape. Saprolite is widespread on Crown Mountain in conjunction with coal bearing strata. These soils often have shallow effective rooting zone of <25 cm and relatively thin and acidic mor forest floor materials (4-8 cm thick). Soil classification is typically E. EB, O.EB and E.DYB with shallow lithic family. This SMU generally has a low potential for soil salvage. This SMU is the most widespread in both the LSA and Project footprint and is found at all but the highest elevations (generally absent from ESSFdkp).

SMU 2b: Very shallow soils (931 ha, 7% LSA; 99 ha, 6% Project footprint)

Very shallow (10-50 cm) soil deposits of colluvium, saprolite (weathered-in-place bedrock) or morainal veneers over bedrock comprise SMU 2b. Soils often contain a high percentage of loose angular coarse fragments on steep slopes (often >45-50% slope gradient). This SMU is common on upper and crest slope positions and has very limited moisture holding capacity. Soil drainage is very rapidly or rapidly drained. Vegetation is often open-canopy, short-stature forest or low shrub or graminoid-dominated. These soils have little or no value for soil salvage. These soils are found with greater frequency as elevation increases throughout the LSA.

*SMU 3: Fine-textured soils (*1,134 ha, 9% LSA; 112 ha, 7% Project footprint)

These soils are found on deep, undulating glacio-lacustrine parent material. Slopes are generally gentle (0-30%) apart from scarp faces. Soil textures sampled range from SiL to SiC, with 15% or fewer coarse fragments. Soil drainage is commonly moderately well- to imperfectly drained, translating to mesic to subhygric soil moisture regimes. Brunisolic Grey Luvisols are the dominant soil sub-group but a wide variety of soil types are found (Table 3-2). These soils can be very prone to surface erosion (if silty) or mass wasting. They are generally unsuitable for soil salvage due to their physical properties and the common presence of a calcic root restricting layer (average depth of 50 cm at more than 50% of sites). These soils are found primarily at Grave Prairie and just north of Highway 3 in the south end of the LSA and as such, are mostly found in the MSdw subzone.

SMU 4a: Deep colluvium (1,147 ha, 9% LSA; 187 ha, 12% Project footprint)

Deep (>100 cm) colluvium on steep slopes (35-90% slope gradient) comprise SMU 4a soils. Deep and loose soils with abundant coarse fragments (>50% by volume) are characteristic. Main soil classifications include O.EB and E.EB. Soil drainage is commonly well to moderately-well (submesic to mesic soil moisture regime). Steep glacial till and colluvium were sometimes hard to distinguish on imagery and soil forming processes may be similar with some gravity processes in soil formation. These soils are seldom conducive to salvage as they are found on slope gradients that do not allow for recovery and their high coarse fragment content limit their productivity.

SMU 4b: Soils with evidence of mass movement or erosion (256 ha, 2% LSA; 71 ha, 5% Project footprint)

This SMU is characterized by colluvial veneers or blankets or morainal (till) that exhibit evidence of historic mass movement or erosion. They exhibit either exposed soil or non-forested vegetation surrounded by forest on steep slopes without obvious snow avalanching. Soils are often deeper than 100 cm and are found on steep slopes (45-90% gradients). They are typically found in mid to lower slope position with imperfect drainage contributing to the instability. While the bulk of the area within polygons classified as SMU 4b may have not experienced instability, significant portions (>30% of the polygon) will have some evidence of historic failure. This SMU is unsuitable for soil salvage.

SMU 4c: Talus (295 ha, 2% LSA; 14 ha, 1% Project footprint)

Rubbly, bouldery talus materials, often with 75-95% angular cobble and stone clasts comprise this SMU. Coarse fragment volume is derived from varied local bedrock types. Slope gradients are 40-90%. Due to the lack of fine materials this SMU is generally classified as non-soil. Soil depth is variable, but generally very shallow. Most of this SMU is non-vegetated, however the lower fringe of talus slopes may exhibit productive ecosystems due to seepage emerging at the base of the talus. This SMU is not suitable for soil salvage.

SMU 4d: Avalanche track (511 ha, 4% LSA; 76 ha, 5% Project footprint)

SMU 4d comprises active snow avalanche terrain with evidence of moving soils (e.g., buried soil horizons; jack-strawed trees or curved tree bases). This SMU is subject to failures especially in high moisture spring periods during active snow melt. Flash overland flooding and channeling/gullying water erosion processes are common especially in the spring freshet. Areas at the toe of slope and across valley are commonly associated with windshear, including blow-down tree events and associated pedoturbation (soil mixing). Avoid disturbing these steep slopes where possible in wet periods. Dry, stable and old avalanche slopes with high coarse fragment content are relatively stable surficial materials. Soil drainage is variable, primarily depending on soil depth and slope position. Where these sites are dominated by tall shrubs, alder or willow, soil drainage is often imperfect.

SMU 5a: Glaciofluvial, gentle slopes (397 ha, 3% LSA; 60 ha, 4% Project footprint)

SMU 5a is comprised of sandy, gravelly, cobbly glacio-fluvial terraces or undulating blankets with slopes of 0 to 35%. Soils are relatively loose with high coarse fragment content, commonly >50% clast volume and a shallow main rooting zone, often <25 cm from surface. Main soil types are brunisols, primarily E.DYB or O.DYB. These soils are often moisture and nutrient deficient for part of the growing season and can support dense, low productivity lodgepole pine forests. These soils are typically found at lower elevations in the LSA. This SMU is generally not desirable for soil salvage due its lack of soil moisture holding capacity.

*SMU 5b: Glaciofluvial terrace scarps (*73 ha, 1% LSA; 12 ha, 1% Project footprint)

This SMU includes the steep, often unstable scarp faces of SMU 5a soils, where they are extensive enough to allow for mapping. These soils are prone to periods of summer drought, especially on warm aspects. Rapid debris failures (dry ravelling) are commonly found near creek features or where undercut by roads. Main soil types are like SMU 5a. Vegetation is often non-forested. These soils are often recognized as minor components within map polygons comprising mostly SMU 5a. These soils are not suited to salvage.

SMU 6a: Mid-high bench fluvial (473 ha, 4% LSA; 13 ha, 1% Project footprint)

These are relatively old fluvial deposits or terraces associated with creeks and are often moderately well to imperfectly drained. Sites are flooded periodically from annually to up to 20 years, often leading to a component of deciduous trees (e.g., black cottonwood). Soil textures and coarse fragment content vary from silty overbank deposits to cobbly, sandy textures laid down by swiftly flowing waters. Soil types include GL.EB and O.MB. Elevations are between 1.5 to 10 m above the present creek level. This type is seldom found more than 50 m from the stream edge. This SMU can be sensitive to compaction and highly susceptible to surface soil erosion depending on soil texture. These soils may be desirable for use in soil salvage, however issues with sedimentation and the disturbance of riparian habitat will likely make salvage problematic.

SMU 6b: Low-bench and active fluvial (288 ha, 2% LSA; 37 ha, 2% Project footprint)

Soils forming in active, moist to wet fluvial deposits (i.e., creek draws and channels) subject to annual flooding leading to exclusion of forest vegetation. Herb and shrub vegetation are found outside of active channel. Textures are generally coarse and coarse fragment content high. Due to their active nature, these soils are not suitable for salvage.

SMU 6c: Fluvial and colluvial fans (124 ha, 1% LSA; not mapped in Project footprint)

Gently sloping (5-25% gradient) fluvial or colluvial deposits found at the mouths of side drainages. Textures are generally coarse (more mixed in colluvial materials) with high coarse fragment content. Surface water channel may or may not be present. Water channels may be subject to change in course during flood or debris flow events. In the LSA, this SMU does not exhibit widespread recent deposition or erosion and has mature forest present. This is a relatively rare SMU covering only 1% of the LSA and not present in the infrastructure area. Due to their variable nature, some of these soils may be suited to salvage, however care will need to be taken in consideration of drainage and surface water patterns.

SMU 7: Wetland Soils (108 ha, 1% LSA; 2 ha, 0.1% Project footprint)

Theses soils are rare in the LSA and are found with organic veneers or blankets or gleyed mineral soils in the case of marshes and some swamps, in depressional sites or adjacent to Alexander Creek or the Elk River. Soils sampled in this SMU belong to the terric subgroup of organic soil orders or the humic gleysol soil great group (T.M, T.H, O.HG). Soil drainage is poorly to very poorly drained. Due their importance to biodiversity, these soils should not be considered for soil salvage. This SMU has the smallest extent of any of the mapped units.

SMU RO: Rock Outcrop (603 ha, 5% LSA; 28 ha, 2% Project footprint)

Very common in upper slope positions at high elevation (ESSFdkp subzone), but absent (at least at mappable scale) at lower elevations (MSdw subzone). Defined as areas with <10 cm of soil over bedrock. This SMU is non-vegetated or sparsely vegetated.

SMU OW: Open Water (78 ha, 1% LSA; 3 ha, 0.2% Project footprint)

This non-soil map unit is rare and consists of ponds, reservoirs and Grave Lake.

SMU A: Anthropogenic (391 ha, 3% LSA; 14 ha, 1% Project footprint)

This map unit consists of human-disturbed surficial materials, including roads, railways, pipelines or rural and agricultural properties. This map unit has soils impacted by changes to soil physical properties significantly from natural soils.

Table 3-2. Soil Mapping Unit (SMU) Characteristics

SMU	Name	Parent Material[1]	Texture	Soil Depth	Slope Gradient%	Slope Position	Soil Drainage[2]	BGC Unit[3]	Soil Classification
1a	Circum-mesic till	Mb (Cb)	SiL, SL, L; 15-40% CFs	>100cm	10-60	mid	w-mw	MSdw, ESSFdk1, (ESSFdkw)	O.EB, E.EB, BR.GL
1b	Lower slope till (and colluvium)	Mb, Cb	SiL, L, SiCL; 0-60% CFs	>100cm	10-30	lower	mw-i	MSdk, ESSFdk1,	O.MB, GL.MB, GL.EB
2a	Moderately shallow soils	Cv, Mv, Dv	SL, L, SiL LS; 30-70% CFs	50-100cm	20-70	upper-mid	r-w	MSdw, ESSFdk1, ESSFdkw	E.EB, O.EB, E.DYB
2b	Very shallow soils	Dv, Dx, Cv,Cx, Mv, Mx	LS, S, SL, SiL; 60-90% CFs	10-50cm	5-90	crest - upper	x-r	ESSFdk1, ESSFdkw, ESSFdkp	O.EB, E.DYB,
3	Fine-textured soils	LGu or p	SiCL, SiC, Si, SiL; 0 (15)% CFs	>100cm	0-30	mid (variable)	mw-i	MSdw (ESSFdk1)	BR.GL, O.GL, GL.EB, O.EB, GL.MB, O.MB
4a	Deep Colluvium	Cb	L, SiL, (SiCL, S SL, LS) 60-90%CFs	>100cm	35-90	mid (upper, lower)	w(r, mw, i)	MSdw, ESSFdk1	O.EB, E.EB
4b	Soils with evidence of mass movement or erosion	Cb, Mb, Cv	unsampled	50->100cm	50-90	mid, lower	i-mw	MSdw, ESSFdk1	unsampled
4c	Talus	rCb	90-100% CFs	50cm->100cm	45-90%	mid	x	ESSFdk1, ESSFdkw, (MSdw)	non-soil
4d	Avalanche track	Cb, Cv	variable	50cm->100cm	30-90%	variable	variable	ESSFdk1, ESSFdkw, (ESSFdkp)	unsampled

SMU	Name	Parent Material[1]	Texture	Soil Depth	Slope Gradient%	Slope Position	Soil Drainage[2]	BGC Unit[3]	Soil Classification
5a	Glaciofluvial, gentle slopes	FGp,j,u	S, LS; 30-80% CFs	>100cm	0-35	Level	r	MSdw, (ESSFdk1), ESSFdkw	O.DYB, E.DYB
5b	Glaciofluvial terrace scarps	FGk,s	S, LS; 30-80% CFs	>100cm	50-90%	variable	r-x	MSdw	O.DYB, E.DYB
6a	Mid-bench Fluvial	Fp,j,u	SiL, LS, S, (CL) variable % CFs	>100cm	0-10%	level	mw-p	MSdw, (ESSFdk1)	GL.EB, O.MB
6b	Low-bench and active Fluvial	Fp	LS, S, SiL, variable % CFs	>100cm	0-10%	level	i-p	MSdw, (ESSFdk1)	O.HG, GL.MB, GL.EB, O.R
6c	Fluvial and Colluvial fans	Ff, Cf	S, SiL,L, variable % CFs	>100cm	10-25%	mid-lower	w-mw	MSdw, ESSFdk1	O.MB, O.R
7	Wetland soils	Ob, Ov, Fp		>100cm	0	level, depression	p-vp	MSdw, (ESSFdk1)	T.M, T.H, O.HG
RO	Rock Outcrop	n/a	n/a	n/a	variable	variable	n/a	ESSFdk1, ESSFdkw, ESSFdkp	non-soil
OW	Open Water	n/a	n/a	n/a	n/a	n/a	n/a	MSdw, (ESSFdk1)	non-soil
A	Anthropogenic	A	n/a	n/a	variable	variable	n/a	MSdw, (ESSFdk1, ESSFdkw)	n/a

[1] Lower case letters refer to surface expression; b=blanket, f=fan, j=gentle slope, k=moderately steep slope, p=plain, s=steep slope, u=undulating, v=veneer, x=very thin veneer
[2] i=imperfectly, mw=moderately well, p=poorly, r=rapidly, vp=very poorly, w=well, x=very rapidly, as defined in BCMoFR & MOE (2010)
[3] brackets denote BGC units where SMU rare

3.2.2 Distribution of Soil Map Units

The most common SMUs in the LSA and Project footprint on an area basis are SMU 1a circum-mesic glacial till and SMU 2a moderately shallow soils (Table 3-3). Combined, these two SMUs account for 45% of the LSA and 51% of the Project footprint. The circum-mesic glacial till soils are found most abundantly at lower elevations (MSdw subzone), while moderately shallow soils become more frequent at higher elevations (ESSFdk1 variant).

The next most abundant SMUs are 4a deep colluvium and 3 fine-textured soils, each found covering 9% of the LSA, and 12% and 6% of the footprint, respectively; and 2b very shallow soil covering 7% of the LSA and 10% of the footprint. SMU 3, predominantly glaciolacustrine soils, are found most frequently at lower elevations (MSdw) in the Grave Prairie area and at the southern end of the LSA.

Apart from the above, the following map units, listed in descending order of area, were found with >1% occurrence in the Project footprint (percentages presented are for the footprint):

- 4d Avalanche tracks –66 ha, 5%
- 4b Soils with evidence of mass movement or erosion – 60 ha, 5%
- 6b Low-bench and active fluvial –37 ha, 2%
- 1b Lower slope position till (and colluvium))—36 ha, 3%
- RO Rock outcrop – 32 ha, 2%
- 5a Glaciofluvial, gentle slopes – 29 ha, 2%

In total, 612 soil polygons were mapped in the LSA.

Table 3-3. SMU area and percentage in LSA and Project footprint

SMU	Area in LSA (ha)	% of LSA	Area in footprint (ha)	% of footprint
1a Circum-mesic glacial till	3,490	27%	304	24%
1b Lower slope position till	289	2%	36	3%
2a Moderately shallow	2,298	18%	347	27%
2b Very shallow	931	7%	127	10%
3 Fine-textured	1,134	9%	71	6%
4a Deep colluvium	1,147	9%	151	12%
4b Soils with evidence of mass movement or erosion	256	2%	60	5%
4c Talus	295	2%	16	1%
4d Avalanche track	511	4%	66	5%
5a Glaciofluvial, gentle slopes	397	3%	29	2%
5b Glaciofluvial terrace scarps	73	1%	5	0.4%
6a Mid-bench fluvial	473	4%	10	1%
6b Low-bench and active Fluvial	288	2%	19	1%
6c Fluvial and colluvial fans	124	1%	2	0.1%
7 Wetland soils	108	1%	1	0.05%
A Anthropogenic	391	3%	12	1%
OW Open Water	78	1%	1	0.05%
RO Rock Outcrop	603	5%	32	2%
Total	12,886	100%	1,287	100%

3.2.3 Soil Erosion Potential (SEP)

Soils with very high erosion hazard (polygons with very high (vh), vh to high (h) SEP rating) comprise 22% of the Project footprint (Table 3-4). While soils with high SEP (polygons with h, h-moderate (m), vh- m, m-vh, m-h SEP rating) comprise an additional 44% of the Project footprint. This is reported for the Project footprint as this will be the area of highest concern, but this interpretation is available across the LSA. Maps displaying erosion potential are found in Appendix 3. The maps in Appendix 3 present the SEP interpretation in simplified hazard classes as noted above and in Table 3-4. Note that for both SEP and SSP, a value of N/A was assigned to anthropogenic soils.

Table 3-4. SEP within the Project footprint SEP within the Project footprint

SEP Category	Area within Project footprint (ha)	% of Project footprint	Hazard Class
vh	72	19%	Very High
vh-h	42	3%	
h	73	6%	High
h-m	30	2%	
vh-m	71	6%	
m-vh	45	3%	
m-h	352	27%	
m	438	34%	Moderate
m-l	125	10%	
l	21	2%	
n/a	13	1%	N/A
Total	1,283	100%	-

3.2.4 Soil Salvage Potential (SSP)

Soils with good potential to be salvaged for rehabilitation purposes (e.g., m, m-h, m-low (l) classes) cover 27% of the Project footprint. (Table 3-5). Another 17% of the footprint has fair potential for soil salvage. As for SEP, this has been reported for the Project footprint. Also, as for SEP, the categories presented in the SSP display maps found in Appendix 4 have been simplified into good, fair and unsuitable classes. Maps of soil salvage potential are provided in Appendix 4 and include interpretations across the LSA. Note that for both SEP and SSP, a value of not applicable (N/A) was assigned to anthropogenic soils.

Table 3-5. Soil Salvage Potential within Project footprint

SSP Category	Area within Project footprint (ha)	% of Project footprint	Suitability Class
m-h	96	7%	Good
m	131	16%	
m-l	57	4%	
l-m	207	16%	Fair
m-vl	13	1%	
l	81	6%	Unsuitable
l-vl	60	5%	
vl-m	91	7%	
vl-l	47	4%	
vl	487	38%	
n/a	13	1%	
Total	1,533	100%	N/A
			-

3.3.Laboratory Analysis

Throughout the 2017 and 2019 baseline sampling programs, 104 soil samples were analyzed for metal concentrations (reported in the Baseline Metal and Polycyclic Aromatic Hydrocarbon (PAH) Report (KES, 2019)) by ALS Environmental (

Table 3-6). One hundred and five soil samples were analysed for pH. Ninety-one samples were analysed for nutrient status (including total Kjeldahl nitrogen and other available nutrients). Twenty-six samples were analysed for particle size (i.e., soil texture). The number of samples for laboratory analysis are outlined in

Table 3-6.

Table 3-6. Summary of soil chemical and physical parameters assessed

ALS Lab Procedure Completed	Total No. Samples Analyzed 2017	Total No. Samples Analyzed 2018	Total No. Samples Analyzed 2019

Available Nitrate, Phosphate, Potassium, Sulphate	25	14	13
Total Kjeldahl N (%)	12	14	13
Particle Size Analysis	12	14	0
pH (2:1 water to soil)	69	14	22
Metals Analyses	68	14	22

Chemical analysis reveals large amounts of variation within SMUs for some parameters, as is expected with large polygons with multiple SMUs attributed (Table 3-7). For example, pH varies from 4.6 to 8.1, very strongly acidic to moderately alkaline[3] in SMU 1a, as is similar in SMUs 3, 4a and 6c (Table 3-8).

[3] pH classes from Soil Survey Manual US Dept. of Agriculture, Chpt. 3 retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253

Table 3-7. Summary of soil chemical analyses (- indicates a value not analysed)

Sample ID	Alt ID	Year Sampled	Easting	Northing	pH	Available Nitrate	Available Phosphate	Available Potassium	Available Sulphate	Total Kjeldahl Nitrogen	Calcium	Magnesium	Potassium	Sodium	SMU
Carex-06	Wetland 18	2019	653468	5520361	7.81	-	-	-	-	-	-	-	-	-	3=1a
Carex-07	Wetland 17	2019	653978	5520862	6.94	-	-	-	-	-	-	-	-	-	3//1a
Carex-08	Wetland 16	2019	653859	5521186	7.31	-	-	-	-	-	-	-	-	-	7
Salix-06	Wetland 14	2019	654385	5521760	7.36	-	-	-	-	-	-	-	-	-	7
Carex-09	Wetland 15	2019	654127	5521555	7.19	-	-	-	-	-	-	-	-	-	7
TB-01		2019	654456	5521920	8.13	2.0	3.5	127	587	0.276	-	-	-	-	3//1a
Shepcan-06	TB19-02	2019	654467	5523379	5.84	<1.0	28.6	151	<4.0	0.071	-	-	-	-	3//1a
Amelaln-06	TB19-V1	2019	653928	5522042	5.67	<1.0	89	178	<4.0	0.049	-	-	-	-	3//1a
Rosa-06	TB19-03	2019	653320	5522217	7.75	<1.0	21.1	281	<4.0	0.172	-	-	-	-	3//1a
Popubal-06	TB19-V3	2019	653338	5521460	8.05	1.1	34.8	154	<4.0	0.141	-	-	-	-	3=1a
Rubupar-06	TB19-06	2019	661210	5523134	4.62	<1.0	8.7	92	<4.0	0.196	-	-	-	-	3=5a
Vaccmem-06		2019	663519	5517832	5.39	<1.0	10.2	168	<4.0	0.126	-	-	-	-	2a/4c
Sambrac-06		2019	661928	5521578	6.42	-	-	-	-	-	-	-	-	-	2a/1a/4a
Equiarv-06	TB19-11	2019	656905	5521876	7.04	-	-	-	-	-	-	-	-	-	1a
Salix-07	TB19-14	2019	664633	5510966	6.99	-	-	-	-	-	-	-	-	-	7
Carex-10	Wetland 5	2019	664710	5510773	6.10	-	-	-	-	-	-	-	-	-	7
TB19-07		2019	663263	5517675	5.23	-	-	-	-	-	-	-	-	-	4b/1a/1b
TB19-08		2019	662978	5519065	5.13	-	-	-	-	-	-	-	-	-	4b
TB19-10		2019	655973	5522841	8.08	17.1	34.8	149	29.3	0.123	-	-	-	-	5a/5b
TB19-12		2019	665059	5516028	6.11	<1.0	12	53	<4.0	0.072	-	-	-	-	1a
TB19-15		2019	664405	5502242	6.15	<1.0	39.0	65	<4.0	0.112	-	-	-	-	5b//A
TB19-16		2019	663798	5502963	8.04	1.7	7.0	69	<4.0	0.219	-	-	-	-	5b
18-04		2018	662535	5521821	4.55	<1.0	16.2	60	<4.0	0.137	-	-	-	-	2a//1a
18-16		2018	663654	5519983	5.11	<1.0	49.7	41	<4.0	0.053	-	-	-	-	4a/2a
18-10		2018	663335	5521485	4.76	<1.0	22.5	47	<4.0	0.123	-	-	-	-	2b/2a
18-14		2018	663653	5521128	5.02	<1.0	117	34	<4.0	0.063	-	-	-	-	2b/2a
18-21		2018	663435	5519093	4.65	<1.0	74	51	<4.0	0.074	-	-	-	-	4a/2a
18-23		2018	663512	5518738	5.12	<1.0	59.0	24	<4.0	0.049	-	-	-	-	4a/2a
18-18		2018	663837	5519535	5.19	<1.0	17.6	47	<4.0	0.075	-	-	-	-	2b
18-5		2018	662555	5521552	4.44	<1.0	7.8	92	<4.0	0.25	-	-	-	-	2a//1a
18-6		2018	662679	5521365	5.09	<1.0	6.7	89	<4.0	0.168	-	-	-	-	2a//1a
18-3		2018	662601	5522014	4.92	<1.0	9.4	30	<4.0	0.094	-	-	-	-	2a//1a
18-28		2018	663314	5517787	5.41	<1.0	42.6	114	<4.0	0.074	-	-	-	-	2a/4c

Sample ID	Alt ID	Year Sampled	Easting	Northing	pH	Available Nitrate	Available Phosphate	Available Potassium	Available Sulphate	Total Kjeldahl Nitrogen	Calcium	Magnesium	Potassium	Sodium	SMU
18-29		2018	663534	5517763	5.43	<1.0	8.9	109	<4.0	0.082	-	-	-	-	2a/4c
18-22-IC		2018	663142	5518590	5.09	<1.0	43.9	68	<4.0	0.074	-	-	-	-	1a/2a
18-22-IIC		2018	663142	5518590	6.22	<1.0	30.9	80	<4.0	0.070	-	-	-	-	1a/2a
Vaccmem-01	DY7	2017	662545	5521593	5.53	<1.0	27.1	125	<4.0	-	-	-	-	-	2a//1a
Vaccmem-02	DY9	2017	663247	5521493	4.72	-	-	-	-	-	-	-	-	-	2b/2a
Amelaln-01	DY17	2017	664789	5505346	6.51	-	-	-	-	-	-	-	-	-	1a
Salix-01	DY19	2017	664629	5503637	7.26	-	-	-	-	-	-	-	-	-	3
Popubal-02	DY29	2017	664583	5511924	7.11	-	-	-	-	-	-	-	-	-	1a/3
Rubupar-01	DY13	2017	665058	5506537	6.04	-	-	-	-	-	-	-	-	-	4b
Rubupar-02	DY14	2017	665028	5506330	6.32	-	-	-	-	-	-	-	-	-	1a
Salix-03	DY5	2017	657369	5521892	7.84	12.9	6.7	98	34.0	-	-	-	-	-	6b/6a/7
Salix-04	DY1	2017	661624	5521864	4.88	-	-	-	-	-	-	-	-	-	3
Shepcan-01	DY40	2017	664573	5509567	6.56	-	-	-	-	-	-	-	-	-	1a/3
Shepcan-02	DY45	2017	653955	5520161	7.88	-	-	-	-	-	-	-	-	-	3//1a
Shepcan-03		2017	663699	5504264	5.47	-	-	-	-	-	-	-	-	-	5b/4a
Rosa-01	DY53	2017	656816	5523489	7.05	-	-	-	-	-	-	-	-	-	1a//4a
Popubal-03	DY55	2017	656448	5522432	7.91	-	-	-	-	-	4330	432	141	<50	5a/5b
Vaccmem-03	DY79	2017	663755	5519680	4.89	-	-	-	-	-	<200	<20	26	<50	4a/2a
Sambrac-01	DY71	2017	661926	5520965	5.49	-	-	-	-	-	1760	305	532	<50	4d//2a=RO
Sambrac-02	DY83	2017	661369	5521944	5.05	-	-	-	-	0.319	<200	34	100	<50	2a/1a/4a
Rosa-02		2017	653169	5521996	6.48	-	-	-	-	-	-	-	-	-	5a
Rosa-03		2017	655215	5524987	5.48	-	-	-	-	-	-	-	-	-	1a/A
Rubupar-03	Equiarv-01	2017	657433	5521906	8.00	-	-	-	-	-	-	-	-	-	4a/1a
Rubupar-04		2017	661234	5523863	5.14	-	-	-	-	-	-	-	-	-	3//2a
Vaccmem-04		2017	661502	5521979	5.47	-	-	-	-	-	-	-	-	-	2a/1a/4a
Sambrac-03		2017	661572	5521901	4.46	-	-	-	-	-	-	-	-	-	2a/1a/4a
Carex-01	Equiarv-02	2017	661749	5521341	5.92	-	-	-	-	-	-	-	-	-	7
Carex-02		2017	661854	5521192		-	-	-	-	-	-	-	-	-	OW
Shepcan-04		2017	664590	5521861	7.14	-	-	-	-	-	-	-	-	-	5a
Shepcan-05	Equiarv-03	2017	664916	5521488	7.14	-	-	-	-	-	-	-	-	-	1b
Rubupar-05	Sambrac-04	2017	664884	5519456	7.60	-	-	-	-	-	-	-	-	-	4a=1a//1b
Sambrac-05		2017	664665	5516712	4.95	-	-	-	-	-	-	-	-	-	6c
Popubal-04	Equiarv-04	2017	664363	5515771	5.28	-	-	-	-	-	-	-	-	-	6c
Carex-03	Equiarv-05	2017	664259	5514932	7.25	-	-	-	-	-	-	-	-	-	6a//7
Popubal-05		2017	664411	5512738	6.23	-	-	-	-	-	-	-	-	-	4a/1a//3

Sample ID	Alt ID	Year Sampled	Easting	Northing	pH	Available Nitrate	Available Phosphate	Available Potassium	Available Sulphate	Total Kjeldahl Nitrogen	Calcium	Magnesium	Potassium	Sodium	SMU
Amelaln-02		2017	664449	5510629	6.51	-	-	-	-	-	-	-	-	-	1a/3/5a
Carex-04		2017	665082	5509691	7.62	-	-	-	-	-	-	-	-	-	6a/7
Amelaln-03		2017	654089	5523877	7.31	-	-	-	-	-	-	-	-	-	1a/3
Rosa-04	Amelaln-04	2017	654596	5523999	7.09	-	-	-	-	-	-	-	-	-	1a/3
Carex-05		2017	655535	5524198	7.42	-	-	-	-	-	-	-	-	-	6b
Rosa-05		2017	655539	5524208	5.33	-	-	-	-	-	-	-	-	-	6b
Amelaln-05		2017	657830	5521872	6.15	-	-	-	-	-	-	-	-	-	4a/1a
Vaccmem-05		2017	663192	5518360	4.63	-	-	-	-	-	-	-	-	-	1a/2a
DY2		2017	661728	5521777	4.38	-	-	-	-	-	-	-	-	-	2a/1a/4a
DY4		2017	661918	5521730	5.97	-	-	-	-	-	-	-	-	-	2a/1a/4a
DY6		2017	662037	5521655	5.61	-	-	-	-	0.253					2a/1a/4a
DY8		2017	662656	5521734	-	-	-	-	-	-	-	-	-	-	A
DY10		2017	663304	5521375	4.51	<1.0	24.3	102	<4.0	-	-	-	-	-	2b/2a
DY11		2017	661999	5521436	4.23	<1.0	22.3	58	<4.0	0.095	-	-	-	-	2a/1a/4a
DY12		2017	661560	5521592	4.93	-	-	-	-	0.099	-	-	-	-	3
DY15		2017	665106	5505940	7.26	-	-	-	-	-	-	-	-	-	1a
DY16		2017	665074	5505818	7.93	-	-	-	-	-	-	-	-	-	6c//3
DY21		2017	664697	5516265	6.33	-	-	-	-	-	-	-	-	-	4b
DY24		2017	664250	5514910	7.25	-	-	-	-	-	-	-	-	-	6a//7
DY46		2017	653933	5520872	7.86	-	-	-	-	-	-	-	-	-	3//1a
DY47		2017	653915	5523805	8.07	-	-	-	-	-	4330	269	195	<50	1a/3
DY48		2017	654403	5523811	5.52	-	-	-	-	-	1270	166	112	<50	1a/3
DY49		2017	654507	5523857	5.07	-	-	-	-	-	-	-	-	-	1a/3
DY51		2017	655607	5524258	7.56	-	-	-	-	-	-	-	-	-	6b
DY57		2017	658192	5521117	7.10	-	-	-	-	0.102	2490	414	178	<50	4a//1b
DY60		2017	659344	5523692	7.99	-	-	-	-	-	-	-	-	-	2a=4a
DY62		2017	660722	5524513	6.89	-	-	-	-	-	3650	858	256	<50	1a/1b
DY64		2017	660795	5524156	-	-	-	-	-	-	300	55	80	<50	1b
DY65		2017	661347	5525004	-	-	-	-	-	0.141	2270	585	181	<50	1a/1b
DY66		2017	654065	5523771	6.46	-	-	-	-	0.134	-	-	-	-	1a/3
DY67		2017	661940	5521375	4.85	-	-	-	-	-	<200	<20	70	<50	2a/1a/4a
DY68		2017	661754	5521366	6.13	-	-	-	-	-	4500	508	929	<100	7
DY69		2017	661815	5521129	4.92	-	-	-	-	-	-	-	-	-	2a/1b
DY70		2017	661877	5521177	5.64	-	-	-	-	-	-	-	-	-	6b
DY72		2017	662055	5521016	5.77	-	-	-	-	-	2400	273	209	<50	2a/1a/4a

Sample ID	Alt ID	Year Sampled	Easting	Northing	pH	Available Nitrate	Available Phosphate	Available Potassium	Available Sulphate	Total Kjeldahl Nitrogen	Calcium	Magnesium	Potassium	Sodium	SMU
DY73		2017	662055	5521016	4.48	-	-	-	-	-	<200	24	62	<50	2a/1a/4a
DY80		2017	662009	5521096	3.96	-	-	-	-	-	-	-	-	-	2a/1a/4a
DY81		2017	663425	5521166	6.13	-	-	-	-	0.42	3230	827	136	<50	1a//4a
DY84		2017	661141	5522043	5.31	-	-	-	-	-	-	-	-	-	1b
DY88		2017	661759	5523034	5.35	-	-	-	-	1.32	-	-	-	-	2a=1a
DY100		2017	663612	5502663	7.82	-	-	-	-	-	-	-	-	-	5b=6a/6b

Table 3-8. Soil nutrient analysis results (mg/kg) by leading SMU

Leading SMU	pH (n)	Total Kjeldahl Nitrogen (%) (n)	Calcium (n)	Magnesium (n)	Potassium (n)	Sodium (n)	Available Nitrate-N (n)	Available Phosphate-P (n)	Available Potassium (n)	Available Sulfate-S (n)
1a	4.6-8.1 (20)	0.07-0.1(4)	1270-4330 (5)	166-858 (5)	112-256 (5)	<50 (5)	<1.0 (2)	12-43.9 (2)	53-68 (2)	< 4.0 (2)
1b	5.3-7.1 (2)	-	300 (1)	55 (1)	80 (1)	<50 (1)	-	-	-	-
2a	3.9-6.4 (23)	0.07-0.3 (11)	<200-2400 (4)	<20-273 (4)	62-100 (4)	<50 (4)	<1.0 (9)	6.7-42.6 (9)	30-168 (9)	<4.0 (9)
2b	4.5-5.2 (5)	0.06-0.1 (3)	-	-	-	-	<1.0 (4)	17.6-117 (4)	34-102 (4)	<4.0 (4)
3	4.6-8.0 (14)	0.07-0.2 (7)	-	-	-	-	<1.0-2.0 (6)	3.5-89 (6)	92-281 (6)	<4.0-587 (6)
4a	4.6-8.0 (9)	0.04-0.1 (4)	<200-2490 (2)	<20-414 (2)	26-178 (2)	<50 (2)	<1.0 (3)	49.7-74 (3)	24-51 (3)	<4.0 (3)
4b	5.1-6.3 (4)	0.1-0.3 (2)	-	-	-	-	<1.0-2.0 (2)	38.7-47.2 (2)	48-85 (2)	<4.0-8.0 (2)
4d	5.49 (1)	-	1760 (1)	305 (1)	532 (1)	<50 (1)	-	-	-	-
5a	6.5-8.1 (4)	0.1 (1)	4330 (1)	432 (1)	141 (1)	<50 (1)	17.1 (1)	34.8 (1)	149 (1)	29.3 (1)
5b	5.5-8.0 (4)	0.1-0.2 (2)	-	-	-	-	<1.0-1.7 (2)	7-39 (2)	65-69 (2)	<4.0 (2)
6a	7.3-7.7 (3)	-	-	-	-	-	-	-	-	-
6b	5.3-7.6 (4)	-	-	-	-	-	-	-	-	-
6c	4.9-7.9 (3)	-	-	-	-	-	-	-	-	-
7	5.9-7.4 (7)	-	4500 (1)	508 (1)	929 (1)	<100 (1)				

Table 3-9. Particle size analysis results

	DY5	DY6 (0-15cm)	DY6 (0-25cm)	DY12	DY30	DY42 (15-30cm)	DY42 (80-90cm)	DY45	DY48	DY62	DY70	DY84	18-04	18-16	18-10	18-14	18-21	18-23	18-18	18-5	18-6	18-3	18-28	18-29	18-22-IC	18-22-IIC
% gravel (>2mm)	2.9	<1.0	2.7	<1.0	9.1	12.9	12.0	<1.0	2.1	22.9	<1.0	23.1	23.0	24.0	1.3	20.2	26.8	20.5	23.2	12.0	17.9	27.2	30.4	12.1	18.7	17.8
% sand (2-0.05mm)	49.9	26.6	25.7	19.2	8.4	23.1	25.7	3.7	9.7	29.8	18.9	27.2	52.8	50.8	60.8	49.8	38.8	45.5	59.2	63.8	70.4	43.2	55.0	70.5	45.0	36.3
% silt (0.05mm – 0.2um)	41.1	56.6	54.5	63.5	66.2	46.1	52.1	49.6	45.4	39.7	55.3	45.1	18.8	22.9	31.6	26.9	30.7	30.0	14.5	16.8	8.7	26.4	11.3	7.5	21.2	41.9
% clay (<0.2um)	6.2	16.8	17.1	17.3	16.4	17.9	10.1	46.7	42.9	7.6	25.9	4.7	5.4	2.4	6.3	3.1	3.8	4.0	3.2	7.4	3.0	3.1	3.3	9.9	15.2	4.0
Texture	Sandy loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silty clay	Silty clay	Silt loam	Silt loam	Silt loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Sandy loam	Loamy sand	Sandy loam	Loamy sand	Sandy loam	Sandy loam	Silt loam

4. DISCUSSION

4.1.Soil Chemistry

Generally, each SMU has great variation in soil pH (e.g., from very strongly acidic to moderately alkaline). This is expected as the majority of SMUs delineated in the LSA are large and often contain more than one variation of soil materials (e.g., 2a/1a/4a) from more than one type of parent material (e.g., till or colluvium). The pH ranges for each SMU are presented in Table 4-1.

Table 4-1. Summary of pH values by SMU

Leading SMU (n)	Minimum Value	Maximum Value	Average Value
1a (20)	4.63	8.07	6.48
1b (2)	5.31	7.14	6.23
2a (23)	3.96	7.99* (6.42)	5.20 (5.08)
2b (5)	4.51	5.19	4.84
3 (14)	4.62	8.13	6.63
4a (9)	4.65	8.00	6.09
4b (4)	5.13	6.33	5.68
4c (0)	Talus SMU (non soil)		
4d (1)	5.49	5.49	5.49
5a (4)	6.48	8.08	7.40
5b (4)	5.47	8.04	6.87
6a (3)	7.25	7.62	7.37
6b (4)	5.33	7.56	6.49
6c (3)	4.95	7.93	6.05
7 (7)	5.92	7.36	6.71

* pH value 7.99 (DY60) is a statistical outlier; the values in parentheses indicate the maximum and average values with the outlier excluded from the data set.

Soil pH varies seasonally and is affected by factors such as moisture, temperature, plant growth and microbial activity. The typical pH range for forest soils is approximately 3.5 to 6.5 (extremely acidic to slightly acidic) while the typical pH range for calcareous soils is approximately 7 to 8.5 (neutral to strongly alkaline; Brady & Weil, 2004). The effects of parent material and ecosystem type on soil pH is reflected in the range of pH values found throughout the LSA. Soil pH can also change drastically with disturbance (e.g., draining wet soils).

Soil pH also controls the availability of many nutrients. Many soil nutrients react with hydrogen ions in the soil solution to produce strong acids (e.g., nitrogen-nitrate and sulphur). Plant growth at the soil surface generally maintains a balance between the positive and negative charges in the soil solution; when more positive charges are available in solution (i.e., cations) plants maintain the balance by releasing negative ions (i.e., anions) or hydrogen into the soil solution. All of these processes combine to stimulate soil acidification in forest soils. However, there are hydrogen ion-consuming processes that also occur in the soil that delay acidification and lead to alkalinity. This includes the input of bicarbonates or carbonates from calcareous parent materials (e.g., limestone, dolomite). Inputs of atmospheric calcium and magnesium also contribute to alkalinity.

Although variation was observed, soil samples with the highest values for calcium were generally found in samples with neutral to moderately alkaline pH values (Table 4-2). Magnesium behaves in a similar way as calcium in the soil, with greater bioavailability at alkaline pH values (i.e., greater than 7; **Error! Reference source not found.**). Calcium levels were observed to decrease substantially in more strongly acidic pH ranges (e.g., less than 6.0). Calcium is essential for plant growth.

Table 4-2. Soil pH and calcium values

Sample ID	**Soil pH**	**Calcium (mg/kg)**
DY68	6.13	4,500
DY47	8.07	4,330
DY55	7.91	4,330
DY62	6.89	3,650
DY81	6.13	3,230
DY57	7.10	2,490
DY72	5.44	2,400
DY71	5.49	1,760
DY48	5.52	1,270
DY83	5.05	<200
DY67	4.85	<200
DY73	4.48	<200
DY79	4.89	<200

Where pH values are greater than 7.5, calcium fixes other essential plant nutrients, like phosphorous and makes them less bioavailable. Phosphorous also becomes less bioavailable at pH values less than 6.0 (Brady & Weil, 2004). While limited trends were observed within the available phosphorous values for the soil samples collected, the lowest values were associated with either very strongly acidic or moderately alkaline pH values (Table 4-3). The highest available phosphorous values were generally associated with pH values of approximately 5.

Table 4-3. Soil pH and phosphorous values

Sample ID	Soil pH	Available phosphorous (mg/kg)
TB19-06	4.62	8.7
TB19-16	8.04	7.0
TB01	8.13	3.5

Available potassium levels across the LSA range from 24 to 281 mg/kg (n=29). Typically, potassium becomes less bioavailable to plants at pH values of approximately 4 to 6 (extremely acidic to moderately acidic) and more bioavailable at higher pH values (i.e., pH 6 and greater; Figure 4-1).

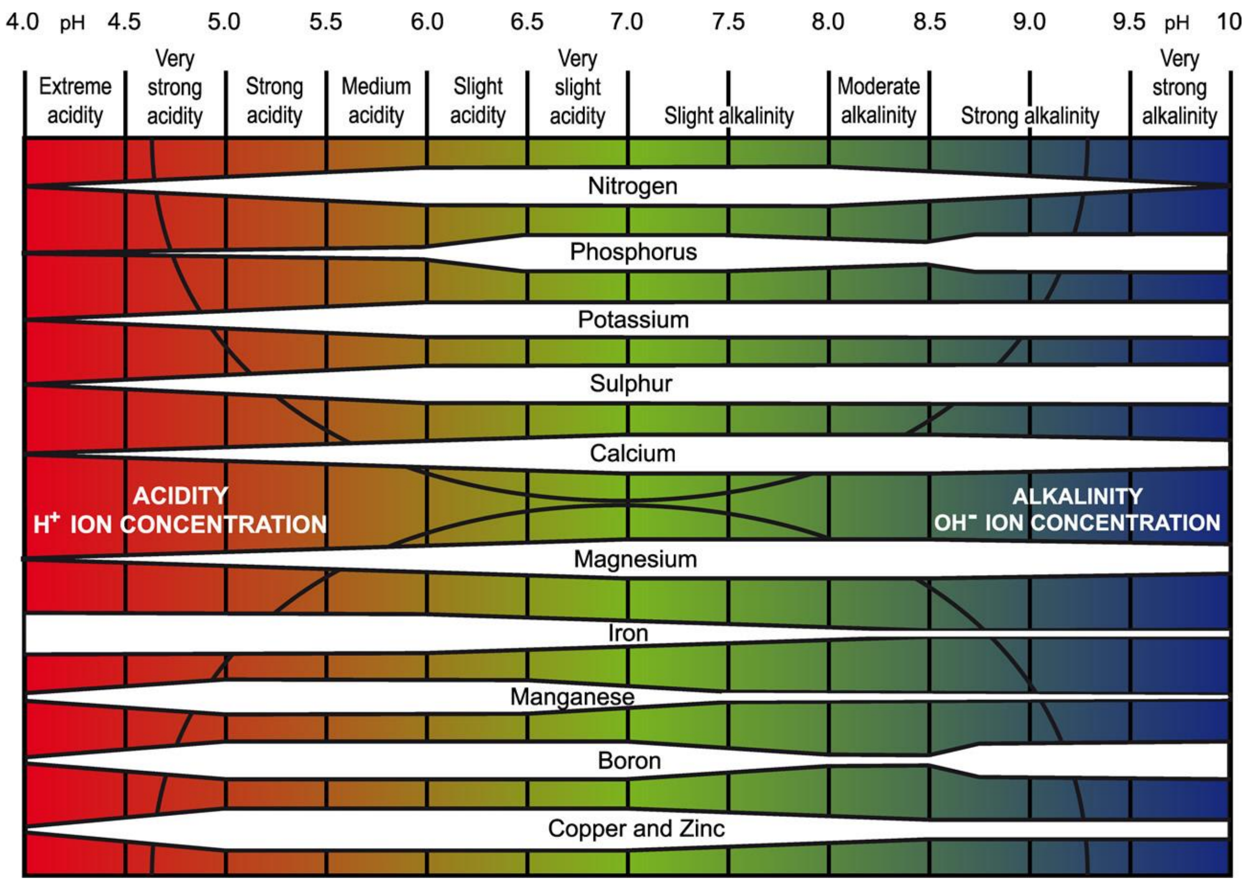

Figure 4-1 Influence of soil pH on plant nutrient availability (Potash Development Association, 2011)

4.2.Soil Texture

Soil texture varies greatly across the LSA with differing parent materials (

Table 4-4). Particle size analyses were performed on 26 samples from within the LSA; 12 associated with the baseline soil classification and mapping and 14 associated with the 2018 exploration drilling program (Table 3-9). Soil textures range from fine (silty clay (SiC)) to coarse (loamy sand (LS)).

Table 4-4. Coarse summary of parent material types and coverage based on SMU

Parent Material Type	% of LSA	% of Footprint
Morainal	28	30
Shallow till, colluvium or saprolite	27	29
Glaciolacustrine	9	7
Colluvium	18	23
Glaciofluvial	4	5
Fluvial	6	3
Fine textured, poorly drained	1	0.1
Rock outcrop	5	2

The only active constituent of soil texture is clay. Clay particles can increase cation exchange capacity, increase phosphorous and potassium fixation, and influence soil pH. The highest percentage of clay particles in a soil sample was 46% as analysed by ALS Environmental (Appendix 2). The soils found throughout the LSA are typically not fine textured. The majority of soils examined have medium (SiL, L), moderately coarse (SL) or coarse textures (LS), as determined through in-field hand texturing. Soil texture also contributes to its erosion potential and suitability for salvage.

4.3.Soil Erosion Potential (SEP)

Soil erosion potential (SEP) refers to the displacement of soil particles primarily due to the action of surface water and, to a lesser extent, wind. Soil erosion can have negative consequences to soil, water and air quality and aquatic ecosystems. The erosion potential was classified into four classes based on a combination of slope gradient, slope length, soil texture, and depth to water restricting layer; Figure 2-1 outlines the criteria used in defining the SEP classes. The areas with the highest potential for erosion are found in association with fine-sand and silt-containing materials and/or near creeks where active creek bank erosion is occurring. Other areas with elevated erosion potential are moderately sloping ground with fine textured materials (SMU 3) and steep ground (>60 % gradient), especially if prone to snow avalanching (SMU 4d).

High erosion potential was identified along watercourses and on steep slopes throughout the LSA. Soils with finer textures have also been identified as having high erosion potential; while fine textured soils with significant clay content are resistant to erosion, there is variation in texture of glaciolacustrine deposits with silty inclusions being very prone to erosion.

The SMU types most prone to soil erosion include SMUs 4b, 4d, 5b, 6a and 6b. While soil map polygons were delineated to capture areas of relatively homogenous soils, within any soil polygon, there may be significant variation in attributes influencing soil erosion susceptibility. For example, slope gradient or soil textures may vary and therefore the estimated SEP for the polygon may not capture this variation. Also, small areas within the polygon that may not be of a scale to be mappable may exhibit very contrasting SEP compared to the rest of the polygon. The mapping of SEP is not intended to remove the need to assess erosion potential in the field before any infrastructure is constructed.

It is expected that surface soil erosion will occur when mineral soil exposed areas are not protected. Erosion is reduced when the disturbed cleared surfaces are covered with rough, loose materials, coarse woody debris, coarse rocky material or vegetation cover, to better control soil displacement and retention of displaced soil particles.

4.4. Soil Salvage Potential (SSP)

As with the assessment of SEP, SSP had many instances where a range of potentials were assigned to a polygon as either the polygon exhibited multiple SMUs or although comprised of one SMU, factors important to SSP varied over the polygon. As with SEP, mapped SSP may differ from that experienced on the ground for a variety of reasons, such as, difficulty in assessing soil fertility or depth from imagery, inherent variability within an SMU, or unmappable scale of variation. Several of the factors cited in assessing soil salvage potential, in particular, soil pH and calcareous subsurface, varied within an SMU and are impossible to assess from imagery. All factors outlined in Table 2-4 in determining soil salvage potential, will need to be further assessed on the ground as salvage operations are planned for and carried out. The mapping of SSP should be thought of as an indication of relative likelihood of finding salvageable soil in order to focus ground assessments.

5. CONCLUSION

Interpretive soil inventory maps were completed for the 12,886 ha LSA, presented at a 1:15,000 scale. The survey intensity levels achieved (SIL 2 for the Project footprint, SIL 3 for the LSA) are appropriate to the use that the maps will be put to. Inventory maps for soil map units, soil erosion potential and soil salvage potential were generated but do not eliminate the need for further on-site assessments during mine development and operation.

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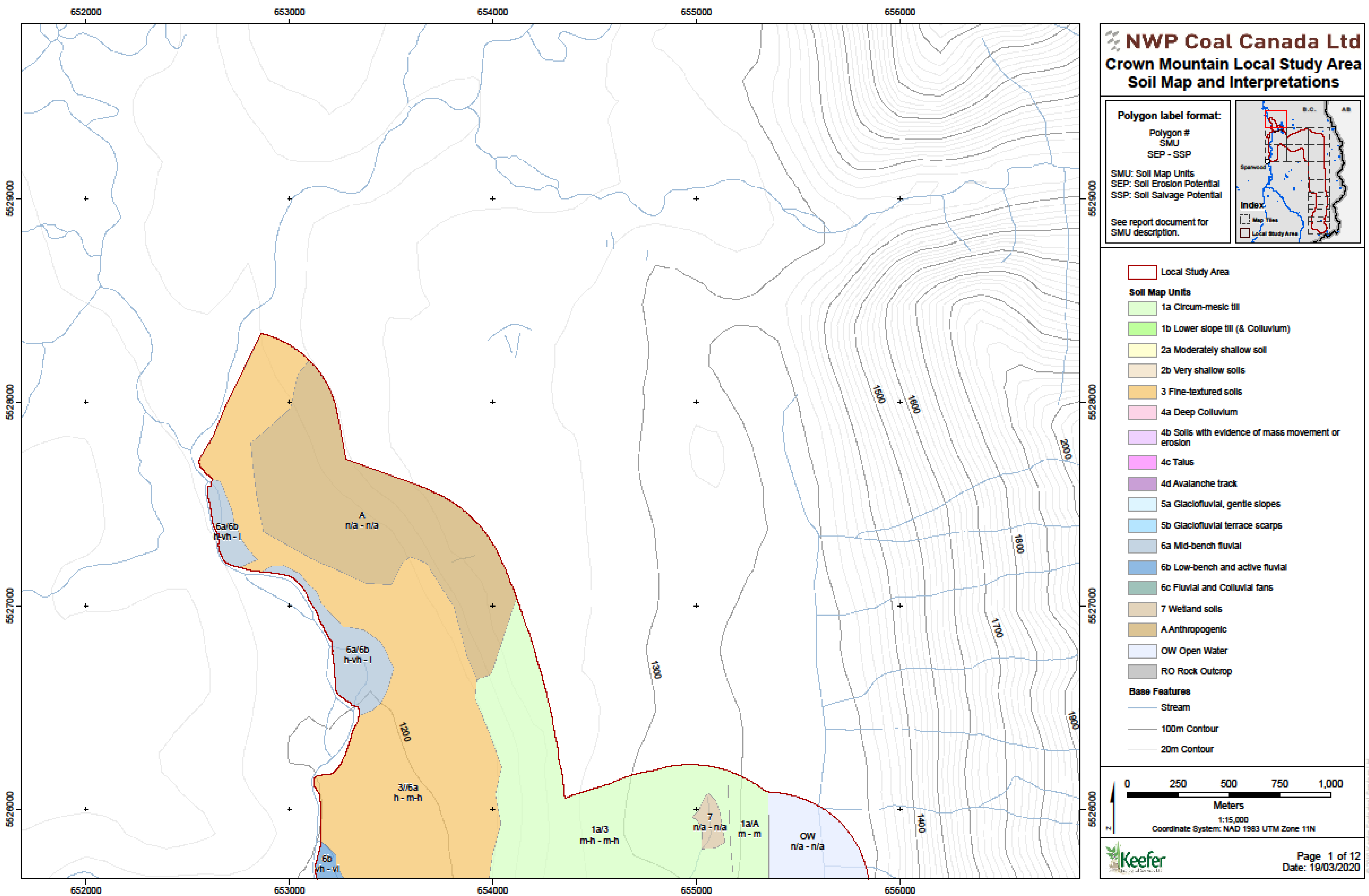
Appendix 1 Soil Mapping

To view all maps, right click map below, open Acrobat Document Object. Maps will open in Adobe Reader. Colour-coding of maps show the leading component of the map polygon.



Keefer Ecological Services Ltd

Appendix 2 Laboratory Certificates of Analysis

To view document, right click page below, open Acrobat Document Object. Document will open in Adobe Reader.

KEEFER ECOLOGICAL SERVICES LTD.
ATTN: Michael Keefer
3816 Highland Road
Cranbrook BC V1C 6X7

Date Received: 25-AUG-17
Report Date: 07-NOV-17 14:27 (MT)
Version: FINAL REV. 2

Client Phone: 250-489-4140

Certificate of Analysis

Lab Work Order #: L1981208

Project P.O. #:	NOT SUBMITTED
Job Reference:	CROWN MTN COAL PROJECT
C of C Numbers:	17-01 to 17-07
Legal Site Desc:	

Comments:

7-NOV-2017 Revision 2: This revision replaces and supersedes all previous revision of this report. As requested the reporting and billing company information has been modified.

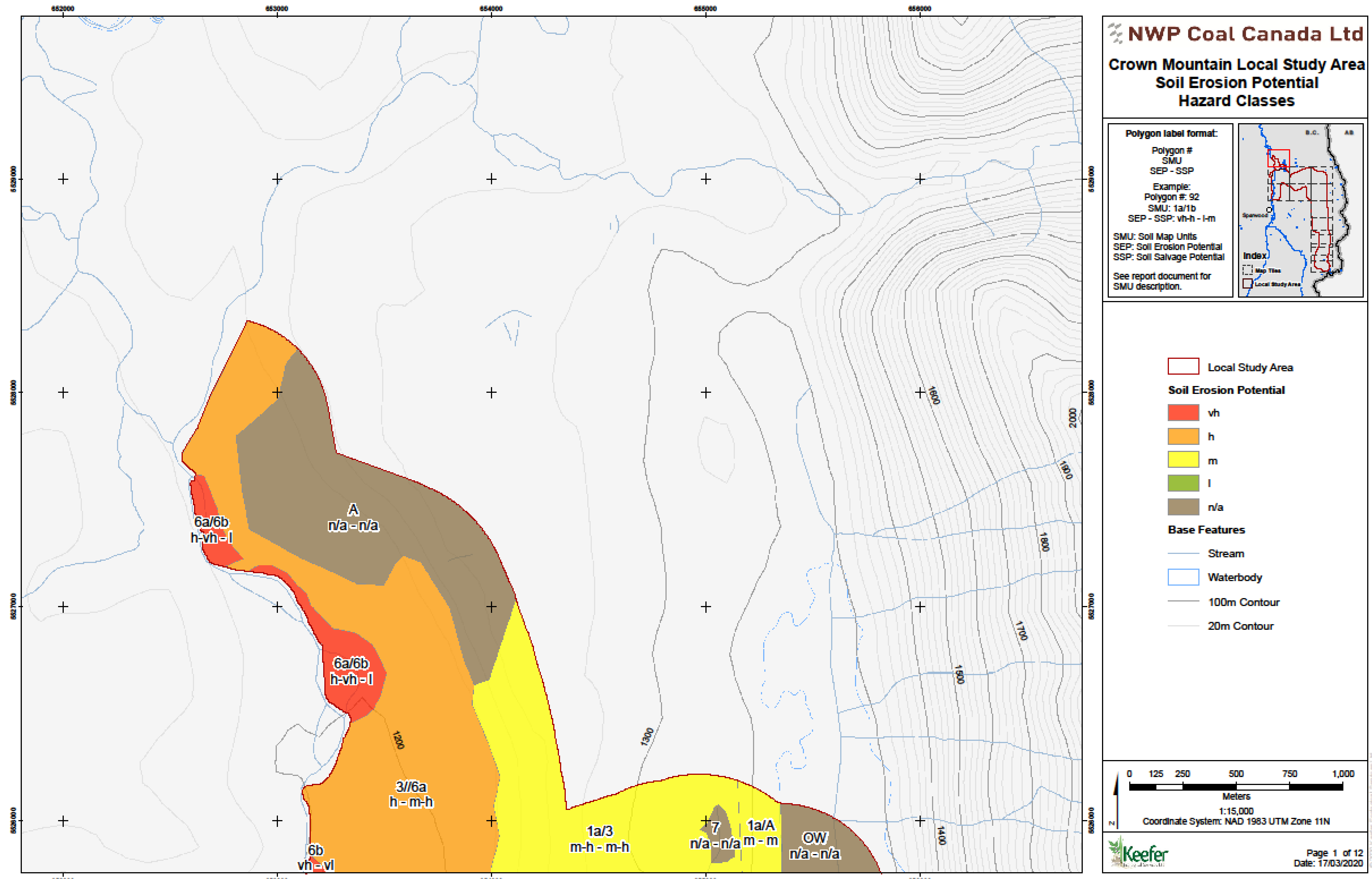
Can Dang
Senior Account Manager

Appendix 3 Soil Erosion Potential Maps

To view all maps, right click map below, open Acrobat Document Object. Maps will open in Adobe Reader.

Soil Erosion Potential Hazard Classes portrayed on the following maps comprise the following groupings of map polygon soil erosion potential ratings:

- Very High Erosion Hazard comprises very high (vh), high to very high (h-vh), very high to high (vh-h) and very high to medium (vh-m) SEP ratings
- High Erosion Hazard comprises high (h), high to moderate (h-m),and moderate to very high (m-vh) SEP ratings
- Moderate Erosion Hazard comprises moderate (m), moderate to high (m-h), moderate to low (m-l) and low to very high (l-vh) SEP ratings
- Low Erosion Hazard comprises low (l) and low to moderate
- N/A refers to Anthropogenic sites or non-soil sites

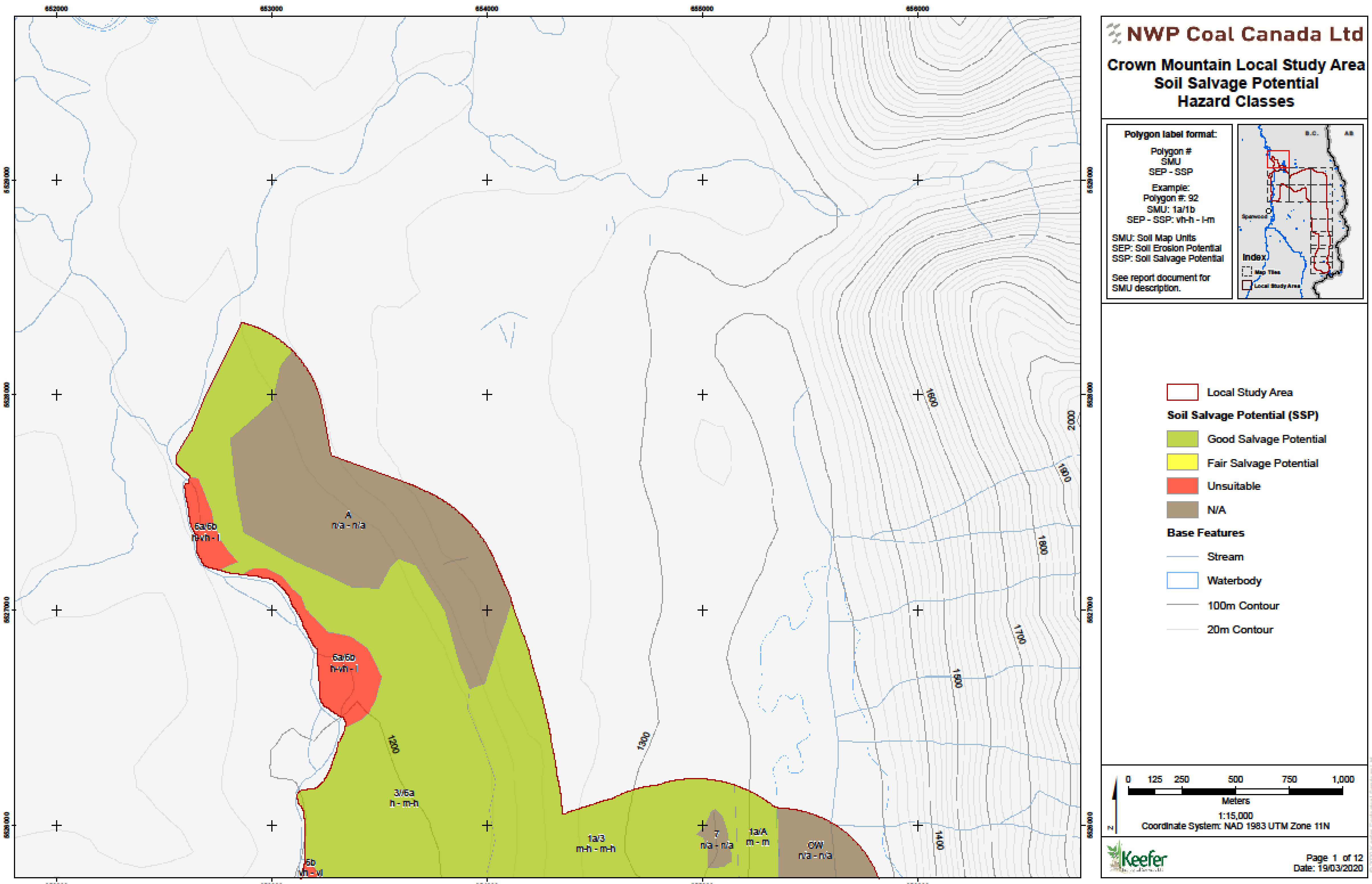

NWP Coal Canada Ltd
Crown Mountain Local Study Area
Soil Erosion Potential
Hazard Classes
Polygon label format:
Polygon #
SMU
SEP - SSP
Example:
Polygon #: 92
SMU: 1a/1b
SEP - SSP: vh-h - l-m
SMU: Soil Map Units
SEP: Soil Erosion Potential
SSP: Soil Salvage Potential
See report document for SMU description.
Index
Local Study Area
Soil Erosion Potential
vh
h
m
l
n/a
Base Features
Stream
Waterbody
100m Contour
20m Contour
0 125 250 500 750 1,000
Meters
1:15,000
Coordinate System: NAD 1983 UTM Zone 11N
Page 1 of 12
Date: 17/03/2020
652000
653000
654000
655000
656000
A
n/a - n/a
6a/6b
h-vh - l
6a/6b
h-vh - l
3//6a
h - m-h
6b
vh - vl
1a/3
m-h - m-h
7
n/a - n/a
1a/A
m - m
OW
n/a - n/a
1200
1300
1400
1500
1600
1700
1800
1900
2000

Appendix 4 Soil Salvage Potential Maps

To view all maps, right click map below, open Acrobat Document Object. Maps will open in Adobe Reader.

Soil salvage potential classes depicted are groupings of map polygon soil salvage potential ratings as follows:

- Good Salvage Potential comprises high (h), moderate to high (m-h), moderate (m), and moderate to low (m-l)
- Fair Salvage Potential comprises low to moderate (l-m) and moderate to very low (m-vl) SSP ratings
- Unsuitable Salvage Potential comprises low (l), low to very low (l-vl), very low (vl), very low to moderate (vl-m) and very low to low (vl-l) SSP ratings
- N/A comprise anthropogenic or non-soil sites.



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