8 Terrain, Surficial Geology, and Soils

8.1 Terrain, Surficial Geology, and Soils Setting

This section provides an overview of the terrain, surficial geology and soils; identifies relevant legislation and guidelines; and assesses the potential effects of the Project on the terrain, surficial geology, and soils in the local study area (LSA). Terrain and surficial geology are described and discussed as major factors affecting soil development; however, the main focus of this section is devoted to soils. Terrain stability and geohazards are discussed in Chapter 9. Local mineralogy and environmental effects associated with geochemistry are discussed in Chapter 10. Section 8.1 provides an abbreviated discussion of surficial geology, terrain, and soils, suitable as background for the assessment of Project environmental effects. A more detailed description of terrain and soil conditions is presented in the *KSM Project: 2009 Soils and Terrain Baseline Report* (Appendix 8-A).

8.1.1 Local Study Area

The LSA is located in the Coast Mountains physiographic region dominated by folded and faulted volcanic and sedimentary rocks originated in Mesozoic era (Valentine et al. 1978). After retreat of late-Wisconsin glaciation (11,000 years ago) most mineral materials deposited in valleys by glaciers were modified by mass wastage processes and redistributed by streams and rivers.

Today the mountain topography is very rugged. Glaciers are common in high elevations. Most steep slopes are covered by bedrock and accumulations of rubbly colluvium. Gentler slopes have a thin mantle of morainal material (glacial till). Thick glacial deposits are generally restricted to the margins of major valley floors and adjacent lower slopes (Valentine et al. 1978). Avalanches and slope failures are common geomorphic processes operating on high and intermediate elevations (above 1,500 masl).

The climate in the LSA is typical of temperate rainforest with average monthly air temperature ranging between -12° and 14.7°C. Within the last four years (2008 to 2011) the highest daily maximum ranged between 25.3° and 30.2°C, and the lowest daily minimum ranged between -22.1° and -31.1°C (Chapter 7). Within the same period annual precipitation ranged from 689 mm at the Teigen Creek station to 1,914 mm at Eskay Creek station. The highest precipitation occurs in the LSA area in September and October. Subarctic conditions are present at high elevations (e.g., above 1,500 masl) where strong winds blowing in westerly direction predominate in winter. At low elevations winds are funnelled through valleys: Arctic air from the northeast in the winter and warm Pacific air from the southwest in the summer.

Regional climate and geological history in combination with local topography and vegetation affect soil landscapes found in the LSA. In high elevations solifluction, nivation, and cryoturbation disrupt, displace, and mix soil horizons, while the cold climate slows down mineral weathering and organic decomposition. Weathered volcanic rocks provide coarse-textured, acidic parent materials. As a result, soil development is often weak. The steep terrain results in unstable slopes where soil development is further hindered by mass movement of surficial materials. Regosols and occasionally Cryosols occur in these areas (Jungen and Lewis 1978). In lower elevations soils are commonly subjected to seepage. Excess moisture and high incidence of poorly drained soils is typical. Due to steep terrain, most common parent material consists of colluvial veneers. On lower slopes, soils often develop on morainal deposits. Dominant soils include Brunisols and Ferro-Humic Podzols characterized by low base saturation, low pH, high organic carbon, and high concentration of iron and aluminium compounds (Jungen and Lewis 1978).

During baseline studies, 66,494 ha were assessed. This area comprises the baseline study area (BSA) and is presented in Figure 8.1-1. The BSA is significantly larger than the LSA and includes the areas surrounding the following Project components:

- Mine Site features including pits, underground mines, rock storage facilities, the Mitchell Ore Preparation Complex (OPC), and related infrastructure;
- Processing and Tailing Management Area (PTMA) including the North, Centre, and South cells, the Treaty Process Plant, the Treaty Creek access road (TCAR) and associated construction camps;
- Mitchell-Treaty Twinned Tunnels (MTT);
- Coulter Creek access road (CCAR) and associated construction camps; and
- Temporary Frank Mackie Glacier access route (TGAR).

The Mine Site is located at high elevation and is dominated by bedrock, colluvial veneers, rockfall, oversteepened coarse moraine, and ice. The PTMA and the TCAR are located in the Teigen and Treaty Creek valleys dominated by deeper colluvial and morainal deposits. The MTT connect the Mine Site and the PTMA. The two underground tunnels will be excavated under bedrock and glaciers. The CCAR is dominated by morainal and, to a lesser degree, colluvial parent materials. The TGAR is a temporary access route dominated by ice.

8.1.2 Relevant Legislation and Guidelines

The *Mines Act* (1996) *Health, Safety and Reclamation Code for Mines in British Columbia* (the Code; BC MEMPR 2008) requires that the environmental protection of land and water resources, as well as the reclamation of disturbed land, be planned in advance and that plans follow standards outlined by the Code. The Code specifies standards that must be achieved during mining activities and requires regular site inspections and annual reporting (Reclamation and Closure, Part 10) to ensure compliance.

Under the *Mines Act* (1996), the Code (BC MEMPR 2008) requires proponents to provide:

- information on surficial geology, terrain mapping, soils , vegetation, wildlife, and present land use (Application for an Environmental Assessment Certificate / Environmental Impact Statement [Application/EIS] Chapters 8, 16, 17, 18, and 23);
- a Soil Salvage and Handling Plan (Application/EIS Section 26.13.1);
- an Erosion Control Plan (Application/EIS Section 26.13.2); and
- a Closure and Reclamation Plan (Application/EIS Chapter 27).

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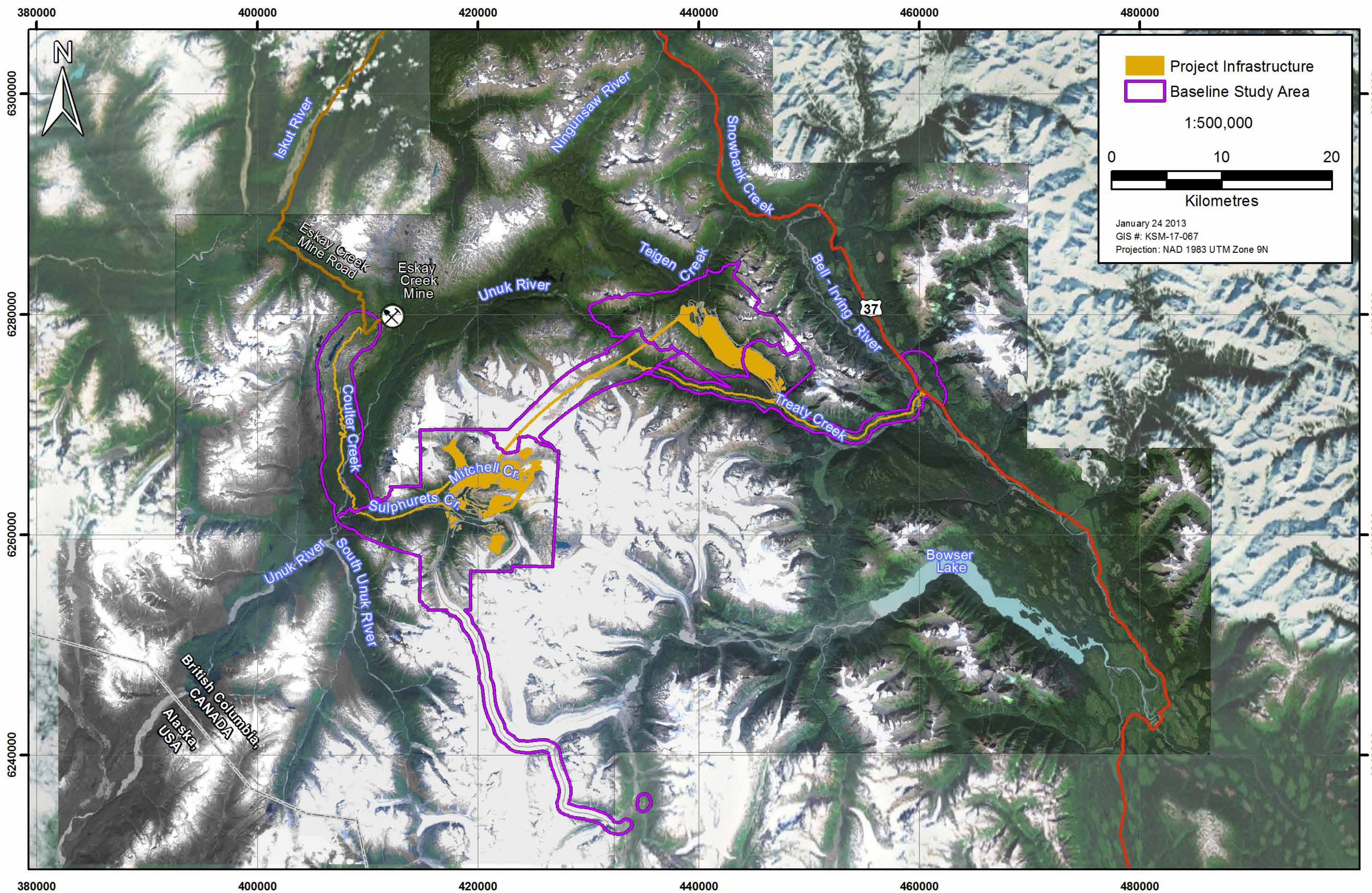

Figure 8.1-1

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Terrain, Surficial Geology, and Soils Baseline Study Area

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Figure 8.1-1

Relevant information requirements set under the Fish Habitat Protection and Pollution Prevention provisions of the *Fisheries Act* (1985) include descriptions of measures that will be taken to avoid or minimize any impacts on the aquatic environment, during Project development or its subsequent operation (Section 37). The *Fisheries Act* (1985) also regulates the discharge of harmful substances into the fish habitat (Section 34) and imposes reporting requirements in case an impact on fish habitat occurs (Section 38). Consideration of the above legislation is particularly important in cases when Project development takes place near shorelines or riparian areas. Potential impacts include migration of chemical contaminants and sediment into the aquatic environment.

Watercourse sedimentation typically results from soil erosion, and, while prevention of both processes is the focus of various best management practices (BMPs), currently it is not regulated by law. However, since unpaved roads have potential to contribute significantly to soil erosion, in British Columbia (BC), road construction within forested areas is governed by the *Forest and Range Practices Act* (2002). The Act requires that road construction adheres to codes provided in the Forest Service Road Use Regulation (BC Reg. 70/2004), which focuses extensively on erosion prevention.

Matters related to contamination of the terrestrial habitat are regulated by the *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* (CCME 2007). These guidelines provide Canada-wide standards for the maximum limits of various toxic substances (e.g., metals, hydrocarbons, pesticides, etc.) in the soil. Similarly, the Contaminated Sites Regulation (BC Reg. 375/96) included in BC's *Environmental Management Act* (2003) lists Soil Criteria for Toxicity to Soil Invertebrates and Plants. These provide numerical standards to define whether a site is contaminated, to determine liability for site remediation, and to assess reclamation success.

8.1.3 Methods and Information Sources

The soils and terrain field study was carried out in the years 2008 and 2009. In 232 inspection sites soil pits were excavated by hand shovel. Collected data included description of landforms, slope gradient and aspect, surficial material type and texture, drainage, geomorphic processes, a number of soil horizon characteristics (e.g., designation, depth, texture, coarse fragment content, etc.), and soil classification. Inspection sites were distributed throughout the BSA with a major focus on areas near the potential locations of the various proposed Project facilities. A total of 141 soil samples were collected. Chemical analyses provided data on soil pH, organic carbon content, and concentration of 30 metals. Resulting data are provided in Appendix 8-A and maps in Appendices 8-B and 8-C.

During baseline studies, the BSA was defined by the height of land or 1.5-km buffer around proposed infrastructure. However, given the evolution of the Project footprint since baseline, several areas were added. The most significant of these is the Treaty Creek Access Corridor (TCAC). Where possible, ecologically relevant boundaries were used in order to ensure the capturing of potential effects of the Project on terrain, surficial geology, and soils.

8.1.4 Surficial Geology and Terrain

The BSA is characterized by steep topography with active geomorphic processes, such as landslides and snow avalanches. Large portions of the property, particularly at the Kerr deposit, are located on steep slopes (Plate 8.1-1). Slopes vary substantially across the Project area, but are primarily moderate to steep (26% to > 70%). Moderate slopes (26% to 50%) are most common, comprising 28% of the BSA. Moderately steep (50% to 70%) and steep (> 70%) slopes represent 21% and 20% of the BSA, respectively. The moderately and steeply sloping terrain (26% slopes and higher) combined represent almost 69% of the BSA. In the remaining area, the terrain is level to moderately gently sloping (0% to 26%). More than 50% of the Mine Site, including pits, underground mines, and rock storage facilities, has slopes in excess of 50%. A set of slope maps is provided in Appendix 8-A.

Plate 8.1-1. Steep slope near the south boundary of the Kerr deposit.

Table 8.1-1 lists the number of slopes assigned to each of the five landslide or avalanche risk categories in eight infrastructure areas of the BSA. Avalanche risk was rated by Alpine Solutions and the risk of mass movement events was rated by BGC Engineering (BGC 2012a and 2012b). Details of these geohazards are presented in Chapter 9 of the Application/EIS.

The region encompassing the Project has been the site of multiple glaciations, after which the land surface was modified by gravity, wind, water, and ice, resulting in large areas of colluvial and fluvial deposits. A large proportion of the BSA is covered on the north, east, and south by glaciers and ice fields, which fill the upper portions of the larger valleys from as low as 1,000 m (in the Mitchell Creek Valley) to the height of land. Glaciers have been retreating for the last several decades; for example, the Mitchell Glacier retreated 35 m between September 2009 and September 2010 (Rescan 2011).

Table 8.1-1. Mass Movement and Avalanche Risk Rating for Slopes within the Local Study Area

Risk	Tailing Management Facility	Treaty Creek Trans-mission Line	Treaty Creek Access Road	Coulter Creek Access Road	Mitchell Pit	Kerr Pit	Sulphurets Pit	Ted Morris Creek Valley	Totals
Very High	0	2	0	1	10	1	0	0	14
High	12	18	12	2	42	8	7	1	102
Mod	5	6	12	2	22	5	13	4	69
Low	8	1	9	4	17	12	19	3	73
Very Low	4	0	0	0	5	1	0	0	10
Total	29	27	33	9	96	27	39	8	268

Note: The values in the table report the number of slopes within each of the risk ratings. Data provided by BGC (2012a and 2012b).

The complexity of the surficial geology in the BSA is highlighted by a wide range of surficial deposits, which occur in varying thickness depending on topography, depositional environment, and post-depositional processes. Bedrock outcrops are commonly found on crest to upper slope positions, while colluvial materials are often found on upper and mid-slopes. Rounded and elongated bedrock outcrops and thick, morainal, glaciofluvial, and fluvial deposits often occur in lowlands and valley bottoms with gentler relief. Organic materials develop in wetland areas where the soil is saturated for extended periods; this often occurs in depressions and backchannel areas of medium and large creeks. Gleyed soils are typically found in seepage sites in lower slope positions.

The spatial extent of surficial materials is shown in Table 8.1-2. Maps showing detailed terrain information for the BSA are provided in Appendix 8-B.

Bedrock and surficial materials often contain elevated concentrations of pyrite, which, when weathered, can produce acidic conditions and lead to mobilization of metals. Many of the naturally occurring groundwater seeps (e.g., present at the Kerr, Sulphurets, and Mitchell deposit areas, McTagg Creek Valley, and Ted Morris Creek Valley) are characterized by low pH and high metal concentrations (see Chapter 10, Geochemistry).

8.1.5 Soils

Soil formation in the BSA is limited by the cold climate and natural disturbance. Biological and chemical soil forming processes that are dependent on soil temperature thresholds can only be carried out during a brief window, while steep slopes limit pedogenesis due to constant downslope movement through soil creep, surface erosion, and mass movement. Soils that develop in colluvial and morainal surficial materials dominate the BSA; soils derived from fluvial, glaciofluvial, and organic deposits are less common (Table 8.1-2, Figure 8.1-2). The dominant mineral soils in the BSA are weakly developed, and include Brunisols (Plate 8.1-2) and Regosols. Other, less common mineral soils are Podzols (Plate 8.1-3) and poorly drained Gleysols (Plate 8.1-4). The Organic soils, found in valley bottoms and depressional areas, are poorly drained and very sensitive to disturbance. They include poorly decomposed Fibrisols and moderately decomposed Mesisols (Plate 8.1-5).

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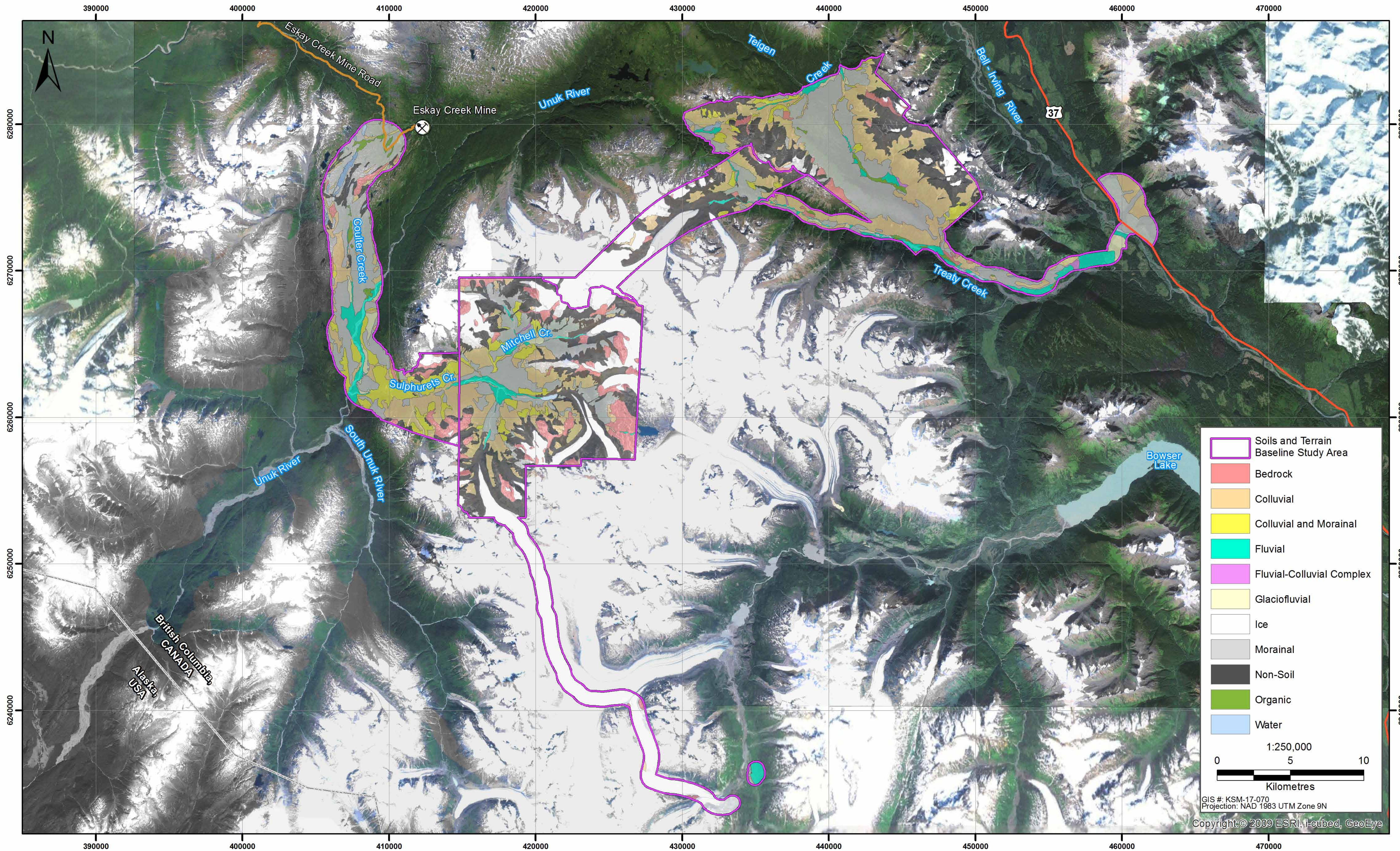

Figure 8.1-2

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Distribution of Surficial Materials in the Baseline Study Area

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Table 8.1-2. Distribution of Surficial Materials in the Baseline Study Area

Soil Mapping Units	CCAC		Mine Site		MTT		PTMA		BSA	
	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA
Colluvial	1,722.2	3.5%	2,526.0	5.1%	646.9	1.3%	4,731.9	9.6%	9,627.0	19.45%
Colluvial-Morainal	1,301.7	2.6%	574.1	1.2%	92.0	0.2%	470.2	1.0%	2,437.9	4.93%
Fluvial	517.4	1.0%	462.9	0.9%	62.0	0.1%	929.0	1.9%	1,971.3	3.98%
Fluvial-Colluvial	-	-	14.0	0.03%	-	-	57.4	0.12%	71.4	0.14%
Glacio-Fluvial	225.2	0.46%	84.2	0.17%	-	-	246.4	0.50%	555.7	1.12%
Ice	125.1	0.3%	6,066.4	12.3%	1,707.3	3.5%	396.9	0.8%	8,295.6	16.76%
Morainal	3,698.1	7.5%	2,847.4	5.8%	676.8	1.4%	5,295.9	10.7%	12,518.1	25.30%
Non soils	681.0	1.38%	5,062.9	10.23%	1,652.2	3.34%	2,913.8	5.89%	10,309.9	20.83%
Organic	203.5	0.41%	-	-	-	-	163.8	0.33%	367.4	0.74%
Bedrock	508.9	1.03%	1,914.5	3.87%	89.5	0.18%	467.1	0.94%	2,980.0	6.02%
Water	168.0	0.34%	33.3	0.07%	2.4	0.00%	145.9	0.29%	349.6	0.71%
Total	**9,151.1**	**18.5%**	**19,585.6**	**39.6%**	**4,929.0**	**10.0%**	**15,818.3**	**32.0%**	**49,484.0**	**100.0%**

CCAC = Coulter Creek Access Corridor.

Plate 8.1-2. Orthic Dystric Brunisol.

Plate 8.1-3. Orthic Humo-Ferric Podzol.

Plate 8.1-4. Poorly drained Orthic Gleysol.

Plate 8.1-5. Organic soil (Typic Mesisol).

Since the mosaic of soil types in the BSA is diverse, soil mapping units (SMUs) have been included on soil maps. SMUs are differentiated according to soil main characteristics, such as dominant parent material, proportion of mineral coarse fragments, and slope. Maps showing the distribution of SMUs within the BSA are provided in Appendix 8-C.

Morainal Soil Mapping Units

The soils that developed in morainal surficial materials occupy approximately 17,963 ha or 31% of the BSA (Table 8.1-3). Morainal materials typically occur as veneers (< 1 m thick) and blankets (> 1 m thick) in the middle to lower topographic positions of gentle to moderate slopes. The soils developed on these materials are mostly well- to imperfectly drained Brunisols with pockets of well- to imperfectly drained Podzols (Plate 8.1-3), imperfectly to poorly drained Gleysols, poorly drained organic soils, and well-drained Regosols. They have high coarse fragment content (except organic soils) and lack the fine material often associated with moraine, as the high rainfall environment and steep terrain have combined to remove much of the fine material.

Colluvial Soil Mapping Units

Colluvial soil mapping units predominately occur from valley bottoms to height of land. They occupy approximately 11,166 ha or 19% of the BSA (Table 8.1-3). They are found both as veneers and blankets and frequently overlie moraine and bedrock. The soils are medium- to coarse-textured with a coarse fragment content averaging 30%, consisting mostly of gravel. The soils that develop in colluvial deposits are mostly well-drained Brunisols and Podzols, with pockets of imperfectly drained Gleysols and Organic soils.

Colluvial – Morainal Complex Soil Mapping Units

Soils developed in colluvial materials are often found closely associated with morainal soils. Approximately 2,438 ha or 5% of the soils have developed on a complex of colluvial and morainal surficial materials (Table 8.1-3). The soils in this group are mostly well-drained Podzols with pockets of well-drained Brunisols. They have moderately fine to coarse textures, with an average coarse fragment content of 24%.

Fluvial Soil Mapping Units

Fluvial soils are developed in parent materials that were transported and deposited by moving water (rivers and streams). In the BSA, fluvial materials occur over a wide range of elevations (238 masl to 1,105 masl), occupying approximately 1,971 ha or 4% of the BSA (Table 8.1-3). The majority of the soils developed on fluvial deposits are found on flat to gentle slopes (0% to 15% grades) along river channels and on inactive floodplains.

Most of the fluvial soils have layers that are well sorted by particle size. The coarse fragment content of these soils varies widely, depending on the characteristics of the fluvial environment from which they were deposited. Soil textures range from medium to coarse (loam, silt loam, sandy loam, loamy sand, and sand). Similarly, soil drainage varies from rapid to poor. Common soils that developed on fluvial deposits include rapidly draining to well-drained Brunisols, Regosols, and poorly drained Gleysols.

Table 8.1-3. Soil Mapping Units in the Baseline Study Area

Soil Mapping Units	CCAC		Mine Site		MTT		PTMA		BSA	
	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA
Colluvial										
C1	-	-	1.9	0.00%	69.8	0.14%	550.9	1.11%	622.6	1.26%
C2	-	-	-	-	9.2	0.02%	942.1	1.90%	951.3	1.92%
C3	165.7	0.33%	128.9	0.26%	38.8	0.08%	554.5	1.12%	887.9	1.79%
C4	52.9	0.11%	63.1	0.13%	28.8	0.06%	497.3	1.01%	642.1	1.30%
C5	1,265.4	2.56%	992.2	2.01%	34.5	0.07%	204.7	0.41%	2,496.8	5.05%
C6	130.0	0.26%	70.1	0.14%	92.6	0.19%	827.3	1.67%	1,119.9	2.26%
C7	61.3	0.12%	694.6	1.40%	116.7	0.24%	313.2	0.63%	1,185.8	2.40%
C8	46.8	0.09%	575.2	1.16%	256.5	0.52%	842.0	1.70%	1,720.6	3.48%
Total C	**1,722.2**	**3.5%**	**2,526.0**	**5.1%**	**646.9**	**1.3%**	**4,731.9**	**9.6%**	**9,627.0**	**19.45%**
Colluvial-Morainal										
CM1	63.9	0.13%	-	-	19.6	0.04%	104.4	0.21%	187.9	0.38%
CM2	94.1	0.19%	64.2	0.13%	30.5	0.06%	10.9	0.02%	199.7	0.40%
CM3	1,143.7	2.31%	509.9	1.03%	41.9	0.08%	354.9	0.72%	2,050.3	4.14%
Total CM	**1,301.7**	**2.6%**	**574.1**	**1.2%**	**92.0**	**0.2%**	**470.2**	**1.0%**	**2,437.9**	**4.93%**
Fluvial										
F1	224.0	0.45%	95.2	0.19%	46.5	0.09%	445.8	0.90%	811.5	1.64%
F2	287.1	0.58%	312.3	0.63%	15.5	0.03%	483.2	0.98%	1,098.0	2.22%
F3	6.3	0.01%	55.5	0.11%	-	-	-	-	61.8	0.12%
Total F	**517.4**	**1.0%**	**462.9**	**0.9%**	**62.0**	**0.1%**	**929.0**	**1.9%**	**1,971.3**	**3.98%**
Fluvial-Colluvial										
FC	-	-	14.0	0.03%	-	-	57.4	0.12%	71.4	0.14%
Glacio-Fluvial										
FG	225.2	0.46%	84.2	0.17%	-	-	246.4	0.50%	555.7	1.12%

(continued)

Table 8.1-3. Soil Mapping Units in the Baseline Study Area (completed)

Soil Mapping Units	CCAC		Mine Site		MTT		PTMA		BSA	
	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA	ha	% of BSA
Ice										
I1	72.2	0.15%	5,539.5	11.19%	1,584.0	3.20%	216.1	0.44%	7,411.8	14.98%
I2	52.9	0.11%	526.9	1.06%	123.3	0.25%	180.8	0.37%	883.8	1.79%
Total Ice	**125.1**	**0.3%**	**6,066.4**	**12.3%**	**1,707.3**	**3.5%**	**396.9**	**0.8%**	**8,295.6**	**16.76%**
Morainal										
M1	203.4	0.41%	147.6	0.30%	129.3	0.26%	3,182.7	6.43%	3,663.0	7.40%
M2	1,284.4	2.60%	791.5	1.60%	62.3	0.13%	901.8	1.82%	3,040.0	6.14%
M3	525.1	1.06%	14.9	0.03%	116.7	0.24%	965.7	1.95%	1,622.3	3.28%
M4	329.2	0.67%	594.9	1.20%	21.1	0.04%	27.3	0.06%	972.5	1.97%
M5	125.4	0.25%	-	-	-	-	112.5	0.23%	237.9	0.48%
M6	405.5	0.82%	507.6	1.03%	338.1	0.68%	89.3	0.18%	1,340.5	2.71%
M7	-	-	544.7	1.10%	9.2	0.02%	16.7	0.03%	570.6	1.15%
M8	825.1	1.67%	246.3	0.50%	-	-	-	-	1,071.3	2.16%
Total M	**3,698.1**	**7.5%**	**2,847.4**	**5.8%**	**676.8**	**1.4%**	**5,295.9**	**10.7%**	**12,518.1**	**25.30%**
Non Soils										
NS	681.0	1.38%	5,062.9	10.23%	1,652.2	3.34%	2,913.8	5.89%	10,309.9	20.83%
Organic										
O	203.5	0.41%	-	-	-	-	163.8	0.33%	367.4	0.74%
Bedrock										
R	508.9	1.03%	1,914.5	3.87%	89.5	0.18%	467.1	0.94%	2,980.0	6.02%
Water										
W	168.0	0.34%	33.3	0.07%	2.4	0.00%	145.9	0.29%	349.6	0.71%
Total	**9,151.1**	**18.5%**	**19,585.6**	**39.6%**	**4,929.0**	**10.0%**	**15,818.3**	**32.0%**	**49,484.0**	**100.0%**

CCAC = Coulter Creek Access Corridor.

Fluvial – Colluvial Complex Soil Mapping Units

Soils developed in complexes of fluvial and colluvial surficial material are found in less than 0.1% of the BSA (71.4 ha) and often occur in valley bottoms bordered by steep ridges. These soils are typically coarse-textured with a high coarse fragment content consisting of gravels, cobbles, and boulders. Typically, these soils are rapidly to well-drained Regosols and Brunisols.

Glaciofluvial Soil Mapping Units

Glaciofluvial soil mapping units comprise soils developed from surficial materials that were transported by glacial rivers. These soils occupy approximately 556 ha or 1.1% of the BSA (Table 8.1-3) and are found sporadically on flat to gently sloping benches at less than 922 masl, bounded by steep-sided slopes. They are well-drained, gravelly by nature, and typically classified as Podzols.

Organic Soil Mapping Units

Organic soil mapping units comprise soils that formed through the accumulation of organic materials, typically in poorly to very poorly drained depressional areas. Organic materials also occur on flat to gentle slopes where the water table is near or at the soil surface. Organic soils occupy approximately 367 ha or 0.7% of the total BSA (Table 8.1-3). They are located mainly in elevations ranging between 876 and 1,200 masl. Approximately 55% (2.3 ha) of the organic soils occur in the Coulter Creek Access Corridor (CCAC) and 45% (164 ha) occur in the PTMA, including the TCAC. The soils are classified as Typic Fibrisols, Typic Mesisols, or Typic Humisols, depending on the degree of decomposition of the organic matter.

Bedrock/Weathered Bedrock

Veneers of weathered and exposed bedrock are common in crest to middle slope positions. These materials occupy approximately 2,980 ha or 6% of the BSA (Table 8.1-3), with more than half occurring in the Mine Site. Soil development is limited. Associated soils are shallow and coarse (sandy loam). Slopes of this mapping unit are variable, from 21% to over 70%, and averaging 56 grades.

Other (Non-soil) Mapping Units

Non-soils occur throughout 21% of the BSA (Table 8.1-3). They cover substantial portions of the Mine Site and MTT area. These mapping units consist of very thin veneers (< 10 cm) of colluvial, weathered bedrock, and morainal material. These non-soil mapping units may have undergone some pedogenesis but are generally not in sufficient amounts to classify them as a soil unit. Examples of non-soil mapping units include weathered bedrock with insufficient soil development to support plant life, actively ravelling steep slopes, and recently deposited glacial material. The slopes comprising non-soil mapping units are variable (0% to > 70%, averaging 60% grade) with rapid to poor drainage.

Ice Mapping Units

Mapping units labelled as ice (or as ice and bedrock complexes) include areas completely or partially covered with snow and ice that show little to no soil development. These mapping units occupy approximately 8,296 ha or 17% of the BSA (Table 8.1-3); however, portions of the BSA at higher elevations have considerably more ice compared to those in valleys. For example, 73%

of this mapping unit occurs in the Mine Site and another 21% in the MTT area, while little or no ice occurs elsewhere.

8.1.6 Soil Analytical Results

Both soil pH and organic carbon content are important parameters in soil classification and for assessing suitability for salvage and reclamation. Determination of the background metal concentration of soils, particularly for metals that are of environmental concern, is required to establish potential effects of mining with regard to soil contamination. It is also important for assessing the suitability of soils for salvage to prevent contamination of soils with naturally lower metal levels.

Analytical results indicate that most mineral soils in the BSA are strongly to very strongly acidic. These soils have low organic carbon content and are non-calcareous, which is typical of the coniferous forest ecosystems in the region.

The mean pH of soils collected from the BSA is 4.9 (0 to 10 cm samples), 5.2 (10 to 20 cm samples), and 5.5 (30 to 50 cm samples; Appendix 8-A). Soil pH variability within each sample group is low. Inputs of organic acids derived from coniferous detritus and high weathering rates of acidic bedrock contribute to the acidity of the soils in the BSA.

Total organic carbon content ranged from 0.2% to 28.0%, by weight (Appendix 8-A). The mean average total organic carbon levels were 6.3% (0 to 10 cm depth), 4.5% (10 to 20 cm depth), and 2.9% (30 to 50 cm depth). Since organic carbon accumulates in soils primarily from the addition of decomposing vegetation litter, its concentration in surface samples (0 to 10 cm) is considerably higher than in subsurface samples. The cold, wet climate and predominance of coniferous organic inputs facilitate organic nutrient cycling dominated by soil fungi, which mainly takes place in the soil humus. As a result, there is little mixing of organic carbon into the mineral soil (a process that requires an abundant soil faunal community), leading to low organic carbon content in mineral soils.

Metal concentrations in soil samples within the BSA vary between sampling locations and depths. Naturally elevated levels of arsenic, copper, molybdenum, and selenium were found in several locations (Appendix 8-A). Table 8.1-4 provides a summary of metal concentration in the BSA and compares the results with the guidelines. Red numbers indicate where guidelines have been exceeded. In a large proportion of collected samples, metal concentrations exceeded industrial limits of the Canadian Soil Quality Guidelines for Protection of Environmental and Human Health (CCME 2007). For example, arsenic Canadian Council of Ministers of the Environment (CCME) guidelines were exceeded in all sampling sites, chromium in 32%, copper in 34%, molybdenum in 5%, nickel in 53%, selenium in 27%, and vanadium in 32% of the 59 sampling sites. These results are presented in Table 8.1-5.

Table 8.1-4. Baseline Metal Concentration Found in Soils within the Local Study Area Compared to Contaminated Sites Regulation and CCME Guidelines

Element	Units	Minimum	Mean	Median	Maximum	CSR Industrial Criteria	CCME Industrial Guideline
Aluminum (Al)	mg/kg	3,680.00	26,602.58	27,150.00	71,500.00	-	-
Antimony (Sb)	mg/kg	5.00	7.00	5.00	81.00	40	20
Arsenic (As)	mg/kg	2.50	38.53	18.15	326.00	100	12
Barium (Ba)	mg/kg	20.60	149.85	117.00	1,110.00	1,500	2,000
Beryllium (Be)	mg/kg	0.25	0.68	0.25	6.47	8	8
Bismuth (Bi)	mg/kg	10.00	10.00	10.00	10.00	-	-
Cadmium (Cd)	mg/kg	0.25	0.45	0.25	2.28	500	22
Calcium (Ca)	mg/kg	25.00	2,523.94	945.00	21,500.00	-	-
Chromium (Cr)	mg/kg	1.00	63.73	53.70	308.00	700	87
Cobalt (Co)	mg/kg	1.00	16.86	11.95	123.00	300	300
Copper (Cu)	mg/kg	10.00	138.80	46.40	1,290.00	250	91
Iron (Fe)	mg/kg	5,640.00	56,808.18	49,950.00	373,000	-	-
Lead (Pb)	mg/kg	15.00	25.61	15.00	306.00	2,000	600
Lithium (Li)	mg/kg	1.00	21.38	19.00	117.00	-	-
Magnesium (Mg)	mg/kg	478.00	9,171.35	9,580.00	121,000.00	-	-
Manganese (Mn)	mg/kg	31.60	1,035.83	647.00	13,200.00	-	-
Mercury (Hg)	mg/kg	0.03	0.24	0.12	3.53	150	50
Molybdenum (Mo)	mg/kg	2.00	9.68	2.00	176.00	40	40
Nickel (Ni)	mg/kg	2.50	44.21	36.35	120.00	500	50
Phosphorus (P)	mg/kg	187.00	1,340.39	1,120.00	6,000.00	-	-
Potassium (K)	mg/kg	100.00	1,271.82	1,110.00	4,000.00	-	-
Selenium (Se)	mg/kg	0.25	1.80	1.12	10.80	10	2.9
Silver (Ag)	mg/kg	1.00	1.25	1.00	5.00	40	40
Sodium (Na)	mg/kg	100.00	144.24	100.00	1,160.00	-	-
Strontium (Sr)	mg/kg	3.07	29.99	14.80	296.00	-	-
Thallium (Tl)	mg/kg	0.50	0.50	0.50	0.50	-	1
Tin (Sn)	mg/kg	2.50	3.27	2.50	21.60	300	300
Titanium (Ti)	mg/kg	21.20	588.93	260.50	4,790.00	-	-
Vanadium (V)	mg/kg	22.30	94.33	81.80	351.00	-	130
Zinc (Zn)	mg/kg	19.10	97.28	87.55	237.00	600	360

Notes:
Red numbers indicate where guidelines have been exceeded. Metal concentration data were derived from field sampling program conducted in the BSA in 2007.
CSR = Contaminated Sites Regulation (BC Reg. 375/96).

Table 8.1-5. Proportion of Sampling Sites where Baseline Metal Concentrations Exceeded CCME Guidelines

	Mine Site		PTMA		CCAC		BSA	
Metals	**# of Sites**	**% of Sites**	**# of Sites**	**% of Sites**	**# of Sites**	**% of Sites**	**# of Sites**	**% of Sites**
Antimony (Sb)	2	9	0	0	0	0	2	3
Arsenic (As)	22	100	25	100	12	100	59	100
Chromium (Cr)	3	14	15	60	1	8	19	32
Copper (Cu)	20	91	0	0	0	0	20	34
Molybdenum (Mo)	3	14	0	0	0	0	3	5
Nickel (Ni)	5	23	21	84	5	42	31	53
Selenium (Se)	11	50	3	12	2	17	16	27
Vanadium (V)	11	50	3	12	5	42	19	32

Note: Metal concentration data were derived from field sampling program conducted in the BSA in 2007.

8.2 Historical Activities

While there is no record or evidence of past mining at the Project site (Rescan 2008), small-scale gold mining occurred during the early twentieth century, immediately west of the property, in Sulphurets and Mitchell creeks. To the east, Pretium Resources is developing the Brucejack property. Other previous mining activity in the Project vicinity includes the Snowfield and Brucejack projects, near the Mitchell Pit; the Eskay Creek Mine, approximately 18 km northwest of the Project; and the Granduc Mine, approximately 30 km to the south. In the past, commercial timber harvesting has occurred along Highway 37 to the east of the Project site.

While previous human activity may have influenced current soil conditions, the proportion of land affected by past human activity and related road use within the BSA is minimal.

8.3 Land Use Planning Objectives

The western portion of the Project is included in the Cassiar Iskut-Stikine Land and Resource Management Plan (CIS LRMP; BC ILMB 2000) and the twin tunnels connecting the Mine Site and PTMA fall within the boundaries of the Nass South Sustainable Resource Management Plan (Nass South SRMP; BC MFLNRO 2012).

One of the objectives of the CIS LRMP is sustainable supply of botanical forest products (mushrooms, berries, and medicinal plants). The outlined strategies include reduction of forest floor disturbance and soil compaction through the use of low-impact silviculture and harvesting systems (BC ILMB 2000).

To protect water resources and to limit the potential for soil surface erosion, the Nass South SRMP developed a target of no occurrences of exposed, erodible soil (more than 50 m^2), which can reasonably be expected to reach the riparian area if exposed to rainfall or stream flow (Section 2.1.1). Plan goals also include maintenance of natural biodiversity and historic disturbance patterns. One of the outlined strategies involves maintenance of natural conditions of soil chemistry, moisture, light, and temperatures in buffers around red-listed plant communities (Section 2.2.2). In addition, to maintain pine mushroom resources and provide opportunities for their sustainable harvest, the Nass South SRMP seeks protection of low-productivity forests growing on rocky ridges and hill tops, as well as on coarse-textured soils near rivers (Section 2.3.1). In an effort to recognize and respect Gitanyow and Nisga'a traditional areas, values, and activities, the Nass South SRMP developed an objective to preserve all cultural sites and tangible cultural resources including geographic features, soil, medicinal plant sites, spiritual sites, and cache pit sites (Section 2.6.1; BC MFLNRO 2012).

8.4 Spatial and Temporal Boundaries

8.4.1 Spatial Boundaries

The footprint of the proposed Project infrastructure comprises 4,195 ha and includes the following components:

- Mine Site features including pits, surficial components of underground mines, rock storage facilities, the Mitchell OPC, and related infrastructure;
- PTMA, including the North, Central, and South cells, the Treaty Process Plant, the TCAC, and construction camps along the TCAR;
- MTT; and
- CCAC and construction camps along the CCAR.

The LSA includes the maximum extent of the proposed Project footprint surrounded by a 100 m buffer and covers approximately 10,021 ha (Figure 8.4-1). The LSA resides fully within the BSA, which is used to provide spatial context for lost and degraded soils.

The buffer width of 100 m is derived from the spatial extent of notable changes in chemical and physical soil properties that might be expected in response to various Project effects, such as dust/metal deposition or the extent of hydrologic effects of roads.

It is true that effects of soil disturbance spread into the surrounding landscape and contribute to the loss and degradation of natural habitat far beyond the area lost under the footprint itself (Seiler 2001). Roads, in particular, despite their limited physical extent, tend to affect wide areas beyond the extent of the pavement. This can happen through a variety of mechanisms including dust deposition; alteration of existing groundwater movement patterns; alteration of light, temperature, and moisture in forested ecosystems; and increased fire potential. For example, Forman (2000) assessed that transport infrastructure in the United States directly affects an area that is about 19 times larger than the 1% of the US land surface that is physically occupied by roads.

Assessment of the width of the affected zone around the Project footprint depends on the choice of methods, timescales, and measured impacts (e.g., on hydrology, microclimate, soil fauna, or soil chemistry); estimates of the area of effect range from tens to hundreds of metres and even kilometres (McGarigal et al. 2001). Review of literature suggests, however, that the vast majority of effects of soil disturbance on soil are concentrated within the first 100 m from the edge of a disturbed area.

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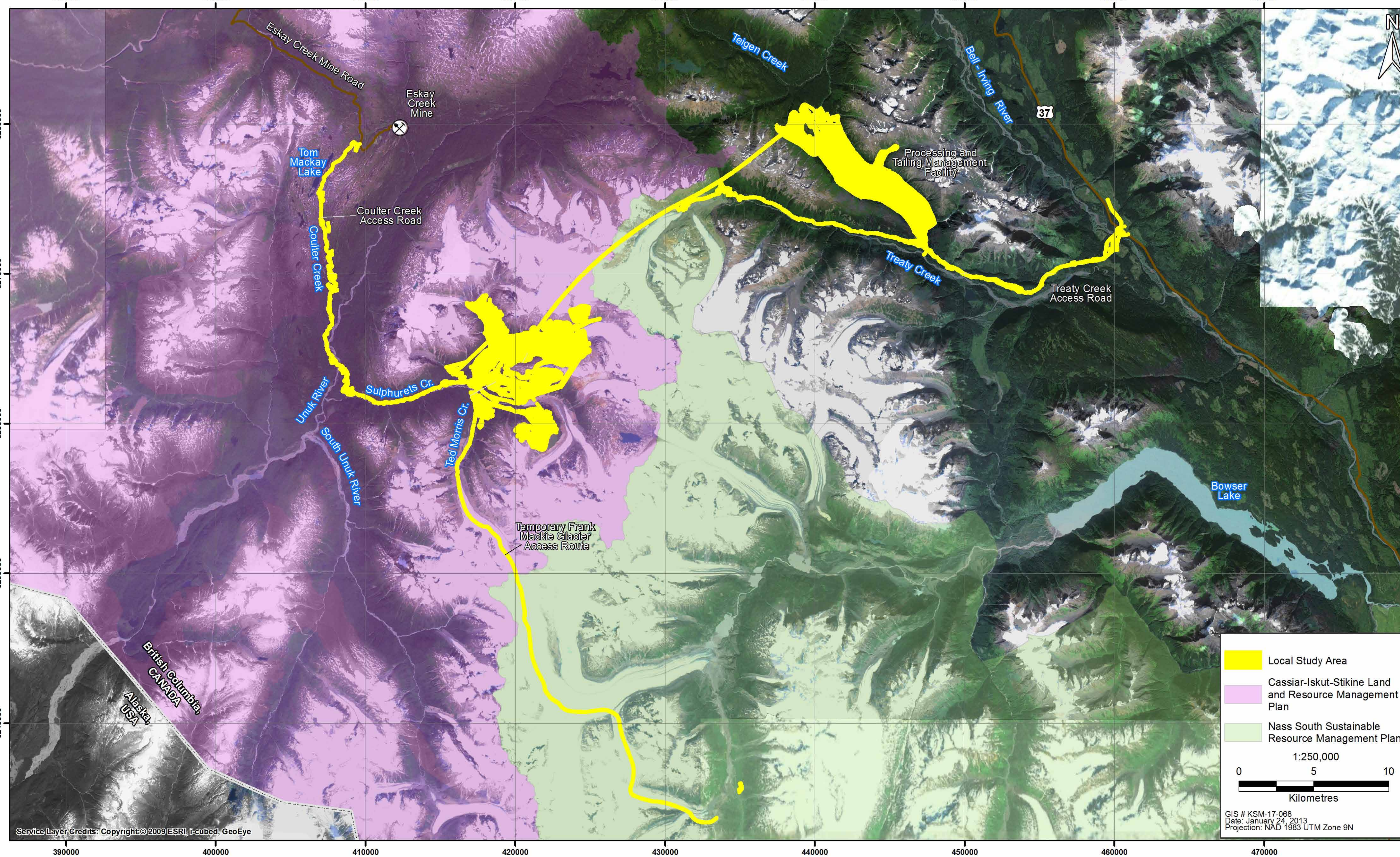

Figure 8.4-1

SEABRIDGE GOLD KSM PROJECT

Rescan Engineers & Scientists

Environmental Local Study Area Boundaries for Terrain and Soils

For example, Tague and Band (2001) have shown that, while soil water saturation deficit is detectable up to 700 m downslope, the greatest effects are observed within the first 100 m below the road. This conclusion is supported by Gelhausen et al. (2000), who show that the depth of a road "edge effect" on soil moisture ranges between 15 and 60 m. Similarly, results published by Matlack (1993) or Forman (1995) suggest that roads cut in forested habitats affect soil temperature within the 50 to 60 m zone. Recorded patterns of dust dispersal from road sources also suggest that dust deposition drops off to background levels, usually within 100 m from the road edge (Forman et al. 1997; Rescan 2012a).

The above conclusions do not imply that the negative effects on terrain and soils are limited to 100 m buffers. It is expected, however, that the most acute effects, capable of influencing the quantity and quality of soil resources, will be largely limited to these buffers. For the above reasons, the 100 m buffer around the maximum extent of the Project footprint was chosen as the spatial boundary for the assessment of the environmental effects of the Project on soils (Figure 8.4-1).

8.4.2 Temporal Boundaries

The temporal boundaries of this assessment are derived from the descriptions of the four main Project phases:

- construction phase (5 years);
- operation phase (51.5 years);
- closure phase (3 years); and
- post-closure phase (250 years).

The construction phase will involve land clearing, soil stripping and stockpiling, and the development of several quarries and borrow pits required for the construction of access roads, mine facilities, and associated infrastructure.

Throughout the operation phase, the area of land used to accommodate mining activities (overburden, rock, and ore storage), mineral crushing/transportation, ore processing, tailing disposal, and water management will increase successively. As the area required for these activities increases, soils will be progressively stripped and stockpiled. The volume of salvaged soil could be restricted by a limited availability of land surface that could be used for safe storage of soil stockpiles.

The closure phase will involve mine decommissioning and reclamation. During this period, mining and processing equipment will be salvaged, and infrastructure components that are no longer required (including buildings, concrete/asphalt, fuel tanks, etc.) will be removed. Much of the disturbed area will be reclaimed, which will involve capping disturbed areas with stockpiled soil and re-vegetating.

The post-closure phase will involve monitoring, which will extend into the foreseeable future. Monitoring will be carried out until it is clear that reclamation objectives have been met.

8.5 Valued Components

Soils provide a medium for vegetation growth and thus influence plant community composition, quality of wildlife habitat, and forest resources. Soils also have other ecologically important functions such as carbon and nutrient storage, flood control, and water filtering. Soils can also moderate sediment and contaminant transport to waterbodies. Soils support, directly and indirectly, many of the land uses in which Aboriginal groups are engaged. Consequently, the effects of mine development on surficial materials, soils, and terrain are assessed in relation to the current capability of the land to support natural vegetation, wildlife habitat, and a broad spectrum of other soil functions.

Identification of soil valued components (VCs) involved an issue scoping process, which included:

- review of the Application Information Requirements;
- review of the issue identification table that was based on public consultation;
- review of regional land management plans;
- consultation with Aboriginal groups;
- review of current legislation; and
- review of scientific literature.

Selection of soil VCs was based on the review of the information sources listed above and the professional expertise of a soil scientist.

8.5.1 Valued Components Included in Assessment

Each VC included in the environmental assessment meets the following three criteria:

1. There is a spatial and temporal overlap between the Project and the VC such that interactions may occur.
2. There is a suitable knowledge base and measurable parameters can be identified for the VC, which can be used to characterize Project interactions and serve as the basis for assessing potential effects of the Project.
3. There is a perceived and reasonable likelihood (i.e., as assessed by government regulators, Aboriginal groups, or stakeholders) that the VC could be affected by the Project.

A review of sources listed in Section 8.5 identified during the scoping process a number of key concerns associated with terrain, surficial geology, and soil. For example, soil quality can be affected by surface compaction, contamination, and erosion associated with mine development activities, such as land clearing, grubbing, surface grading, and soil salvage. Potential compaction and contamination during redistribution of salvaged soil may also affect soil quality during decommissioning and closure. Accidental spills and release of deleterious substances can potentially contaminate undisturbed, as well as reclaimed, areas. Accumulation of dust from mining activities can also influence the chemical composition of soils and lead to metal contamination. Alteration of the landscape can occur as a consequence of overburden removal, mineral material excavation, rock storage, and terrain re-contouring. This may affect terrain stability and accelerate soil erosion in post-closure ecosystems and could have indirect effects on other terrestrial and aquatic VCs, such as hydrology and water quality. Effects associated with terrain stability and geohazards are assessed in Chapter 9. Local mineralogy and environmental effects associated with geochemistry are discussed in Chapter 10.

Soil quantity and soil quality have been chosen as soil VCs that could be affected by the Project. Reduction of soil quantity through erosion, mass wasting, burial, excavation, and construction reduces the area available to support vegetation growth and provide nutrient, carbon, and water cycling. Reduction in soil quality can result from changes in site drainage patterns, compaction, or contamination. It can also occur from alteration of soil attributes such as structure, organic matter content, pH, chemical composition, and microbial activity. Reductions in soil quantity and quality can affect the ecological function of ecosystems, habitat quality, and water quality. This, in turn, can affect traditional hunting, fishing, and plant gathering.

Most sensitive organic soils occur in poorly drained areas on lower slopes and occupy approximately 1.6% of the total BSA, mainly in in the CCAC and PTMA and the TCAC. Their loss and degradation are included in a broader discussion of the Project effects on soil quantity and quality.

Table 8.5-1 lists the identified VCs and rationale for their selection.

Table 8.5-1. Identification and Rationale for Terrain, Surficial Geology, and Soils Valued Component Selection

Subgroup	Valued Component	Identified by*				Rationale for Inclusion
		AG	G	P/S	O	
Terrain, Surficial Geology, and Soils	Soil quantity	Y	Y	Y	Y	Necessary to maintain ecological function of ecosystems; has direct influence on wildlife habitat availability; affects traditional hunting, fishing, trapping, and gathering needs; protection required by *Mines Act* (1996).
	Soil quality	Y	Y	Y	Y	Affects ecological function and quality of fish and wildlife habitat, quality of groundwater resources and associated human and wildlife needs; affects traditional way of life of local Aboriginal peoples; protection required by *Environmental Management Act* (2003), *Mines Act* (1996).

***AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; O = Other.**

8.5.2 Valued Components Excluded from Assessment

No other VCs related to soils were identified by the Aboriginal groups, government, public, or professional experts.

8.6 Scoping of Potential Effects for Terrain, Surficial Geology, and Soils

The potential effects of each Project component on soil quantity and quality are summarized in Table 8.6-1. This table provides a general overview of the anticipated interactions between the Project activities and their potential adverse effects on soils. The potential effects on soils were assessed for each Project area (e.g., Mine Site, PTMA, TCAC, and CCAC) and for each of the mine development phases. Tables in Appendix 8-D provide an overview of the potential effects of the Project components expected in each phase.

While the degree of soil development varies across the Project area, the surficial materials near the proposed Project have been relatively undisturbed by human activity to date. The level of soil disturbance related to Project development is described in this assessment as: (1) areas lost (potential effects of the Project on soil quantity), and (2) areas degraded (potential effects of the Project on soil quality).

Soil loss commonly occurs during development of infrastructure from the construction phase through to closure and post-closure. Lost areas count as the most severe ground disturbance. Examples of activities that result in soil loss include soil removal or burial during pit development, overburden or rock storage, tailing disposal, and road construction. These construction activities limit or eliminate the ability of soils to support vegetation and provide other ecological functions.

Loss of soils may be temporary or permanent. Affected soils are classified as permanently lost when it is anticipated that the disturbed area will not be reclaimed by the end of the closure/post-closure phases and when the duration of the effect is expected to extend into the far future (e.g., the effect is expected to last more than 70 years). For example, post-closure use of the access roads (e.g., for continued maintenance of transmission lines, tower service, vegetation control within the right-of-way, etc.) represent permanently lost areas. Some lost areas, however, are expected to regain most of their pre-disturbance functionality after effective reclamation. In such cases, the same effect is considered to be temporary and the duration assigned to the effect (short, medium, or long term) depends on the predicted recovery period. A short-term effect is expected to last one year or less, a medium-term effect is defined as lasting from one to eleven years, and a long-term effect lasts between 12 and 70 years. Effects that are expected to last for more than 70 years are considered to extend into the far future. In view of harsh climatic and topographic conditions in the BSA, most disturbed soils are in this category, even if the areas undergo reclamation.

Areas where soil disturbance does not involve soil removal, burial, or large-scale erosion are described as "degraded." These are primarily found along roads, in laydown areas, or in 100 m buffers around mine components. Soil degradation (loss of soil quality) may occur in the form of soil compaction, contamination (often via dust accumulation), surface erosion, and/or decreased soil fertility. Soil compaction, typically caused by construction activities and associated heavy equipment traffic, affects vegetation establishment and growth and may result in increased surface runoff and soil erosion. Soil compaction may cause decreased root penetration and soil aeration, and altered site hydrology (e.g., reduced infiltration and conductivity, and/or changes to seepage patterns). These are potentially detrimental effects to site productivity and are most common under wet soils on steep and irregular terrain.

Table 8.6-1. Potential Project Effects on Soil Quantity and Quality

Project Region	Project Area	Loss of Soil Surface under Component Footprint	Loss of Soil due to Erosion, or Mass Movement	Soil Compaction	Soil Contamination	Loss of Soil Fertility
Mine Site	Camp 3: Eskay Staging Camp	X	X	X	X	X
	Camp 7: Unuk North Camp	X	X	X	X	X
	Camp 8: Unuk South Camp	X	X	X	X	X
	Coulter Creek Access Corridor	X	X	X	X	X
	Mitchell Operating Camp	X	X	X	X	X
	McTagg Rock Storage Facility	X	X	X	X	X
	McTagg Twinned Diversion Tunnels	X	X	X	X	X
	McTagg Power Plant	X	X	X	X	X
	Mitchell Rock Storage Facility	X	X	X	X	X
	Camp 4: Mitchell North Camp (for MTT Construction)	X	X	X	X	X
	Mitchell Ore Preparation Complex	X	X	X	X	X
	Mine Site Avalanche Control	X	X	X	X	X
	Iron Cap Block Cave Mine	X	X	X	X	X
	Mitchell Pit	X	X	X	X	X
	Mitchell Block Cave Mine	X	X	X	X	X
	Mitchell Diversion Tunnels	X	X	X	X	X
	Upper Sulphurets Power Plant	X	X	X	X	X
	Mitchell Truck Shop	X	X	X	X	X
	Water Storage Facility	X	X	X	X	X
	Camp 9: Mitchell Initial Camp	X	X	X	X	X
	Camp 10: Mitchell Secondary Camp	X	X	X	X	X
	Water Treatment and Energy Recovery Area	X	X	X	X	X
	Sludge Management Facilities	X	X	X	X	X
	Sulphurets Laydown Area	X	X	X	X	X
	Sulphurets-Mitchell Conveyor Tunnel	X	X	X	X	X

(continued)

Table 8.6-1. Potential Project Effects on Soil Quantity and Quality (completed)

Project Region	Project Area	Loss of Soil Surface under Component Footprint	Loss of Soil due to Erosion, or Mass Movement	Soil Compaction	Soil Contamination	Loss of Soil Fertility
Mine Site *(cont'd)*	Sulphurets Pit	X	X	X	X	X
	Kerr Rope Conveyor	X	X	X	X	X
	Kerr Pit	X	X	X	X	X
	Camp 2: Ted Morris Camp	X	X	X	X	X
	Explosives Manufacturing Facility	X	X	X	X	X
	Temporary Frank Mackie Glacier Access Route	X	X	X	X	X
	Camp 1: Granduc Staging Camp	X	X	X	X	X
Processing and Tailing Management Area	Mitchell-Treaty Twinned Tunnels	X	X	X	X	X
	Construction Access Adit	X	X	X	X	X
	Mitchell-Treaty Saddle Area	X	X	X	X	X
	Camp 6: Treaty Saddle Camp	X	X	X	X	X
	Camp 5: Treaty Plant Camp	X	X	X	X	X
	Treaty Operating Camp	X	X	X	X	X
	Treaty Ore Preparation Complex	X	X	X	X	X
	Concentrate Storage and Loadout	X	X	X	X	X
	North Cell Tailing Management Facility	X	X	X	X	X
	East Catchment Diversion	X	X	X	X	X
	Centre Cell Tailing Management Facility	X	X	X	X	X
	South Cell Tailing Management Facility	X	X	X	X	X
	Treaty Creek Access Corridor	X	X	X	X	X
	Camp 11: Treaty Marshalling Yard Camp	X	X	X	X	X
	Camp 12: Hwy 37 Construction Camp	X	X	X	X	X
Off-site Transportation	Highway 37 and 37A	-	-	X	X	X

X = interaction between component and effect.

There is a risk that soils could be contaminated due to spills of deleterious substances throughout the Project life. These substances may accumulate in the soils, increasing the concentration of metals and other pollutants and may lead to loss of soil fertility and increased toxicity to vegetation and soil fauna, or, in extreme cases, render soil unsuitable to support ecological functions.

The term "degraded" is also used for the area within the 100 m buffers around the proposed infrastructure. Such areas are likely to sustain little or no direct disturbance. Nevertheless, these areas could be affected by alteration of drainage, dust deposition, erosion, forest fires, or other unanticipated changes related to unplanned emergency activities. For example, excessive or prolonged dust deposition onto otherwise undisturbed soils may result in accumulation of heavy metals in areas adjacent to mine components, such as the mine pits, ore preparation complexes, roads, or PTMA. Migration of acidic leachate from rock storage facilities could also contaminate the soil.

Buffer areas, however, can serve as important sources of reproductive plant material (e.g., seeds or spores), which can be used when re-vegetating adjacent disturbed areas with native species. In this way they can fulfill an important, beneficial role in reclamation.

Wind and water erosion of soil, usually induced by soil surface disturbance or vegetation removal, can result in the loss of fertile soil horizons and may introduce sediments into watercourses. Soil fertility can also be compromised during soil salvaging operations. For example, there is a risk that soil fertility will be reduced if fertile surface soils are inadvertently mixed with infertile subsurface material.

8.6.1 Construction

Construction of the mine will result in a loss of soil through excavation, burial, or erosion of surficial materials (Table 8.6-1; Appendix 8-B). Soil will be salvaged from areas that will be used for construction of the pits, Treaty Process Plant, Tailing Management Facility (TMF), overburden, topsoil, ore and rock storage areas, construction camps, quarries, borrow pits, drainage diversion/collection ditches, and roads. During the process of soil salvage and stockpiling, soil may be compacted and mixed, which will likely lead to loss of its natural structure and sequence of horizons.

During construction, soil can be degraded by erosion, compaction, contamination, or other physical, chemical, and biological changes leading to a loss of soil fertility. This could occur within the 100 m buffer areas around the mine facilities, tunnel portals, laydown areas, construction camps, quarries, borrow pits, soil stockpiles, in areas disturbed by construction of the stream diversions, and along roads. Some soil contamination is anticipated due to inadvertent small spills of cement, reagent, fuel, lubricant, or other materials during construction. Soil stripping and stockpiling may result in a reduction of soil fertility due to compaction and mixing of the fertile surface soils with overburden or other unsuitable material. A gradual loss of organic matter, native plant reproductive material, and microbial activity is expected to occur in the soil stockpiles, resulting in a loss of fertility (Defra 2009).

8.6.2 Operation

During operation, spatial loss will continue to increase due to the expanding footprint of mine facilities, such as the pits, the rock storage areas, and the TMF (Table 8.6-1; Appendix 8-B). During this phase, two construction camps and associated facilities, and the temporary rock storage sites, located at the Mitchell-Treaty Saddle Area and at the CCAR, will be decommissioned and reclaimed.

It is expected that soil quality will be adversely affected within the 100 m buffers around mine facilities, storage areas, ore preparation and transportation facilities, the Treaty Process Plant, and TMF, as well as along the roads. Soil degradation could result from changes in local hydrology, erosion, and disturbance from vehicles and construction equipment. In addition, deposition of dust containing high concentrations of metals (e.g., along the transport route for the concentrate), as well as spills of cement, processing reagents, fuels, lubricants, and other materials, could lead to soil contamination in some of the buffer areas.

8.6.3 Closure

During Project closure approximately 20% of the LSA will be reclaimed. The land directly under the footprints of the pits, retained mine infrastructure, water management facilities, un-vegetated portions of the rock storage facilities, and the remaining roads (approximately 25% of the LSA) will be lost permanently (Table 8.7-1, Appendix 8-B). Approximately 40% of the LSA (areas located in the buffers surrounding the retained Project components) will remain degraded. The remaining 15% of the LSA consists of the recovering areas reclaimed during previous Project phases that did not attain their pre-disturbance capacities.

8.6.4 Post-closure

After closure there is a possibility of continued soil degradation in buffer areas around the remaining facilities (e.g., water diversion, hydro facilities, roads, and the transmission line) that are required for maintenance. Management of soil during the life of the Project will affect the long-term recovery of soil productivity. For example, moving soil to and from the stockpiles will negatively affect soil structure. Long-term storage will lead to anaerobic conditions, which reduce soil fertility (Defra 2009). Consequently, it will take many years for soils to recover to baseline biological conditions and to resume its natural functions (e.g., structure, organic matter, microbial activity, nutrient cycling, moisture conductivity, etc.).

8.7 Potential for Residual Effects for Terrain, Surficial Geology, and Soils

The potential effects of each Project component on soil quantity and quality have been summarized in Table 8.6-1. Table 8.7-1 provides an overview of the spatial and temporal extent of this process by summarizing the estimated areas of land that may be lost or degraded throughout the mine life. A portion of the lost and degraded areas will be reclaimed as mitigation for this effect. The extent of reclaimed areas is shown in Table 8.7-1.

8.7.1 Loss of Soil Quantity

This section discusses the loss of ecologically functional soil under the footprint of the Project and due to erosion during construction, operation, closure and post-closure phase activities. Loss of ecologically functional soil can take place through direct loss of an area of the land due to Project footprint development or from bulk soil erosion from non-vegetated land surfaces.

Table 8.7-1. Summary of Lost, Degraded, and Reclaimed Areas by Project Phase and by Soil Mapping Unit

				Construction						Operation						Closure					
		Total Area of LSA		Lost		Degraded		Reclaimed		Lost		Degraded		Reclaimed		Lost		Degraded		Reclaimed	
Soil Mapping Units		**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**	**ha**	**% of BSA**
Morainal	M1	1,437.7	2.16%	637.1	0.96%	672.7	1.01%	9.0	0.01%	673.9	1.01%	469.8	0.71%	243.6	0.37%	337.1	0.51%	471.2	0.71%	571.2	0.86%
	M2	1,311.4	1.97%	459.1	0.69%	716.5	1.08%	14.2	0.02%	509.2	0.77%	574.9	0.86%	194.9	0.29%	238.0	0.36%	623.6	0.94%	324.1	0.49%
	M3	363.2	0.55%	101.6	0.15%	221.5	0.33%	-	-	116.0	0.17%	217.3	0.33%	29.9	0.04%	56.6	0.09%	206.7	0.31%	74.1	0.11%
	M4	445.2	0.67%	73.7	0.11%	165.8	0.25%	-	-	250.3	0.38%	164.1	0.25%	23.2	0.03%	130.7	0.20%	151.0	0.23%	126.9	0.19%
	M5	28.0	0.04%	4.9	0.01%	22.9	0.03%	-	-	3.4	0.01%	21.8	0.03%	0.2	0.00%	2.7	0.00%	20.3	0.03%	0.7	0.00%
	M6	267.1	0.40%	73.1	0.11%	92.2	0.14%	-	-	182.9	0.27%	64.8	0.10%	4.6	0.01%	106.6	0.16%	49.4	0.07%	77.4	0.12%
	M7	288.3	0.43%	23.0	0.03%	43.7	0.07%	-	-	200.0	0.30%	79.9	0.12%	-	-	152.0	0.23%	80.4	0.12%	54.8	0.08%
	M8	113.0	0.17%	22.7	0.03%	56.0	0.08%	-	-	61.7	0.09%	49.4	0.07%	0.5	0.00%	61.6	0.09%	50.5	0.08%	0.1	0.00%
	Total M	**4,253.8**	**6.40%**	**1,395.2**	**2.10%**	**1,991.3**	**2.99%**	**23.2**	**0.03%**	**1,997.3**	**3.00%**	**1,642.0**	**2.47%**	**496.9**	**0.75%**	**1,085.3**	**1.63%**	**1,653.1**	**2.49%**	**1,229.3**	**1.85%**
Colluvial	C1	278.7	0.42%	31.3	0.05%	147.7	0.22%	0.1	0.00%	137.0	0.21%	131.6	0.20%	10.1	0.02%	15.8	0.02%	128.8	0.19%	121.2	0.18%
	C2	207.7	0.31%	27.0	0.04%	160.0	0.24%	-	-	30.6	0.05%	162.6	0.24%	12.1	0.02%	30.1	0.05%	164.2	0.25%	4.1	0.01%
	C3	350.9	0.53%	52.3	0.08%	140.4	0.21%	-	-	168.9	0.25%	109.1	0.16%	68.4	0.10%	47.5	0.07%	129.1	0.19%	121.1	0.18%
	C4	229.1	0.34%	49.7	0.07%	109.8	0.17%	0.1	0.00%	83.3	0.13%	104.6	0.16%	39.9	0.06%	26.7	0.04%	104.8	0.16%	96.3	0.14%
	C5	448.4	0.67%	76.5	0.11%	165.3	0.25%	1.7	0.00%	181.9	0.27%	238.1	0.36%	19.9	0.03%	138.0	0.21%	241.5	0.36%	49.3	0.07%
	C6	130.6	0.20%	21.5	0.03%	34.6	0.05%	-	-	31.6	0.05%	78.6	0.12%	3.4	0.01%	8.9	0.01%	77.1	0.12%	23.8	0.04%
	C7	236.5	0.36%	17.6	0.03%	43.1	0.06%	-	-	142.0	0.21%	90.4	0.14%	-	-	130.6	0.20%	89.9	0.14%	11.6	0.02%
	C8	96.8	0.15%	6.2	0.01%	23.5	0.04%	-	-	28.4	0.04%	68.4	0.10%	-	-	17.0	0.03%	68.4	0.10%	11.4	0.02%
	Total C	**1,978.7**	**2.98%**	**282.1**	**0.42%**	**824.5**	**1.24%**	**1.8**	**0.00%**	**803.7**	**1.21%**	**983.4**	**1.48%**	**153.9**	**0.23%**	**414.6**	**0.62%**	**1,003.7**	**1.51%**	**438.7**	**0.66%**
Colluvial-Morainal	CM1	89.5	0.13%	25.5	0.04%	56.5	0.08%	-	-	33.7	0.05%	40.8	0.06%	14.8	0.02%	23.2	0.03%	34.0	0.05%	18.7	0.03%
	CM2	93.2	0.14%	21.6	0.03%	66.9	0.10%	0.0	0.00%	17.6	0.03%	73.1	0.11%	1.9	0.00%	6.5	0.01%	72.3	0.11%	11.0	0.02%
	CM3	281.6	0.42%	31.3	0.05%	113.0	0.17%	-	-	121.7	0.18%	143.4	0.22%	12.0	0.02%	96.7	0.15%	133.5	0.20%	32.2	0.05%
	Total CM	**464.3**	**0.70%**	**78.4**	**0.12%**	**236.3**	**0.36%**	**0.0**	**0.00%**	**172.9**	**0.26%**	**257.3**	**0.39%**	**28.7**	**0.04%**	**126.4**	**0.19%**	**239.8**	**0.36%**	**61.8**	**0.09%**
Fluvial	F1	124.7	0.19%	16.2	0.02%	104.2	0.16%	-	-	23.0	0.03%	96.1	0.14%	4.0	0.01%	10.5	0.02%	79.3	0.12%	12.5	0.02%
	F2	423.5	0.64%	186.5	0.28%	226.8	0.34%	5.6	0.01%	179.9	0.27%	190.3	0.29%	28.9	0.04%	79.1	0.12%	179.4	0.27%	121.6	0.18%
	F3	35.5	0.05%	19.8	0.03%	8.8	0.01%	-	-	28.2	0.04%	0.1	0.00%	-	-	19.4	0.03%	-	-	8.9	0.01%
	Total F	**583.7**	**0.88%**	**222.6**	**0.33%**	**339.8**	**0.51%**	**5.6**	**0.01%**	**231.1**	**0.35%**	**286.4**	**0.43%**	**32.9**	**0.05%**	**109.0**	**0.16%**	**258.7**	**0.39%**	**142.9**	**0.21%**
Fluvial-Colluvial	FC	47.0	0.07%	11.3	0.02%	23.1	0.03%	-	-	29.2	0.04%	17.1	0.03%	0.3	0.00%	11.2	0.02%	16.6	0.03%	18.7	0.03%
Glacio-Fluvial	FG	176.1	0.26%	79.0	0.12%	96.1	0.14%	-	-	77.4	0.12%	79.6	0.12%	18.9	0.03%	14.2	0.02%	67.5	0.10%	63.0	0.09%
Ice	I1	812.1	1.22%	127.3	0.19%	639.9	0.96%	-	-	7.4	0.01%	44.9	0.07%	-	-	7.4	0.01%	44.9	0.07%	-	-
	I2	140.2	0.21%	20.4	0.03%	75.3	0.11%	-	-	46.0	0.07%	55.8	0.08%	-	-	46.0	0.07%	55.8	0.08%	-	-
	Total I	**952.4**	**1.43%**	**147.6**	**0.22%**	**715.1**	**1.08%**	**0.0**		**53.5**	**0.08%**	**100.7**	**0.15%**	**0.0**		**53.5**	**0.08%**	**100.7**	**0.15%**	**0.0**	
Non soils	NS	1,111.7	1.67%	235.6	0.35%	409.1	0.62%	-	-	607.7	0.91%	434.3	0.65%	13.7	0.02%	549.2	0.83%	432.4	0.65%	54.4	0.08%
Organic	O	123.9	0.19%	68.1	0.10%	46.6	0.07%	-	-	75.1	0.11%	29.8	0.04%	19.0	0.03%	42.5	0.06%	25.5	0.04%	50.9	0.08%
Bedrock	R	312.9	0.47%	30.0	0.05%	62.6	0.09%	-	-	146.5	0.22%	163.1	0.25%	2.7	0.00%	147.2	0.22%	161.4	0.24%	0.3	0.00%
Water	W	16.1	0.02%	1.0	0.00%	12.0	0.02%	-	-	0.9	0.00%	13.9	0.02%	0.2	0.00%	0.9	0.00%	12.6	0.02%	-	-
Total		**10,020.7**	**15.07%**	**2,550.9**	**3.84%**	**4,756.6**	**7.15%**	**30.6**	**0.05%**	**4,195.3**	**6.31%**	**4,007.7**	**6.03%**	**767.2**	**1.15%**	**2,553.9**	**3.84%**	**3,972.0**	**5.97%**	**2,060.2**	**3.10%**

Loss of Soil due to Footprint Development

During Project life, 4,195 ha of land will be lost due to construction of facilities such as the pits, waste rock storage facilities, roads, and quarries. Most ecological functions of the soil will be temporarily or permanently lost in these areas. Potentially affected soils include a large amount of soil developed on till blankets or veneers (Table 8.7-1). The soils that are lost will mainly include well- to imperfectly drained Brunisols and Podzols (SMUs M1, M2, and M4). There is also a risk of the loss of non-soils and soils developed on colluvial deposits.

It is expected that the quarries and borrow pits in the CCAR, as well as a portion of the Mitchell-Treaty Saddle Area, will be reclaimed during the first five years of mine operation. In addition, some of the areas developed near the Mitchell-Treaty Saddle Area (e.g., construction camp, laydown, and storage areas), along the CCAR (construction camp and rock storage facilities), and along the Temporary Frank Mackie Glacier access route will be reclaimed during operation. The 2,060 ha of land categorized as temporarily lost during construction or operation phases (e.g., the Treaty Process Plant, Treaty OPC, PTMA, as well as a portion of the rock storage facilities and roads) will be reclaimed during closure and post-closure.

Over 60% of the proposed reclaimed areas occur in the lower portions of gentle to moderate slopes that are currently overlain by imperfectly to poorly drained soils developing in morainal deposits. About 20% occur on the moderately to steeply sloped areas overlain by coarser textured colluvial derived soils and non-soils. It is expected that in most reclaimed areas, the slopes and underlying materials will have changed substantially because of mining activity. For example, a large portion of the rock storage facility that will be constructed on steep slopes will have extensive flat surfaces at the time of reclamation.

About 50% of the land lost during construction and operation will be reclaimed during or after mining activity. Approximately 2,554 ha of land located under the footprints of the components retained after mine closure (e.g., within the perimeter of the mining pits or under the surface of the remaining roads), will be lost permanently. Over 30% of permanently lost areas are located within non-soil mapping units. The remaining portion is dominated by soils derived from moraine and colluvium.

Soils that developed on organic materials (124 ha in the LSA, most of which are located in the proposed PTMA) are the most sensitive to disturbance. During construction 68 ha of organic soils will be lost. This area will increase to 75 ha during the operation phase (Table 8.7-1). A portion of organic soils will be reclaimed after closure, but it is expected that the resulting ecosystems will be considerably different from the original ones. The organic soils located within the proposed footprint will be salvaged, stored, and used to enhance reclamation material.

Loss of Soil due to Erosion

Much of the Project development area is characterized by moderate to steep slopes (Section 8.1.4). Steep slopes are particularly common in and around the Mine Site, where most of the proposed mine infrastructure and rock storage facilities will be located. Under such conditions, slope stability issues and erosion control will be particularly challenging. The areas of particularly high erosion risk include buffers along the roads and water crossings. Potential for soil loss exists on most slopes where vegetation has been removed or the integrity of the soil surface has been disturbed. The highest probability of soil loss due to erosion will be during mine construction and closure. Removal of vegetation during Project component development as well as gradual removal of soil from the stockpile berms and spreading it over reclaimed areas during closure may expose the soils to increased erosion.

8.7.1.1 Mitigation for Loss of Ecologically Functional Soil

Mitigation for Loss of Soil due to Footprint Development

The main objective of the Terrain, Surficial Geology and Soil Management and Monitoring Plan (Section 26.13) is to minimize the area of land where the ecological function of soil is lost or severely compromised. To facilitate this, land will be cleared only in areas necessary for mine activities during each phase. One of the principles followed in developing the overall Project plan has been to minimize the area covered by the Project footprint. In addition, to the extent practicable, environmentally sensitive or technically difficult areas have been avoided through facility layout planning.

Where practical, disturbed areas will be reclaimed and re-vegetated as soon as it is feasible to do so. During Project construction and operation close to 800 ha (8% of the LSA) will be reclaimed. Another 20% of the LSA will be reclaimed during Project closure. Soil salvage and stockpiling constitutes an important aspect of this mitigation practice. During construction (mainly during the development of mine facilities), soil will be stripped and stockpiled for future reclamation. This process will continue on a smaller scale during operation to match the expanding footprint of certain mine areas (e.g., rock storage facilities and PTMA).

Mitigation for Bulk Soil Erosion

Erosion control measures will focus on preventing soil loss associated with wind, water, and gravity. Re-vegetation of soil stockpiles, ditches, road cuts, and embankments started during construction and continued during operation will reduce the potential of soil erosion. Erosion control measures include seeding exposed soils with an erosion control seed mix or hydro-seeding with a mix of seed, mulch, and a tackifier as soon as practicable. Where required, especially in sloped areas and along water diversion channels, more intensive soil erosion control measures will be adopted, such as construction of channel bank protection or the installation of erosion control blankets or bonded fibre matrices onto the soil surface. Slope stabilization techniques, including terracing or installing bioengineering structures, such as wattle fences and modified brush layers, may also be used on highly erodible soils and on long or steep slopes. Silt fences may also be used to contain sediments eroding off-site or entering waterways. Rock material, willow bundles, or gabions will also be used, as required, to protect erodible channel banks. Please refer to Terrain, Surficial Geology, and Soil Management and Monitoring Plan (Section 26.13) for a more detailed description of the erosion and sedimentation control program and mitigation methods.

Establishing an erosion monitoring system at the beginning of construction will be necessary to verify proper implementation and effectiveness of mitigation measures. If monitoring data indicate that the mitigation methods are not adequately controlling soil erosion, adaptive management measures directed towards identification and implementation of a new or modified mitigation approach will be promptly initiated (CEA Agency 2009). More details on mitigation are provided in the Terrain, Surficial Geology and Soil Management and Monitoring Plan (Section 26.13).

8.7.1.2 Soil Quantity: Potential Residual Effects due to Loss of Ecologically Functional Soil Area and Soil Bulk Erosion

With mitigation measures implemented as planned, Project development will result in the permanent loss of 2,554 ha of land (Table 8.7-1) under the footprint of Project components retained after closure (e.g., waste rock and tailing storage, mining pits, and roads). Additional soil losses will be associated with soil erosion from un-vegetated surfaces such as roads. The permanent loss of ecologically functional soil due to the above-mentioned effects will constitute a residual adverse effect on one VC: soil quantity. Table 8.7-2 summarizes the extent as well as the spatial and temporal aspects of these potential effects.

8.7.2 Degradation of Soil Quality

It is expected that soil quality will be affected during the Project life within the Project footprint. In order to capture potential effects outside the footprint, a 100 m buffer has been applied around the mine facilities, including the Treaty Process Plant, tunnel portals, laydown areas, TMF, rock storage facilities, and soil stockpiles, as well as along the diversion channels, roads, and transmission lines. The following sections discuss the pathways and extent of potential soil degradation and Table 8.7-3 provides a summary of discussed findings.

Soil degradation is defined as the loss of soil quality due to adverse effects. Soil degradation is caused by contamination, erosion, and loss of soil structure due to disturbances such as excavation, transport, or surface compaction. Transportation and long-term storage of soil can also adversely affect soil fertility.

<u>Soil Contamination</u>

Rocks and surficial materials present in the LSA contain elevated concentrations of pyrite, which, when exposed to oxygen and water, can produce acidic conditions and lead to mobilization of metals (Price and Errington 1998). Mining pit walls, waste rock storage piles, ore stockpiles, borrow areas, quarries, roads, laydown areas, and areas cleared for infrastructure construction are expected to produce acidic drainage containing dissolved aluminum, arsenic, cadmium, copper, iron, lead, selenium, and zinc (see Chapter 10, Geochemistry). Furthermore, tailing material will contain high concentrations of antimony, arsenic, cadmium, copper, iron, molybdenum, selenium, silver, and sulphur. While a number of potential pathways of metal distribution within the adjacent ecosystems are possible (Zhi-Qing 1996), two main pathways involving aerial deposition with dust and aqueous transportation by groundwater are most likely. Within the first decade of Project development the severity of soil contamination will be likely limited but it is expected to increase over time. Soil contamination can also result from potential spills of reagents, lime, cement, fuels, lubricants, or other chemicals during the mine life and during the post-closure phase.

<u>Soil Compaction</u>

Soil compaction, typically caused by construction activities and associated heavy equipment traffic, can affect vegetation establishment and growth. It can also result in increased surface runoff and soil erosion. The area of land affected by surface compaction, and the severity of this adverse effect, is generally expected to be most prevalent during the construction and closure phases.

Roads constructed on slopes can interfere with subsurface water flow and runoff, making the slopes vulnerable to erosion and slope failures (Noss 1995; Gunn 2009). Furthermore, some level of land subsidence is expected in the mining pit areas. The exact effect of land subsidence on soil compaction is difficult to establish; however, due to potential changes in slope stability, soil mass movement and soil compaction can be anticipated near the mining pits.

<u>Loss of Soil Fertility</u>

While stripping and stockpiling operations are necessary to conserve soil for future mine reclamation, the process itself can result in soil degradation through the loss of soil structure, compaction, and erosion. With time, such activity can result in the loss of native plant reproductive material, organic matter, and faunal and microbial activity. Mixing of fertile topsoils with subsoils during soil salvage can result in a reduction of soil quality.

Soil fertility can also be affected by alteration of soil drainage patterns due to Project development (e.g., local changes in groundwater table related to watercourse diversions, underground tunnel construction, changes in natural seepage pathways associated with road construction, etc.). Exposed soil surfaces (e.g., forest roads) are known to reduce infiltration, capture and channelize surface runoff, and modify subsurface flow paths (Luce and Wemple 2000; Tague and Band 2001), which all affect the soil moisture regime and thus a number of related soil characteristics, affecting soil fertility. Soil erosion associated with roads also decreases soil productivity in surrounding areas (Bulmer et al. 2008).

Roads can also affect soil fertility by increasing solar radiation and air movement in previously shaded environments, which leads to changes in soil temperature and moisture (Matlack 1993; Forman 1995; Gehlhausen et al. 2000), alters composition and activity of soil micro-organisms (Pimientel et al. 1995), and increases the risk of fire occurrence (USFS 1996; Arienti et al. 2009). Fires in turn, affect a variety of physical and chemical properties of soil, including the loss of organic matter and reduced infiltration, which, interacting with removal of slope stabilizing vegetation, results in increased runoff and soil erosion (NWCG 2001).

8.7.2.1 Mitigation for Soil Degradation

Refuelling stations and heavy equipment maintenance facilities will be designed to minimize and control spillage. Spill response equipment and procedures will be available on-siteand the storage, handling, and use of petroleum products and chemicals will comply with regulatory requirements. Mitigation will include clean-up of any spills that occur, to minimize the inflow of contaminants to soils. Contaminated soils will be disposed of appropriately off-site, or treated on-site by bioremediation (details are provided in Terrain, Surficial Geology and Soil Management and Monitoring Plan, Section 26.13). The amount of human-generated waste will be minimized through reduction, reuse, recycling, and proper disposal of remaining material (details in Domestic and Industrial Waste Management Plan, Section 26.6).

Reclamation methods that reduce equipment traffic during soil removal and redistribution will be employed to lessen soil compaction (details in Chapter 27).

Table 8.7-2. Potential Residual Effects on Soil Quantity

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quantity	Construction	Mine Area	Camp 1 – Granduc	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 2 - Ted Morris Staging	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect
			Camp 3 - Eskay	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 4 – MTT Construction Camp	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 5 - Treaty Plant	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	No	No residual effect.
			Camp 6 - Treaty Saddle	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	No	No residual effect.
			Camp 7 - Unuk North	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 8 - Unuk South	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 9 - Mitchell Initial	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 10 - Mitchell Secondary	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Camp 11 - Treaty Marshalling Yard	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Coulter Creek Access Corridor	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	No	No residual effect.
			Explosives Manufacturing Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			McTagg Diversion Tunnel	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.

(continued)

Table 8.7-2. Potential Residual Effects on Soil Quantity (continued)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quantity *(cont'd)*	Construction *(cont'd)*	Mine Area *(cont'd)*	Water Treatment & Energy Recovery Area	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mine Site Avalanche Control	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Mitchell Diversion Tunnel	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mitchell Operating Camp	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mitchell Ore Preparation Complex	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mitchell Pit	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Mitchell Rock Storage Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Sludge Management Facilities	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Sulphurets Pit	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Sulphurets Laydown Area	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Temporary Frank Mackie Glacier Access Route	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Truck Shop	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Upper Sulphurets Power Plant	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Water Storage Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
	Operation	Mine Area	Iron Cap Block Cave Mine	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.

(continued)

Table 8.7-2. Potential Residual Effects on Soil Quantity (continued)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quantity *(cont'd)*	Operation *(cont'd)*	Mine Area *(cont'd)*	Kerr Pit	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Kerr rope conveyor	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			McTagg Power Plant	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			McTagg Rock Storage Facililty	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Mitchell Block Cave Mine	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Sulphurets-Mitchell Conveyor Tunnel	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
	Construction	Processing and Tailing Management Area	Camp 12 - Highway 37 Construction	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			Centre Cell Tailing Management Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			construction access adit	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	No	No residual effect..
			East Catchment Diversion	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mitchell-Treaty Tunnel	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Mitchell-Treaty Tunnel Saddle Area	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			North Cell Tailing Management Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
			Treaty Creek Access Road	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.
			Treaty Operations Camps	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint and soil erosion from roads.

(continued)

Table 8.7-2. Potential Residual Effects on Soil Quantity (completed)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quantity *(cont'd)*	Construction *(cont'd)*	Processing and Tailing Management Area *(cont'd)*	Treaty Ore Prep Complex	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
	Operation	Processing and Tailing Management Area	Concentrate Storage and Loadout	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control, reclaim early.	No	No residual effect.
			South Cell Tailing Management Facility	Soil loss under footprint; potential soil erosion from cleared areas and soil stockpiles.	Management Practices	Minimize footprint, apply BMP for soil salvage and erosion control.	Yes	Permanent loss of soil under component footprint.
	Construction	Highways	Highway 37 and 37A	No effect on soil quantity is expected.	Management Practices	Apply BMP for soil salvage and erosion control.	No	No residual effect.

Table 8.7-3. Potential Residual Effects on Soil Quality

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quality	Construction	Mine Site	Camp 1: Granduc Staging Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 2: Ted Morris Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 3: Eskay Staging Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 4: Mitchell North Camp (for MTT construction)	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 5: Treaty Plant Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 6: Treaty Saddle Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 7: Unuk North Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 8: Unuk South Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 9: Mitchell Initial Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 10: Mitchell Secondary Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Camp 11: Treaty Marshalling Yard Camp	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			CCAC	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Explosives Manufacturing Facility	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			McTagg Twinned Diversion Tunnels	Potential soil erosion.	Management Practices	Apply BMP for erosion/sedimentation control; establish monitoring program early.	Yes	Decreased soil fertility in buffers surrounding components retained after closure.

(continued)

Table 8.7-3. Potential Residual Effects on Soil Quality (continued)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quality *(cont'd)*	Construction *(cont'd)*	Mine Site *(cont'd)*	Water Treatment and Energy Recovery Area	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mine Site Avalanche Control	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mitchell Diversion Tunnels	Potential soil erosion.	Management Practices	Apply BMP for erosion/sedimentation control; establish monitoring program early.	Yes	Decreased soil fertility in buffers surrounding components retained after closure.
			Mitchell Operating Camp	Potential soil erosion; rutting and compaction; contamination with waste, fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mitchell Ore Preparation Complex	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mitchell Pit	Potential soil erosion; subsidence; contamination with metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mitchell Rock Storage Facility	Potential soil erosion; contamination with metals, changed moisture regime.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, contamination in buffers surrounding components retained after closure.
			Sludge Management Facilities	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Sulphurets Pit	Potential soil erosion; subsidence; contamination with metals.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, changed moisture regime in buffers surrounding components retained after closure.
			Sulphurets Laydown Area	Potential soil erosion; contamination with metals, changed moisture regime.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, contamination in buffers surrounding components retained after closure.
			Temporary Frank Mackie Glacier Access Route	Potential contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for contamination control; establish monitoring program early, remediate as required.	No	No residual effect.
			Mitchell Truck Shop	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.

(continued)

Table 8.7-3. Potential Residual Effects on Soil Quality (continued)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quality *(cont'd)*	Construction *(cont'd)*	Mine Site *(cont'd)*	Upper Sulphurets Power Plant	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Water Storage Facility	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
	Operation	Mine Site	Iron Cap Block Cave Mine	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Kerr Pit	Potential soil erosion; subsidence; contamination with metals.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, changed moisture regime in buffers surrounding components retained after closure.
			Kerr Rope Conveyor	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			McTagg Power Plant	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			McTagg Rock Storage Facility	Potential soil erosion; contamination with metals, changed moisture regime.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, contamination in buffers surrounding components retained after closure.
			Mitchell Block Cave Mine	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Sulphurets-Mitchell Conveyor Tunnel	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
	Construction	Processing and Tailing Management Area	Camp 12: Highway 37 Construction Camp	Potential soil erosion; rutting and compaction; contamination with waste, fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			Centre Cell Tailing Management Facility	Potential soil erosion; contamination with metals.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early, remediate as required.	Yes	Decreased soil fertility, erosion and contamination in buffers surrounding components retained after closure.
			construction access adit	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.

(continued)

Table 8.7-3. Potential Residual Effects on Soil Quality (completed)

VC	Timing Start	Project Region(s)	Project Area(s)	Description of Effect due to Component(s)	Type of Project Mitigation	Project Mitigation Description	Potential Residual Effect	Description of Residuals
Soil Quality *(cont'd)*	Construction *(cont'd)*	Processing and Tailing Management Area *(cont'd)*	East Catchment Diversion	Potential soil erosion, changed moisture regime.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility in buffers surrounding components retained after closure.
			Mitchell-Treaty Twinned Tunnels	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Mitchell-Treaty Saddle Area	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			North Cell Tailing Management Facility	Potential soil erosion, contamination with metals.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility in buffers surrounding components retained after closure.
			Treaty Creek Access Road	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Treaty Operating Camp	Potential soil erosion; rutting and compaction; contamination with waste, fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
			Treaty Ore Preparation Complex	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.
	Operation	Processing and Tailing Management Area	Concentrate Storage and Loadout	Potential soil erosion; rutting and compaction; contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for erosion/sediment control; establish soil monitoring program early, remediate and reclaim.	No	No residual effect.
			South Cell Tailing Management Facility	Potential soil erosion, contamination with metals.	Management Practices, Monitoring and Adaptive Management	Apply BMP for erosion/sedimentation control; establish soil monitoring program early.	Yes	Decreased soil fertility in buffers surrounding components retained after closure.
	Construction	Highways	Highway 37 and 37A	Potential soil contamination with fuel, oil, fluid, cargo spills, metals.	Management Practices	Apply BMP for transportation of loose material; establish soil monitoring program early, remediate as required.	No	No residual effect.

Mitigation of soil degradation associated with salvage operations often focuses on minimizing the number of times the soil is moved, reducing the vehicle traffic over the soil surface, and avoiding handling soils when they are too dry or too wet. Through the guidance of a qualified soil specialist, control of the stripping and stockpiling operations can reduce mixing topsoil with less fertile materials. Reducing the erosion of soil stockpiles will be accomplished by timely re-vegetation of the stockpile berms;erosion monitoring and prevention programs will be established. More details are provided in the Terrain, Surficial Geology, and Soil Management and Monitoring Plan (Section 26.13).

A comprehensive monitoring program will be established prior to mine construction to assess proper implementation and effectiveness of mitigation measures. Assessment of disturbances during construction will include sampling and geochemical characterization (e.g., for evidence of metal leaching and acid rock drainage) of road cuts and material sources). Adaptive management measures directed toward identification and implementation of new or modified mitigation approaches will be initiated if monitoring data indicate that mitigation is not able to eliminate or adequately reduce soil degradation (CEA Agency 2009).

8.7.2.2 Soil Quality: Potential Residual Effects due to Soil Degradation

Soil degradation associated with Project development will affect soil quality. It is expected that, during the Project life, soil quality may be adversely affected in 4,008 ha of 100 m buffers around Project facilities. After mine closure, the quality of soil will be gradually restored in the buffer areas through soil remediation and reclamation. However, soil degradation (e.g., contamination with metals, changes in soil reaction, increased erosion, etc.) will potentially continue in up to 3,972 ha of the buffered area around the remaining mine facilities due to the ongoing human activity in these areas after mine closure. These residual effects may interact with residual changes in slope hydrology, effects of previous vegetation clearing (e.g., in laydown areas, conveyer corridors, or transmission line), and increased forest fire potential due to increased human access and vehicle traffic. The resulting additive or synergistic interactions (e.g., changed soil moisture and vegetation removal by forest fire leading to dramatic increase in soil erosion) may exacerbate soil degradation and make slopes vulnerable to erosion or failure. Table 8.7-3 summarizes the extent and the spatial and temporal aspects of these effects.

8.8 Significance of Residual Effects for Terrain, Surficial Geology, and Soils

Two VCs associated with terrain, surficial geology, and soils have been identified: soil quantity and soil quality. Residual environmental effects associated with the development of the Project on the two VCs include:

<u>Soil Quantity</u>

- permanent loss of 2,554 ha of surface area under Project footprint infrastructure remaining after closure; and
- loss of unknown amounts of soil due to erosion.

Soil Quality

- Soil degradation resulting from a combination of soil contamination, soil compaction, and loss of soil fertility. Permanent soil degradation is expected in up to 3,972 ha of buffers surrounding components retained after closure.

8.8.1 Residual Effect Descriptors for Terrain, Surficial Geology, and Soils

The key residual effect descriptors used in this assessment are summarized and defined in Table 8.8-1.

8.8.2 Residual Effects Assessment for Soil Quantity

The significance of effects that will not be fully addressed by planned mitigation measures (residual effects) is assessed in Table 8.8-2. The assessment considers the magnitude, spatial extent, duration, frequency, context and reversibility of the potential effects, as well as soil resilience to the effects, as defined in Chapter 5 (Effects Assessment Methodology). The assessment also discusses the probability of occurrence of the identified significant effect and the level of scientific confidence associated with the assessment of significance.

8.8.2.1 Permanent Loss of Ecologically Functional Soil under the Footprints of the Remaining Mine Components

Development of the Project will be associated with a residual loss of ecological soil function on approximately 2,554 ha of land. The loss of soils under the footprints of retained mine components (Table 8.8-2) will extend into the foreseeable future. Assuming no major landslides or erosion events, it will affect approximately 3.84% of the BSA.

To assess the effect of the loss of ecologically functional soil at a meaningful scale, the soil loss was compared with the total area of local watersheds. The maximum area of soil surface lost under the Project footprint will be equal to approximately 2% of the Unuk River or 1% of the Upper Bell-Irving River watersheds, in which most of the Project components are located. After closure, the area of residual soil loss under the remaining Project components will be equal to 1.3% of the Unuk River watershed.

The loss will have a relatively low impact on soils with high ecological values, such as those located in riparian zones, wetland complexes, alpine meadows, and river floodplains. Over 21% of permanently lost areas are currently overlain by non-soils, and another 5.7% are covered by bedrock or ice (Table 8.7-1). The remaining portion is dominated by morainal and colluvial deposits, of which 43% are located on steep terrain (> 50% slope grade) and/or are characterized by harsh climatic conditions. Out of the 124 ha of organic soils located in the LSA, 25.5 ha could become degraded by the Project and 42.5 ha will be permanently lost.

Considering the above listed soil characteristics, as well as the size and location of the lost land outside of the most ecologically valuable soil resources in the region (BC ILMB 2000), the magnitude of the soil loss is predicted to be medium. The exceptions are some of the soils lost under the footprints of the PTMA, Treaty OPC, TCAR, CCAR, and Treaty operating camp.

Table 8.8-1. Definitions of Significance Criteria for Terrain, Surficial Geology, and Soils Residual Effects

Timing	Magnitude	Geographic Extent		Duration	Frequency	Reversibility	Context (Resilience)	Likelihood of Effects	
		Physical/Biophysical	**Socio-economic**					**Probability**	**Confidence Level**
When will the effect begin?	*How severe will the effect be?*	*How far will the effect reach?*		*How long will the effect last?*	*How often will the effect occur?*	*To what degree is the effect reversible?*	*How resilient is the receiving environment or population? Will it be able to adapt to or absorb the change?*	*How likely is the effect to occur?*	*How certain is this analysis? Consider potential for error, confidence intervals, unknown variables, etc.*
Construction Phase	**Negligible**: No detectable change from baseline conditions.	**Local**: Effect is limited to the immediate Project footprint (e.g., within a 100 m buffer).	**Individual / Household**: Effect is limited to individuals, families, and/or households.	**Short-term**: Effect lasts approximately 1 year or less.	**One Time**: Effect is confined to one discrete period in time during the life of the Project.	**Reversible Short-term**: Effect can be reversed relatively quickly.	**Low**: the valued component is considered to have little to no unique attributes and/or there is high resilience to imposed stresses.	**High**: It is highly likely that this effect will occur.	**High**: > 80% confidence. There is a good understanding of the cause-effect relationship and all necessary data are available for the Project area. There is a low degree of uncertainty and variation from the predicted effect is expected to be low.
Operation Phase	**Low**: Differs from the average value for baseline conditions to a small degree (e.g., within the range of natural variation and well below a guideline or threshold value).	**Landscape**: Effect is limited to a broader area than "local" (e.g., watershed), but still remains tied to the Project footprint.	**Community**: Effect extends to the community level.	**Medium-term**: Effect lasts from 1 to 5 years.	**Sporadic**: Effect occurs rarely and at sporadic intervals.	**Reversible Long-term**: Effect can be reversed over many years.	**Neutral**: the valued component is considered to have some unique attributes, and/or there is neutral (moderate) resilience to imposed stresses; or	**Medium**: This effect is likely, but may not occur.	**Medium**: 40 to 80% confidence. The cause-effect relationships are not fully understood, there are a number of unknown external variables, or data for the Project area are incomplete. There is a moderate degree of uncertainty; while results may vary, predictions are relatively confident.
Closure Phase	**Medium**: Differs substantially from the average value for baseline conditions and approaches the limits of natural variation, but below or equal to a guideline or threshold value.	**Regional**: Effect extends across the broader region (e.g., Regional Study Area, multiple watersheds, etc.).	**Regional / Aboriginal Peoples**: Effect extends across the broader regional community / economy, or across one or more First Nations group(s).	**Long-term**: Effect lasts between 6 and 40 years.	**Regular**: Effect occurs on a regular basis.	**Irreversible**: Effect cannot be reversed.	**High**: the valued component is considered to be unique, and/or there is low resilience to imposed stresses.	**Low**: This effect is unlikely but could occur.	**Low**: < 40% confidence. The cause-effect relationships are poorly understood, there are a number of unknown external variables, and data for the Project area are incomplete. High degree of uncertainty and final results may vary considerably.
Post-closure Phase	**High**: Differs substantially from baseline conditions beyond a guideline or threshold value, resulting in a detectable change beyond the range of natural variation.	**Beyond regional**: Effect extends beyond the regional scale, and may extend across or beyond the province.	**Beyond Regional**: Effect extends beyond the regional scale, and may extend across or beyond the province.	**Far Future**: Effect lasts more than 40 years.	**Continuous**: Effect occurs constantly.				

Table 8.8-2. Summary of Residual Effects on Soil Quantity

Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Extent	Duration	Frequency	Reversibility	Context	Likelihood of Effects: Probability	Likelihood of Effects: Confidence Level	Significance Determination	Follow-up Program
Permanent loss of soil under component footprint	Coulter Creek Access Corridor	Construction	High	Local	Far future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Explosives Manufacturing Facility	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	McTagg Twinned Diversion Tunnels	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Water Treatment and Energy Recovery Area	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mine Site Avalanche Control	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Diversion Tunnels	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Operating Camp	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Ore Preparation Complex	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Pit	Construction	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Rock Storage Facility	Construction	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Sludge Management Facilities	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Sulphurets Pit	Construction	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Sulphurets Laydown Area	Construction	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Temporary Frank Mackie Glacier Access Route	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Upper Sulphurets Power Plant	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Water Storage Facility	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Centre Cell Tailing Management Facility	Construction	High	Local	Far Future	One-time	Irreversible	High	High	Medium	Not Significant (Moderate)	Not Required
	Construction Access Adit	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	East Catchment Diversion	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell-Treaty Twinned Tunnels	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell-Treaty Saddle Area	Construction	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	North Cell Tailing Management Facility	Construction	High	Local	Far Future	One-time	Irreversible	High	High	Medium	Not Significant (Moderate)	Not Required
	Treaty Creek Access Road	Construction	High	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Treaty Operating Camp	Construction	High	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Treaty Ore Preparation Complex	Construction	High	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Iron Cap Block Cave Mine	Operation	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Kerr Pit	Operation	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	McTagg Power Plant	Operation	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	McTagg Rock Storage Facility	Operation	Medium	Local	Far Future	Sporadic	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Block Cave Mine	Operation	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	Sulphurets-Mitchell Conveyor Tunnel	Operation	Medium	Local	Far Future	One-time	Irreversible	Neutral	High	Medium	Not Significant (Minor)	Not Required
	South Cell Tailing Management Facility	Operation	High	Local	Far Future	One-time	Irreversible	High	High	Medium	Not Significant (Moderate)	Not Required

(continued)

Table 8.8-2. Summary of Residual Effects on Soil Quantity (completed)

Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Extent	Duration	Frequency	Reversibility	Context	Likelihood of Effects		Significance Determination	Follow-up Program
									Probability	Confidence Level		
Permanent loss of soil due to mass movement or erosion	Coulter Creek Access Road	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Construction Access Adit	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	East Catchment Diversion	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	East Catchment Diversion Dam	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Explosives Manufacturing Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	McTagg Twinned Diversion Tunnels	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	McTagg Rock Storage Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Mine Site Avalanche Control	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Pit	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	Mitchell Rock Storage Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Mitchell-Treaty Saddle Area	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	North Treaty Upper Road	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	South Cell TMF	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Sulphurets Laydown Area	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Treaty Creek Access Road	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Treaty Operating Camp	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required
	Upper Sulphurets Power Plant	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
	Water Storage Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Low	Not Significant (Minor)	Not Required
Overall Residual Effect	All	Construction to Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	High	Medium	Not Significant (Minor)	Not Required

Portion of these components will be located on deep, most fertile, and sensitive soils in the LSA (developed in Organic, Morainal and Fluvial materials deposited in the valleys). Since Project development is expected to alter these soils well beyond the level of their natural variability, the effect magnitude will be high. Nevertheless, because fertile and sensitive soils comprise comparatively small proportion of the lost area (e.g., 1.7% of lost soils are Organic), the overall magnitude of the soil loss is predicted to be medium.

The spatial extent of land loss is expected to remain local (limited to the immediate area of the Project surface facilities). It is expected that the duration of this effect will extend into the far future (more than 70 years). The loss will occur with one-time or sporadic frequencies. The effect is considered irreversible as the soils in some areas of the mine (e.g., pits) will be permanently lost. Considering the natural predominance of low quality, young soils in the BSA, the resilience of the receiving environment to land loss is neutral. While the likelihood of soil loss due to Project activity is high, the confidence in the predicted outcome is medium (due to potential interactions with natural disturbances such as landslides, fire, etc.).

Overall, due to low quality of soils and high natural incidence of soil disturbance in the BSA, the effect of permanent soil loss in the retained portions of the proposed Project is expected to be **not significant (minor)**.

8.8.2.2 Permanent Loss of Soil Bulk due to Erosion

Disturbed areas from which vegetation has been removed (e.g., laydown areas, stream diversions, borrow pits, and roads) are typically associated with soil erosion and mass wastage and lead to bulk soil losses. The magnitude of these losses is highly dependent on the total area of exposed soil surface. Roads, especially sections located on slopes, tend to contribute most to the overall soil loss. Because roads act as surface drainage networks that increase runoff and concentrate surficial flow, most of the eroded soil ends up in streams and lakes. Consequently, the rate of watercourse sedimentation reflects well the intensity of soil erosion and can be used as an indicator of erosion rate.

The ratio of total length of roads present within a total area (in km per km^2 or miles per square mile) is commonly used in the scientific literature to assess road density. Indicators and associated benchmarks for watershed monitoring prepared by ESSA Technologies Ltd. for the BC Ministry of Environment (Porter et al. 2012) suggest that the recommended road densities on unstable/steep slopes (e.g., slopes greater than 60% grade) should remain below 0.12 km/km^2 and in riparian areas below 0.16 km/km^2. A threshold value of 0.28 km/km^2 has been suggested by the US Fish and Wildlife Service in Oregon as the watershed road density at or below which stream sedimentation is considered low (USFWS 1998).

Predicted road density associated with the KSM Project will reach 0.08 km/km^2 in the Unuk River watershed and 0.02 km/km^2 in the Upper and Lower Bell-Irving River watersheds. Considering the above predictions, the magnitude of the bulk soil loss associated with erosion is expected to be medium (not exceeding the limits of natural variation). The spatial extent of this effect will be apparent at the landscape level (beyond Project footprint within a broader watershed area). The loss will occur with sporadic frequency and is expected that its duration will extend into the far future (more than 70 years). The effect is considered irreversible, as the eroded soils will be permanently removed from their original locations. Judging by the high incidence of natural disturbances, the resilience of the receiving environment is low (the context is high). While the likelihood of soil loss due to erosion is high, the confidence in the predicted outcome is medium or low (due to potential interactions with natural slope failures, fire, etc.). Consequently, a follow-up program designed to verify predictions of identified environmental effects will be required in the areas of decreased slope stability (Chapter 9).

Overall, the effect of residual loss of soil due to erosion is expected to be **not significant (minor)**.

8.8.3 Residual Effects Assessment for Soil Quality

This section provides an overview of the potential significant residual effects of the Project on soil quality.

8.8.3.1 Soil Degradation

Despite dedication of resources and effort to monitoring and mitigation programs, some aspects of soil degradation within the 100 m buffers will either remain undetected or not easily repaired. Examples of such effects include alteration of soil moisture regime, changes in flora and fauna communities, erosion of the most fertile fractions of soil, loss of soil structure, etc. Soil degradation may affect one of the CIS LRMP objectives: the sustainable supply of botanical forest products (mushrooms, berries, and medicinal plants) in the affected area (BC ILMB 2000). It is predicted that degradation of up to 3,972 ha of land located within 100 m wide buffers around the footprints of mine components retained after closure will continue in the foreseeable future. While it is expected that a considerable portion of reclaimed areas will recover over time, the harsh local climate and demanding site topography will likely limit the success of the reclamation efforts planned for the 2,060 ha of land upon mine closure. Consequently, Project development will result in the long-term degradation of soil on up to 6,032 ha of land (Table 8.8-3)—the area equal to approximately 3% of the Unuk River watershed.

Residual effects on the physical, chemical, and biological soil conditions in disturbed areas are expected to display a wide range of variation, both in terms of severity and duration. While it is possible that the severity, duration, and type of environmental effects associated with the Project will substantially differ from those induced by natural causes, it is important to recognize that the incidence of soil degradation in the BSA (Sections 8.1.3 and 8.1.5) is naturally high. In view of this fact, and because it is expected that monitoring and mitigation programs (Section 26.13) will effectively mitigate the more severe instances of soil degradation, the overall magnitude of the incremental Project-related disturbance is expected to be medium. The predicted spatial extent of this effect will be apparent at the landscape level (concentrated within the 100 m wide buffers around the retained Project footprint). The duration of soil degradation will extend into the far future. The frequency of events leading to soil degradation will be sporadic throughout and beyond the Project's life. The effect is considered irreversible because on a large proportion of land the causal agents will not be removed. Considering the generally low productivity and high acidity of the affected soils (which results in low buffering capacity to acidification), the resilience of the receiving environment in response to Project-related soil degradation effects is expected to be low (thus, the context will be high).

Table 8.8-3. Summary of Residual Effects on Soil Quality

Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Extent	Duration	Frequency	Reversibility	Context	Likelihood of Effects: Probability	Likelihood of Effects: Confidence Level	Significance Determination	Follow-up Monitoring
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Construction access adit	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Coulter Creek Access Corridor	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility in buffers surrounding components retained after closure.	East Catchment Diversion	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Explosives Manufacturing Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility in buffers surrounding components retained after closure.	McTagg Diversion Tunnel	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Water Treatment & Energy Recovery Area	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mine Site Avalanche Control	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility in buffers surrounding components retained after closure.	Mitchell Diversion Tunnel	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell Operating Camp	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell Ore Preparation Complex	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell Pit	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility and contamination in buffers surrounding components retained after closure.	Mitchell Rock Storage Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell-Treaty Tunnel	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell-Treaty Tunnel Saddle Area	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility in buffers surrounding components retained after closure.	North Cell Tailing Management Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Moderate)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Sludge Management Facilities	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, changed moisture regime in buffers surrounding components retained after closure.	Sulphurets Pit	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, contamination in buffers surrounding components retained after closure.	Sulphurets laydown area	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Treaty Creek Access Road	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required

(continued)

Table 8.8-3. Summary of Residual Effects on Soil Quality (completed)

Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Extent	Duration	Frequency	Reversibility	Context	Likelihood of Effects		Significance Determination	Follow-up Monitoring
									Probability	Confidence Level		
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Treaty Operations Camps	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Treaty Ore Prep Complex	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Upper Sulphurets Power Plant	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Water Storage Facility	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Iron Cap Block Cave Mine	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, changed moisture regime in buffers surrounding components retained after closure.	Kerr Pit	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	McTagg Power Plant	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility and contamination in buffers surrounding components retained after closure.	McTagg Rock Storage Facililty	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Mitchell Block Cave Mine	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Decreased soil fertility and contamination in buffers surrounding components retained after closure.	South Cell Tailing Management Facility	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Moderate)	Not Required
Decreased soil fertility, compaction, or contamination in buffers surrounding components retained after closure.	Sulphurets-Mitchell Conveyor Tunnel	Operation	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required
Overall Residual Effect	All	Construction	Medium	Landscape	Far Future	Sporadic	Irreversible	High	Medium	Low	Not Significant (Minor)	Not Required

Due to high variability of baseline conditions in the Project area and the large number of potentially interacting adverse factors (e.g., short vegetative season, low temperatures, high metal concentration in the soil, potential disruption of groundwater flow patterns, etc.) the likelihood of soil degradation due to Project activity is medium and the confidence in the predicted outcome is low. The exception are the deep, fertile and often sensitive (Organic) soils in the Treaty and Coulter Creek valleys, and soils located in vicinity of sources of potential contamination with metals (e.g., PTMA, OPC). In these areas the likelihood of soil degradation is high and monitoring will be required. Overall, the effect of degradation of soil quality around the retained portions of the Project infrastructure is predicted to be **not significant (minor)**.

8.9 Potential Cumulative Effects for Terrain, Surficial Geology, and Soils

8.9.1 Scoping of Cumulative Effects

Disturbance of terrain and soils will occur during construction, operation, and closure of the proposed Project. Direct soil loss (affecting soil quantity) is most likely to occur within the footprints of the Mine Site and the PTMA. Soil degradation (affecting soil quality) may result from compaction or mixing of soil layers, vegetation removal, or soil contamination within the footprint and within the 100 m buffer around it. Indirect effects on soil quality may be also associated with the deposition of metal-laden dust (e.g., from rock blasting, crushing, and transportation), alteration of natural seepage patterns, changes in moisture regime, and increased solar radiation in previously shaded environments. Figure 8.9-1 shows the spatial distribution of currently known human activities in the vicinity of the Project.

The proximity of several disturbances occurring near the Project area may induce additive or synergistic interactions between environmental effects, resulting in altered severity of the residual effects of the Project on soil quantity and quality. Given that soils require sufficient time to recover after reclamation activities have been completed, these interactions may also persist over the long term.

Loss of soil quantity (e.g., due to soil excavation, burial, and/or erosion) or degradation of soil quality (e.g., due to compaction, contamination, or loss of fertility) related to past, current, and future human activities has to overlap spatially and temporally with similar soil disturbances associated with the KSM Project to cause a potential cumulative effect. The concepts of spatial and temporal linkages between human activities are discussed in the following sections.

8.9.1.1 Spatial Linkages with Other Projects and Human Actions

As the area of the industrial footprint and the density of road networks within the matrix of predominantly natural ecosystems gradually increase, the level of interactions between the environmental effects of individual projects is expected to rise. Because the spatial and temporal scales of observation can have a considerable impact on conclusions regarding the ecological significance of those interactions (McGarigal et al. 2001), it can be difficult to precisely delineate the extent of the area in which such interactions could be meaningfully assessed. Consequently, a considerable effort was focused on choosing appropriate spatial scales within which the effects of the KSM Project were expected to contribute to the overall cumulative impact under consideration.

Conversion of natural landscapes into industrial use is usually associated with a vast increase in disturbance of soil surface, which can modify soil hydrologic conditions within a watershed (details in Section 8.7.2) and thus affect soil fertility. Due to an important role of water in transportation of various chemical pollutants (through precipitation, leaching, deposition of dust on snow-covered surfaces, percolation, subsurface flow, etc.), watersheds are also natural units within which distribution of most contaminants takes place. Soil erosion and resulting sedimentation of watercourses are also usually discussed at the watershed scale.

Scientific evidence suggests that the most important environmental impacts associated with soil disturbance are related to soil erosion and subsequent sedimentation of streams (Forman 1997; Seiler 2001; Smerdon et al. 2009). Thus, it seems reasonable to conduct the cumulative assessment of such impacts within the framework of natural watersheds.

The KSM Project footprint extends into three watersheds (Unuk River, Upper Bell-Irving River, and Lower Bell-Irving River). In view of the reasons listed above, it was assumed that the outline of the three watersheds provides the best scale for the assessment of cumulative effects associated with the development of the KSM Project. Thus, a spatial linkage between residual effects of two projects is established if their respective areas affected by soil disturbance are included within the outline of the three watersheds. The extent of the three watersheds has been used as the spatial boundary of the Cumulative Effects Assessment Area and is shown in Figure 8.9-1. The Cumulative Effects Assessment Area measures approximately 729,784 ha.

The Eskay Creek Mine, an underground gold and silver mine, and the Sulphurets Underground Development Project are the only past projects with a spatial linkage to potential effects on terrain and soils from the Project (Figure 8.9-1). Future human actions with potential spatial linkages include:

- the Northwest Transmission Line (NTL), currently under construction;
- proposed development of Snowfield Project;
- proposed development of the Brucejack Mine; and
- proposed development of Treaty Creek Hydroelectric Project.

8.9.1.2 Temporal Linkages with Other Projects and Human Actions

After replacement of the excavated, buried, or eroded soil with salvaged material, a reclaimed area undergoes a period of recovery. During that time physical, chemical, and biological characteristics of the soil changes and its ecological functionality increases (Croke, Hairsine, and Fogarty 2001; Sadikshya 2008). The length of the recovery period varies substantially depending on conditions of the site and on the quality of reclamation material used. Long-term chronosequence studies indicate that disturbed soil microbial communities require about 15 to 30 years to transition to a stable community structure (Insam and Domsch 1988; Mummey et al. 2002; Anderson et al. 2004; Sadikshya 2008; Adl 2008).

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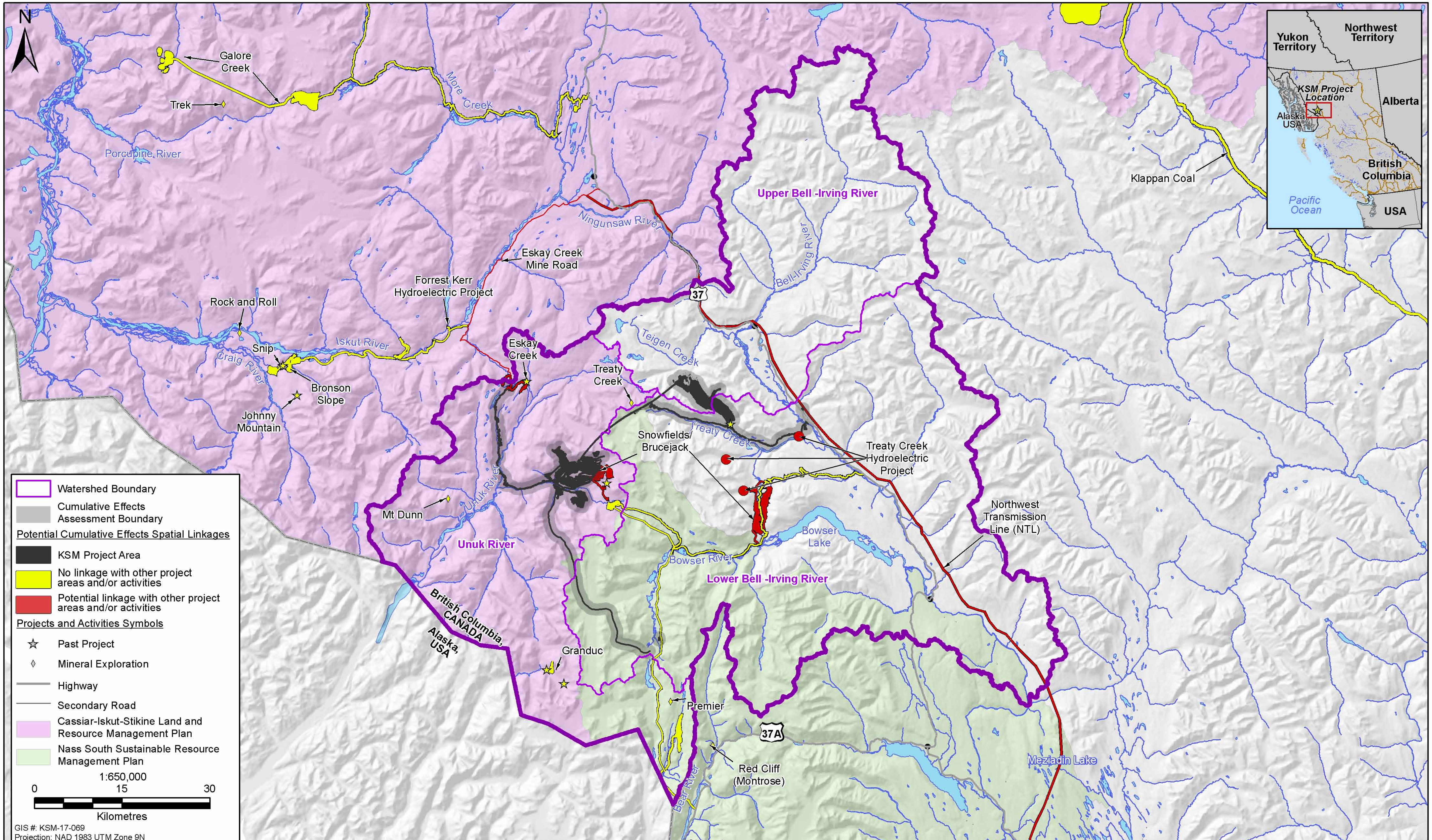

SEABRIDGE GOLD
KSM PROJECT

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Figure 8.9-1

Spatial Distribution of Human Activities in KSM Project Area

Considering the difficult climatic and terrain conditions at the Project site, it is assumed that soil recovery on areas that have been reclaimed will take 30 years, on average. Consequently, ecological functionality of soil is considered deteriorated or lost from the time the area is stripped or buried until 30 years after it is reclaimed. Similarly, it is assumed that soil degradation takes place from the time it is affected by factors leading to its compaction, contamination, or loss of fertility, until 30 years after it is remediated and reclaimed. Therefore, for the purpose of the Cumulative Effects Assessment, a temporal linkage between the soil degradation events associated with different projects may be established when periods of reduced soil functionality (including 30-year recovery periods) overlap.

The Eskay Creek Mine is the only past project that has the potential to overlap temporally with the environmental effects to terrain and soils resulting from development of the Project. Future human actions with potential temporal linkages with the Project include:

- proposed development of Snowfield Project;
- proposed development of Brucejack Mine; and
- proposed development of Treaty Creek Hydroelectric Project.

Table 8.9-1 summarizes the potential linkages between the Project and other human activities with regard to terrain and soils.

Table 8.9-1. Summary of Potential Cumulative Linkages between the KSM Project and Other Human Activities with Regard to Terrain and Soils

	Action/Project	Past	Present	Future
Past Projects	Eskay Creek Mine	X; use of Eskay Creek Mine road.	NL	NL
	Granduc Mine	NL	NL	NL
	Johnny Mountain Mine	NL	NL	NL
	Kitsault Mine (Closed)	NL	NL	NL
	Snip Mine	NL	NL	NL
	Sulphurets Project	X; use of Hwy 37; close proximity to KSM Project footprint.	NL	NL
	Swamp Point Aggregate Mine	NL	NL	NL
Present Projects	Forrest Kerr Hydroelectric	NL	NL	NL
	Long Lake Hydroelectric	NL	NL	NL
	NTL	NL	X; use of Highway 37; close proximity to KSM Project footprint.	NL
	Red Chris Mine	NL	NL	NL
	Wolverine Mine	NL	NL	NL

(continued)

Table 8.9-1. Summary of Potential Cumulative Linkages between the KSM Project and Other Human Activities with Regard to Terrain and Soils (completed)

	Action/Project	Past	Present	Future
Reasonably Foreseeable Future Projects *(cont'd)*	Bear River Gravel	NL	NL	NL
	Bronson Slope Mine	NL	NL	NL
	Brucejack Mine	NL	NL	X; use of Eskay Creek Mine road and other KSM Project access routes; close proximity of development.
	Galore Creek Mine	NL	NL	NL
	Granduc Copper Mine	NL	NL	NL
	Kitsault Mine	NL	NL	NL
	Kutcho Mine	NL	NL	NL
	McLymont Creek Hydroelectric			
	Arctos Anthracite Coal Project	NL	NL	NL
	Schaft Creek Mine	NL	NL	NL
	Snowfield Project	NL	NL	X; use of Eskay Creek Mine road and other KSM Project access routes; close proximity of development.
	Storie Moly Mine	NL	NL	NL
	Turnagain Mine	NL	NL	NL
	Treaty Creek Hydroelectric	NL	NL	X; proximity to the PTMA, presumed use of the TCAR.
Land Use Activities	Agricultural Resources	NL	NL	NL
	Fishing	NL	NL	NL
	Guide Outfitting	NL	NL	NL
	Resident and Aboriginal Harvest	NL	NL	NL
	Mineral and Energy Resource Exploration	NL	NL	NL
	Recreation and Tourism	NL	NL	NL
	Timber Harvesting	NL	NL	NL
	Traffic and Roads	NL	NL	NL

NL = No linkage (no spatial and temporal overlap, or potential effects do not act in combination).
X = Potential spatial and temporal linkage with project or action.

Past Projects

The Eskay Creek Mine was an underground gold-silver mine located approximately 18 km from the centre of the proposed Mitchell Pit. Between 1998 and 2004, 27 ha of land was cleared, nine of which were reclaimed by 2004 (Barrick Gold Corp. 2004). After closure in 2008, a portion of the mine infrastructure was decommissioned. Operation of the mine required construction of the Eskay Creek Mine road. The CCAR will be built from km 70 of this road. Because the mine was closed recently and because the CCAR will connect with the areas disturbed by the Eskay Creek Mine, both temporal and spatial links for potential cumulative interaction with the KSM Project have been established.

The Sulphurets was an advanced exploration project located near Brucejack Lake. Newhawk Gold Mines Ltd. excavated underground workings between 1986 and 1990 as part of an advanced exploration and bulk sampling program. Construction of the underground workings generated approximately 124,000 t of waste rock, which was placed as a shallow pad along the southern boundary of Brucejack Creek and used as the foundation for the camp and other facilities (Price 2005). The project never went into production, and in 1998 Newhawk Gold Mines Ltd. decided to reclaim the property (Price 2005). Overland access was from Highway 37, along a logging road to a barge landing on Bowser Lake, then by dirt road along the Bowser River to the toe of the Knipple Glacier and up the mountain to access the glacier, 7 km on an ice road up the Knipple Glacier and 1 km on a mine road along southern edge of Brucejack Lake to the Sulphurets Camp.

Present

The NTL will be a 344-km long 287-kV power transmission line. The line will follow Highway 37 between the Skeena Substation at Terrace and a new substation near Bob Quinn Lake (BC Hydro 2012) and thus will pass near the junction of the TCAR and Highway 37. Construction began in January 2012 and the transmission line is expected to be operational in 2014 (BC Hydro 2012), which will potentially make mining, power, and other projects in these remote regions more economically feasible.

Future

The Brucejack Mine property is located immediately east of the KSM Project area. It is included in the KSM Project Cumulative Effects Assessment because of its close proximity and because it is expected to enter the environmental assessment process in the near future. It is anticipated that the project will begin construction in 2014 and be operational by 2016. The mine lifespan is expected to be a minimum of 16 years. Beside underground mining operations, the footprint would include a process plant, a camp facility, a tailing storage facility, and a power transmission line. Access to the mine would be along a 70-km exploration road extending along Wildfire Creek, Scott Creek, the Bowser River, and up the Knipple Glacier (Rescan 2012b). The road construction began in 2012, and will require upgrades for use during mine operations.

The Snowfield property is adjacent to the KSM Project such that it may be influenced by KSM Project access plans (Snowden 2012). This project has not yet entered the BC Environmental Assessment process, but it is included in the Cumulative Effects Assessment because of its close proximity to and likely temporal overlap with the KSM Project. While the Snowfield Project is in the early planning stage, it is anticipated that construction will not begin until the KSM Project is operational in 2018. The expected project lifespan is 27 years. The project footprint includes a pit and crusher, and a conveyor that will transport ore through a tunnel to a processing plant and tailing facility in the Scott Creek watershed (Wardrop 2010). A separate access road from Highway 37 to the Treaty Process Plant is proposed (Wardrop 2010).

The Treaty Creek Hydroelectric Project is proposed to the immediate southwest of the proposed KSM Project TMF. It is in the early planning stage and is considered in the Cumulative Effects Assessment because of its close proximity to and likely temporal overlap with the KSM Project. The project is expected to be small-scale and will involve the use of run-of-river technology (Northern Hydro 2012).

The nearby projects that are not expected to have spatial links with the KSM Project include the Bronson Slope Mine and Forrest Kerr Hydroelectric Power Project. Both projects are located in a different watershed than the KSM Project and they are located more than 25 km away. Details regarding each of these projects are provided in Chapter 5.

8.9.2 Cumulative Effects Assessment for Soil Quantity

Given the assumptions discussed in Sections 8.9.1.1 and 8.9.1.2, the following past, existing, and reasonably foreseeable future activities have the potential to overlap spatially and temporally with the loss of ecologically functional soil, primarily due to loss of land surface area and soil erosion associated with the development of the KSM Project:

- closed Eskay Creek Mine;
- current NTL;
- proposed Treaty Creek Hydroelectric Project;
- proposed development of the Snowfield Project; and
- proposed development of the Brucejack Mine.

Table 8.9-2 lists the human activities that could potentially interact with soil quantity associated with the KSM Project.

Table 8.9-2. Summary of Projects and Human Activities with Potential to Interact Cumulatively with Expected Project-specific Residual Effects on Soil Quantity

Description of Effect	Potential for Cumulative Impact: Relevant Projects and Activities				
	Eskay Creek Mine	Sulphurets Project	Treaty Creek Hydroelectric	Brucejack Mine	Snowfield Project
Soil Quantity: Loss of Land Surface Area	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkages between disturbed areas
Soil Quantity: Bulk Erosion	Potential spatial and temporal linkage with the CCAR	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkage with TCAR	Potential spatial and temporal linkage between affected areas (e.g., mining pits)	Potential spatial and temporal linkage between affected areas (e.g., mining pits)

A summary of cumulative residual effects on soil quantity is provided in Table 8.9-3.

Table 8.9-3. Summary of Cumulative Residual Effects on Soil Quantity

															Likelihood of Effects							
Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Magnitude Adjusted for CE	Extent	Extent Adjusted for CE	Duration	Duration Adjusted for CE	Frequency	Frequency Adjusted for CE	Reversibility	Reversibility Adjusted for CE	Context	Context Adjusted for CE	Probability	Probability Adjusted by CE	Confidence Level	Confidence Adjusted by CE	Significance	Significance Adjusted for CE	Follow up Monitoring	Follow up Monitoring Adjusted by CE
Soil Quantity: Loss of land Surface Area	Roads and other non-reclaimed areas retained after closure	Construction	Medium	Medium	Local	Regional	Far future	Far future	One-time	Sporadic	Irreversible	Irreversible	Neutral	High	High	High	Medium	Medium	Not Significant (Moderate)	Not Significant (Moderate)	Not Required	Not Required
Soil Quantity: Bulk Erosion.	Roads and other non-reclaimed areas retained after closure	Construction	Medium	Medium	Landscape	Regional	Far future	Far future	Sporadic	Sporadic	Irreversible	Irreversible	High	High	High	High	Medium	Medium	Not Significant (Minor)	Not Significant (Moderate)	Not Required	Not Required
Overall Effect	All	Post-closure	Medium	Medium	Landscape	Regional	Far future	Far future	Sporadic	Sporadic	Irreversible	Irreversible	High	High	High	Medium	Medium	Low	Not Significant (Minor)	Not Significant (Moderate)	Not Required	Not Required

Note:

CE = Cumulative Effect

For a complete list of Project components see Table 8.8-2.

8.9.2.1 Project-specific Residual Effects on Soil Quantity That Are Not Likely to Result in Cumulative Effects

All KSM Project-specific environmental effects on soil quantity will likely result in similar cumulative effects resulting from interactions with other projects. Table 8.9-1 lists a number of projects that are not expected to interact cumulatively with the residual effects associated with the KSM Project. Lack of cumulative interaction results from the absence of spatial overlap between the projects (see the assumptions discussed in Sections 8.9.1.1 and 8.9.1.2).

8.9.2.2 Cumulative Effect of Loss of Ecologically Functional Soil

Permanent access roads and non-reclaimed, disturbed areas such as landings, laydown areas, and borrow pits contribute to a direct loss of soil quantity otherwise available to perform a number of ecological functions and constitute a fundamental change in land use (Bulmer et al. 2008).

Landslides and other forms of soil erosion represent both losses of bulk soil and decreases in site productivity (Miles et al. 1984; Smith et al. 1986, Bulmer et al. 2008). It has been shown that high road densities (e.g., above 0.12 km of road per km^2 on slopes above 60% grade, or above 0.16 km/km^2 in riparian areas; Porter et al. 2012) are correlated with high soil erosion and high sediment transport to streams (USFS 1996; BC MOF 2001; Gustavson and Brown 2002), high landslide frequency (Porter et al. 2012), an increased risk of fire occurrence (USFS 1996; Arienti et al. 2009), and high tree mortality (USFS 1996). Consequently, as the proportion of developed land under the footprint of various projects increases, the cumulative effect of this loss on soil ability to store carbon and nutrients and control ground water movement is expected to gradually decrease. Assessment of the overall expected soil loss and the proportional contribution of the Project to that change will be discussed in the following sections.

<u>Project-specific Cumulative Effects Mitigation for Loss of Land Surface Area</u>

Project-specific mitigation efforts (Section 26.13) will concentrate on minimizing the extent of disturbed soil by strictly adhering to Project development strategies coupled with efforts to re-vegetate disturbed areas in a timely matter. Land will be cleared only in the areas necessary for mine development during each phase, and salvageable soil will be stripped and stockpiled for future reclamation; reclamation of disturbed areas will be enacted as soon as it is feasible. The area of non-reclaimed mine components retained after closure will be minimized.

Employment of BMPs and most current monitoring and mitigation methods are expected to limit the intensity of soil erosion along the roads during mine operation and after closure.

<u>Other Project/Activity Mitigation to Address Loss of Land Surface Area</u>

The cumulative effects of soil loss associated with proposed future projects can be addressed by early review of alternative design options and introduction of changes leading to reduction of the area on which ecological function of soil will be lost to soil excavation, burial, or erosion. Furthermore, implementation of policies to minimize the area and duration of soil disturbance by each of the participating projects will constitute an important mitigation strategy. Development of comprehensive soil management plans and following BMPs for road construction, road maintenance, soil salvage, and stockpiling constitute vital aspects of this mitigation effort.

While the above strategies require participation of each of the involved projects, proactive and comprehensive regional planning will also provide effective mitigation of the cumulative effects of soil loss. Whenever feasible, resource sharing (e.g., highways, power lines, water, fuel stations, etc.) could be considered.

Determination of Potential for Residual Cumulative Effect and Significance of Loss of Land Surface Area

Disturbed areas such as roads, laydown areas, stream diversions, and borrow pits contribute to a direct loss of soil surface otherwise available to perform a number of ecological functions. The magnitude of this effect will change in time, reflecting the temporal dynamics of soil disturbance in the region.

Review of available data suggests that the total footprint area associated with the development of the projects expected to have spatial and temporal links with the KSM Project is estimated at approximately 8,355 ha (estimates are based on available information on the proposed projects – see Section 5.3). Of course, because project closures will be staggered, the area of disturbed land is expected to change in time. The extent of disturbed area will also depend on reclamation success, which, due to predominantly harsh climatic and edaphic conditions, is expected to be generally difficult. Therefore, the maximum extent of the total expected disturbed area of the spatially/temporarily linked projects will likely best reflect the magnitude of the predicted soil loss.

The projects spatially/temporarily linked with the KSM Project (Eskay Creek Mine, Sulphurets Project, Brucejack Mine, Snowfield Project, NTL, and Treaty Creek Hydroelectric Project) are located within the three adjacent watersheds: Unuk River, Upper Bell-Irving River, and Lower Bell-Irving River. The total area of these watersheds is 729,784 ha. Thus, assuming no major landslides, it appears that within the next few decades approximately 1.4% of the land area will potentially lose the ability to maintain the full spectrum of ecological function.

In view of the above data and in consideration of the high incidence of natural soil disturbance in the region (Section 8.1.4), the magnitude of the cumulative loss of land surface area is predicted to be medium (not exceeding limits of natural variation). The effect is expected to extend spatially across multiple watersheds (regional) and temporarily into the far future (more than 70 years). The loss will occur as a series of sporadic events and is considered irreversible as the soils in some areas (e.g., mining pits) will be permanently lost. Judging by the high occurrence of natural slope failures in the area (Section 8.1.4) the resilience of the receiving environment to additional disturbance is low (the context is high). The likelihood of soil loss under the footprints of proposed projects is high, but because the area of disturbed land is expected to change in time and because the footprints of some future project have been estimated with considerable approximation, the confidence in the predicted outcome is medium (Table 8.9-3).

Overall, the effect of soil loss under the footprints of the proposed projects in the region is expected to be **not significant**.

Determination of Potential for Residual Cumulative Effect and Significance of Soil Bulk Erosion

Disturbed areas from which vegetation has been removed (e.g., laydown areas, stream diversions, borrow pits, and especially roads) are typically associated with soil erosion and mass wastage, which leads to bulk losses. The magnitude of these processes is highly dependent on the amount of exposed soil surface and roads, especially roads located on slopes, which tend to contribute most significantly to overall soil loss. Because roads increase runoff and drainage efficiency, most of the eroded soil ends up in streams and lakes. Consequently, the rate of watercourse sedimentation reflects the intensity of soil erosion.

The ratio of the total length of roads within an area (in km per km^2 or miles per square mile) is commonly used in the scientific literature to assess road density. Indicators and associated benchmarks for watershed monitoring prepared by ESSA Technologies Ltd. for the BC Ministry of Environment (Porter et al. 2012) suggest that if the fish populations are expected to remain below the moderate risk criterion, road densities across entire watershed should stay below 1.2 km/km^2. Recommended road densities on unstable/steep slopes (e.g., slopes greater than 60% grade) should remain below 0.12 km/km^2 and in riparian areas below 0.16 km/km^2. A threshold value of 0.28 km/km^2 has been suggested by the US Fish and Wildlife Service as the watershed road density at or below which stream sedimentation does not adversely affect fish populations in Oregon (USFWS 1998).

Predicted road density in the three watersheds encompassing the proposed projects spatially and temporarily linked with the Project is expected to reach 0.14 km/km^2. The highest road density of 0.18 km/km^2 is predicted in the Lower Bell-Irving River watershed. Since the predicted road density due to proposed projects only slightly exceeds the recommended thresholds, the magnitude of the cumulative soil loss associated with erosion is expected to be medium. The spatial extent of this effect will be regional (expected to extend spatially across multiple watersheds) and its duration will extend into the far future (more than 70 years). The effect will occur sporadically and is considered irreversible, as most of the eroded soil will be permanently lost. In view of high incidence of natural soil disturbance in the area, the resilience of the receiving environment is considered low (and thus, the context is high). The likelihood of soil loss due to erosion is high but due to a number of unknown external variables (e.g., future weather patterns, fire potential, seismic activity, etc.) the confidence in the predicted outcome is medium (Table 8.9-3).

Overall, the cumulative effect of permanent bulk soil loss resulting from soil erosion at the proposed projects in the region is expected to be **not significant**.

8.9.2.3 Overall Cumulative Effect on Soil Quantity

The cumulative loss of soil quantity is expected to extend spatially across multiple watersheds and its duration will extend into the far future. The loss of soil quantity will occur as a series of sporadic events and is considered irreversible as most of the excavated, buried, or eroded soil will be permanently lost. Due to the proposed employment of BMPs, modern monitoring, and mitigation methods, the magnitude of this effect is expected to be medium and resilience of the receiving environment is predicted to be neutral. The likelihood of soil losses is high but due to a number of unknown external variables, the confidence in the predicted outcome is medium (Table 8.9-3). Overall, the cumulative effect of permanent soil loss at the proposed projects in the region is expected to be **not significant**.

8.9.3 Cumulative Effects Assessment for Loss of Soil Quality

Given the assumptions discussed in Sections 8.9.1.1 and 8.9.1.2, the following past, existing, and planned human activities have the potential to overlap spatially and temporally with residual soil degradation associated with the development of the Project:

- closed Eskay Creek Mine;
- present NTL;
- proposed Treaty Creek Hydroelectric Project;
- proposed development of the Snowfield Project; and
- proposed development of the Brucejack Project.

Table 8.9-4 lists human activities that can potentially interact with soil degradation associated with the KSM Project.

Table 8.9-4. Summary of Projects and Activities with Potential to Interact Cumulatively with Expected Project-specific Residual Effects on Soil Quality

Description of Effect	Potential for Cumulative Impact: Relevant Projects and Activities				
	Eskay Creek Mine	Sulphurets Project	Treaty Creek Hydroelectric	Brucejack Mine	Snowfield Project
Soil Quality: Compaction	Potential spatial and temporal linkage between compacted areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkage between compacted areas	Potential spatial and temporal linkage between compacted areas	Potential spatial and temporal linkage between compacted areas
Soil Quality: Contamination	Potential spatial and temporal linkage between contaminated areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkage between contaminated areas	Potential spatial and temporal linkage between contaminated areas	Potential spatial and temporal linkage between contaminated areas
Soil Quality: Loss of Fertility	Potential spatial and temporal linkage between affected areas	Potential spatial and temporal linkages between disturbed areas	Potential spatial and temporal linkage between affected areas	Potential spatial and temporal linkage between affected areas	Potential spatial and temporal linkage between affected areas

8.9.3.1 Project-specific Residual Effects on Soil Quality Not Likely to Result in Cumulative Effects

Table 8.9-1 lists a number of projects that are not expected to interact cumulatively with the residual effects associated with the Project. Lack of cumulative interaction usually results from the absence of spatial overlap between the projects (see the assumptions discussed in Sections 8.9.1.1 and 8.9.1.2).

8.9.3.2 Cumulative Effect of Degradation of Soil Quality

Soil degradation is caused by contamination, compaction, and loss of fertility due to changes in structure, hydrological patterns, erosion, transportation, and long-term storage. Contamination can result from aerial deposition of metals from mined minerals (e.g., dust; Zhi-Qing 1996) and from potential spills of fuels and other chemicals used by mining and power-generating industries. Some level of soil contamination can also be attributed to metal leaching from waste rock storage areas and from roads cut through acid generating rock. Soil compaction, typically caused by construction activities, reduces the ability of soil to support life and often leads to increased surface runoff and erosion (Noss 1995; Gunn 2009). Industrial development also leads to disruption of natural soil drainage patterns and necessarily involves soil disturbance through salvage, long-term storage, and redistribution. Landslides and other forms of soil erosion associated with roads decreases the productivity of surrounding areas (Smith et al. 1986; Bulmer et al. 2008). Roads also increase the risk of fire occurrence (USFS 1996; Arienti et al. 2009), and tree mortality (USFS 1996).

Consequently, as the proportion of developed land increases, the cumulative spatial extent of soil degradation is expected to rise. Soil degradation associated with the six projects considered in this Cumulative Effects Assessment is expected to spatially and temporarily interact with soil degradation due to the development of the KSM Project. Assessment of the predicted cumulative soil degradation, and the proportional contribution of the Project in those changes, will be discussed in the following sections.

Project-specific Cumulative Effects Mitigations for Degradation of Soil Quality

Facilities in which chemical substances are used (e.g., explosives manufacturing, water treatment, and heavy equipment maintenance facilities, or refuelling stations) will be designed to minimize and control spillage. Spill response equipment and procedures will be followed and mitigation will include immediate spill area remediation to minimize the inflow of contaminants into soil if spills occur (details in Section 26.13.3). Dust abating technologies including windbreaks, fences, water sprays, and dust suppression fluids (Section 26.11.2) may be employed. Assessment of disturbances during construction will include sampling and geochemical characterization (e.g., metal leaching and acid rock drainage) of road cuts and material sources. The amount of human-generated waste (e.g., batteries, aerosol cans, insecticides, etc.) that have potential to contaminate soil will be minimized through reduction, reuse, recycling, and proper disposal of remaining material (details in Section 26.6).

Traffic outside of the designated KSM Project travel routes will be discouraged. Reclamation methods that reduce equipment traffic during soil redistribution will be employed to lessen soil compaction (details in Chapter 27).

Provision of training and supervision by a qualified soil specialist during salvage operations will minimize the frequency of soil transport, prevent handling soils when they are either too dry or too wet and reduce mixing of the topsoil with less fertile materials. Erosion of the stockpiled soil will be reduced by timely re-vegetation of the stockpile berms. More details are provided in the Terrain, Surifical Geology and Soil Management and Monitoring Plan (Section 26.13).

A comprehensive monitoring program will be established at the beginning of mine construction to verify proper implementation and effectiveness of mitigation measures (Sections 8.7.1.1 and 8.7.2.1).

Other Project/Activity Mitigations to Address Degradation of Soil Quality

It is expected that the BMPs will be followed during soil salvage, stockpiling, and reclamation and that modern erosion/sedimentation control, spill control, and environmental monitoring programs will be established at each of the existing and planned projects in the region.

Determination of Potential for Residual Cumulative Effect and Significance of Degradation of Soil Quality

Previous impacts of one mine (Eskay Creek) and one mineral exploration project (Sulphurets Project), as well as subsequent development of three mining projects (KSM, Brucejack, and Snowfield), one power generation project (Treaty Creek Hydroelectric), and one power transmission project (NTL) in the area raise the possibility of cumulative interactions between different forms of soil degradation associated with each of the projects.

The proposed Project will affect the level of soil contamination (e.g., with metals leaching from the exposed road cuts, accidental chemical spills, deposition of metal-laden dust, etc.), soil compaction (due to machinery and truck traffic), and loss of soil fertility (e.g., associated with changes in hydrological patterns, erosion, and prolonged soil storage). While changes to baseline conditions are unavoidable, strict application of monitoring and mitigation programs will limit the extent and magnitude of soil degradation to Project footprints and the 100 m buffers around the footprints. It is also expected that, because the four largest of the six interacting projects are metal mines, environmental effects associated with each of them (e.g., effects of roads on soil erosion and stream sedimentation, metal/dust deposition, etc.) will be similar. Consequently, it is likely that the cumulative soil degradation due to development of these projects will only have a landscape-scale additive extent and that synergistic interactions with other types of disturbances will be largely avoided.

As previously discussed (Section 8.9.2.2), the total area of proposed cumulative soil loss will affect approximately 1.4% of the land covered by the three adjacent watersheds that surround the six interacting projects. The exact residual footprint of the other proposed projects is not currently known, but assuming that the proportion of project maximum footprint to the total area of degraded buffer areas surrounding residual footprints after closure will be similar to that for the KSM Project, it can be expected that approximately 1.1% of the three watershed areas (close to 730,000 ha) may be affected by soil degradation.

In view of the above prediction, the magnitude of the cumulative soil quality degradation is expected to be medium. The spatial extent of this effect will be regional (expected to extend spatially across multiple watersheds) and its duration will extend into the far future (more than 70 years). Soil degradation will occur as a series of sporadic events and is considered irreversible, as some project components will remain in place in the foreseeable future. In consideration of the naturally high incidence of soil disturbance (Section 8.1.4), high metal contamination (Section 8.1.5), low soil buffering capacity and high acidity, the resilience of the receiving environment is considered low (thus, the context is high). The likelihood of soil degradation is medium but due to a number of unknown external variables (future weather patterns, fire potential, effectiveness of mitigation across a number of projects), the confidence in the predicted outcome is low (Table 8.9-5). Overall, the cumulative effect of soil degradation resulting from the development of the six interacting projects in the region is expected to be **not significant**.

Table 8.9-5. Summary of Cumulative Residual Effects on Soil Quality

Description of Residual Effect	Project Component(s)	Timing of Effect	Magnitude	Magnitude Adjusted for CE	Extent	Extent Adjusted for CE	Duration	Duration Adjusted for CE	Frequency	Frequency Adjusted for CE	Reversibility	Reversibility Adjusted for CE	Context	Context Adjusted for CE	Likelihood of Effects: Probability	Likelihood of Effects: Probability Adjusted by CE	Likelihood of Effects: Confidence Level	Likelihood of Effects: Confidence Adjusted by CE	Significance	Significance Adjusted for CE	Follow up Monitoring	Follow up Monitoring Adjusted by CE
Decreased soil fertility in buffers surrounding components retained after closure.	Roads and other non-reclaimed areas retained after closure	Construction	Medium	Medium	Landscape	Regional	Far future	Far future	Sporadic	Sporadic	Irreversible	Irreversible	High	High	Medium	Medium	Low	Low	Not Significant (Minor)	Not Significant (Minor)	Not Required	Not Required
Soil compaction in buffers surrounding components retained after closure.	Roads and other non-reclaimed areas retained after closure	Construction	Medium	Medium	Landscape	Regional	Far future	Far future	Sporadic	Sporadic	Irreversible	Irreversible	High	High	Medium	Medium	Low	Low	Not Significant (Minor)	Not Significant (Minor)	Not Required	Not Required
Soil contamination in buffers surrounding components retained after closure.	Roads and other non-reclaimed areas retained after closure	Post-closure	Medium	Medium	Landscape	Regional	Far future	Far future	Sporadic	Sporadic	Irreversible	Irreversible	High	High	Medium	Medium	Low	Low	Not Significant (Minor)	Not Significant (Minor)	Not Required	Not Required

Notes:

CE = Cumulative Effect

8.9.3.3 Overall Cumulative Effect on Soil Quality

The cumulative degradation of soil quality resulting from the development of six interacting projects (Section 8.9.3.1) is expected to have regional spatial extent (three watersheds). Soil degradation will occur as a series of sporadic events, will extend into the far future, and is considered irreversible. Due to proposed employment of BMPs and monitoring and mitigation methods, the magnitude of this effect is expected to be medium and resilience of the receiving environment is predicted to be low. The likelihood of soil degradation is medium but due to a number of unknown external variables, the confidence in the predicted outcome is low. The cumulative degradation of soil quality due to the proposed projects in the region is expected to be **not significant**.

8.10 Summary Assessment of Potential Environmental Effects on Terrain, Surficial Geology, and Soils

The assessment of Project effects on soil quantity and quality has focused on the area immediately surrounding the proposed footprint because the potential environmental effects of mine development on terrain and soils are relatively localized. For the same reason, the linkages between the effects of Project development and the effects of other human activities in the region have been considered only where close spatial proximity of potentially affected areas would likely occur.

This assessment identified the following potential residual effects on soils associated with the Project: permanent loss of ecologically functional soil under retained footprint; permanent loss of soil due to erosion (both affecting soil quantity); and degradation of soil due to contamination, compaction, and loss of fertility (affecting soil quality).

The extent of potential effects from Project development on soils is ultimately dependent on the implementation of monitoring, mitigation, and reclamation programs. To this end, a number of mitigation strategies have been identified and are being incorporated into three environmental management plans (Section 26.13). To restore the land capability to baseline levels as much as possible and to preserve a variety of traditional land uses, suitable soil will be salvaged, appropriately preserved, and made available for reclamation (see Section 26.13.1, Soil Salvage and Handling Plan). The goal of the Erosion Control Plan (Section 26.13.2) is to prevent the loss and degradation of soils due to erosion, mitigation of natural soil drainage disruption around mine infrastructure, and control of sedimentation of watercourses downstream of Project operations. The primary mitigation methods rely on the use of appropriate erosion/sedimentation control technology and timely re-vegetation of disturbed soil. The Soil Contamination Prevention Plan (Section 26.13.3) guides soil protection from substances that have the potential to exert an adverse effect on soil quality and, indirectly, affect air, water, and organisms that may contact the soil. It also guides on-site remediation of reagent, fuel, lubricant, and cement spills.

Residual soil loss (under retained Project components and due to erosion) is expected in areas where pits will be developed and where several other Project components (e.g., TMF, Water Treatment Plant, and roads) will be retained after closure. Potential for cumulative interaction with five other projects in the region has been identified. In view of high occurrence of natural soil loss and relatively small spatial extent of the residual soil loss, the environmental significance of soil loss is assessed as **not significant**—both in terms of direct contribution of the Project and in terms of the cumulative effect of all interacting projects.

Residual soil degradation (due to contamination, compaction, and loss of fertility) is predicted in areas adjacent to the retained Project components (e.g., roads, tunnel portals, water diversion channels, etc.). It is predicted that, due to the naturally low soil quality and in view of proposed monitoring and mitigation programs, soil degradation will result in a **not significant** change from the baseline. A potential for interaction with soil disturbances caused by other projects has been recognized. Due to the spatially limited extent of these effects and expected employment of monitoring, mitigation, and best management practices, it is expected that the cumulative degradation of soil quality due to interacting projects will also be **not significant**.

Table 8.10-1 summarizes the assessment of the potential effects of the KSM Project on soil quantity and quality.

Table 8.10-1. Summary of Assessment of Potential Environmental Effects: Terrain and Soils

Valued Component	Phase of Project	Potential Effect	Key Mitigation Measures	Significance Analysis of Residual Effects	Significance Analysis of Cumulative Effects
Soil Quantity	Construction to Post-closure	Permanent loss of soil under footprints of retained infrastructure; bulk soil loss due to erosion.	Minimize footprint, salvage soil, reclaim as soon as possible, and minimize erosion.	Not significant	Not significant
Soil Quality	Construction to Post-closure	Decreased soil fertility, compaction, and contamination in 100 m wide buffers around retained infrastructure.	Apply BMP for soil salvage, stockpiling, reclamation; erosion/sedimentation control; control dust; restrict off road traffic; establish soil monitoring program early; remediate contaminated areas.	Not significant	Not significant

8.11 Terrain, Surficial Geology, and Soils – Conclusions

The Project area is characterized by steep topography (large portions of the BSA are located on moderate to steep slopes) with loose talus resulting from naturally occurring rockslides and slumps. Colluvial and morainal surficial materials dominate the valleys, and ice and bedrock prevail in upper slopes. Soil formation in the BSA is limited by the cold climate and extreme topographic conditions. Consequently, most developed soils occur in valleys. Most sensitive, organic soils occur in poorly drained areas on lower slopes and occupy approximately 1.6% of the total BSA—mainly in in the CCAC and PTMA and the TCAC.

Analytical results indicate that most mineral soils in the BSA are strongly acidic, have generally low organic carbon content, and are non-calcareous. Naturally elevated levels of metals, exceeding BC Contaminated Site Regulation (BC Reg. 375/96) standards for industrial sites, (antimony – 1% of samples; arsenic – 6% of samples; copper – 11% of samples; molybdenum – 4% of samples; and selenium – 1% of samples) were found in several locations near the proposed mining pit areas.

Project development will affect two VCs: soil quantity and quality. Loss of soil quantity under the mine footprint and due to erosion reduces the area and volume of ecologically functional soil, while changes in site drainage patterns, soil compaction, and contamination will potentially affect soil quality characteristics such as structure, viability and diversity of microbiological flora, pH, and chemical composition. Reductions in soil quantity and quality influence the ecological function of ecosystems, and degrade habitat and water quality, thus affecting traditional hunting, fishing, and plant gathering.

There are no widely recognized guidelines for acceptable limits of soil loss or degradation of soil ecological function, and in any case, such effects are difficult to quantify. One of the limitations of this assessment is that the rating of effect magnitude relies on a qualitative evaluation of potential losses to both quantity and quality of soil. Government quantitative guidelines are currently available only for the assessment of soil contamination. Consequently, the assessment of environmental effects is based on Seabridge's commitment to preventive measures (e.g., BMPs, monitoring).

Based on review of technical and scientific literature it was assumed that the buffer width of 100 m will capture the spatial extent of most changes in chemical and physical soil properties that might be reasonably expected in response to various environmental effects associated with the KSM Project. For the assessment of cumulative effects, the outline of three adjacent watersheds (Unuk River, Upper Bell-Irving River, and Lower Bell-Irving River) was used to establish a potential linkage between the neighbouring projects.

Long-term chronosequence studies indicate that disturbed soil microbial communities require an approximately 15 to 30 year-long recovery to develop a stable structure. Considering the difficult climatic and terrain conditions at the proposed Mine Site, it was assumed that soil recovery will take, on average, 30 years. Thus the temporal boundary of 30 years was adopted for the assessment of cumulative effects.

Considering the predominance of low quality of soil in the BSA, the high incidence of natural disturbance, and the location of permanently lost areas relative to the regionally most valuable soil resources, the magnitude of the soil loss is predicted to be medium. While the spatial extent of this effect is expected to remain local, the duration of the land loss will extend into the far future. The loss will occur with sporadic frequency throughout and beyond the life of the Project. The effect is considered irreversible, as the soils in some areas of the mine (e.g., mine pits and/or some roads) will be permanently lost. Due to the scarcity of quality soils and the high degrees of acidity in those present, the resilience of the receiving environment is considered low. While the likelihood of soil loss due to Project development is high, the confidence in the predicted outcome is medium due to potential interactions with natural slope instability, seismic activity, and other projects. Overall, the effect of permanent loss of soil in the retained portions of the proposed Project is expected to be **not significant**. Cumulative interactions with other projects are expected to increase the extent of soil loss to a regional scale but the overall environmental significance will remain **not significant**.

In view of the expected employment of monitoring and mitigation programs, the magnitude of soil degradation is expected to be low. The predicted spatial extent of this effect will be local and its duration will extend into the far future with sporadic frequency throughout and beyond the Project life. Soil degradation is considered irreversible because the potential causal agents will not be removed. There is a high incidence of natural slope erosion and sporadically high soil metal concentrations; however, the high degree of acidity present in the soils means that they have limited capacity to buffer further chemical inputs. Therefore, the resilience of the receiving environment is considered low. Due to high variability of baseline conditions in the Project area, the likelihood of soil degradation due to Project activity is medium and the confidence in the predicted outcome is intermediate. Overall, the effect of soil degradation on soil quality around the retained portions of the Project infrastructure is predicted to be **not significant**. Cumulative interactions with other projects are expected to increase the extent of soil degradation to a regional scale but the overall environmental significance will remain **not significant**, both in terms of the contribution of the KSM Project and all projects combined.

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