# RED MOUNTAIN UNDERGROUND GOLD PROJECT
# VOLUME 3 | CHAPTER 9
# LANDFORMS AND NATURAL LANDSCAPES

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# 9 LANDFORMS AND NATURAL LANDSCAPES EFFECTS ASSESSMENT

## 9.1 Introduction

The purpose of this effects assessment is to present the potential effects of the proposed Red Mountain Underground Gold Project (the Project) on those issues of greatest environmental, social, cultural, and economic importance to the public, the government, Aboriginal Groups, stakeholders, and the scientific community.

This chapter presents the effects assessment for the Landforms and Natural Landscapes intermediate component (IC). This IC was included because of the potential effects of the Project on soil quantity, soil quality, and terrain stability.

The effects assessment is based on information provided in the Ecosystems, Vegetation, Terrain, and Soils Baseline Report (Volume 8, Appendix 9-A), Red Mountain Geophysical Baseline (Volume 8, Appendix 9-B), and Terrain Stability Assessment for the Project Footprint Study Area (Volume 8, Appendix 9-C) and follows the effects assessment methodology described in Volume 3, Chapter 6 (Effects Assessment Methodology). The potential effects of the Project on Landforms and Natural Landscapes form an effect pathway to selected receptor VCs, including:

- Wildlife;
- Vegetation and Ecosystems;
- Surface Water Quality;
- Fish and Fish Habitat; and
- Human Health.

VCs will be informed by effects to the following Landforms and Natural Landscapes ICs:

- Soil Quantity
    - Soil quantity affects ecological function and quality of vegetation and ecosystems, fish and wildlife habitat, quality of groundwater resources, and associated human and wildlife needs. It affects Aboriginal and Treaty Interests and requires protection required by the *Environmental Management Act* (2003) and *Mines Act* (1996).
- Soil Quality
    - Soil quality is necessary to maintain ecological function of ecosystems; has direct influence on wildlife habitat availability; affects Aboriginal and Treaty Interests, such as hunting, fishing, trapping, and gathering; and protection is required by the *Mines Act* (1996).

- Terrain Stability and Geohazards:
  - It is important to understand the dynamic physical environment in order to mitigate through design and manage the risks that Project interactions with existing geohazards and potentially unstable terrain present to the environment and the Project.

Landforms and natural landscapes are an aspect of the environment that may be altered by the Project, as proposed by IDM Mining Ltd. (IDM). Figure 9.1-1 to Figure 9.1-3 illustrate the entire Project footprint and the established disturbance limits for the Mine Site (location of Upper and Lower Portals) and for Bromley Humps (location of Process Plant and Tailings Management Facility [TMF]).

**Figure 9.1-1: Project Overview**

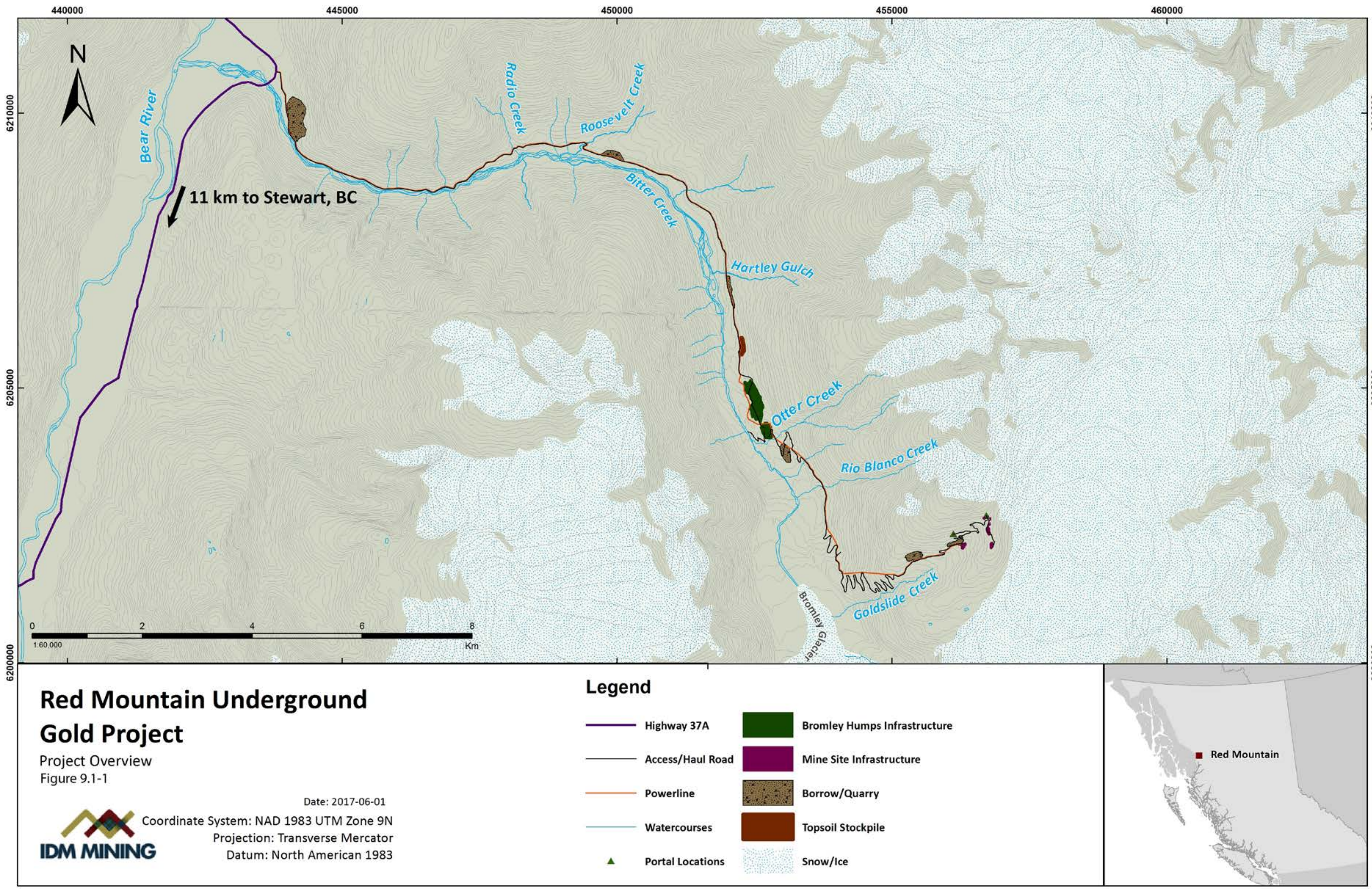


**Figure 9.1-2: Project Footprint – Bromley Humps**

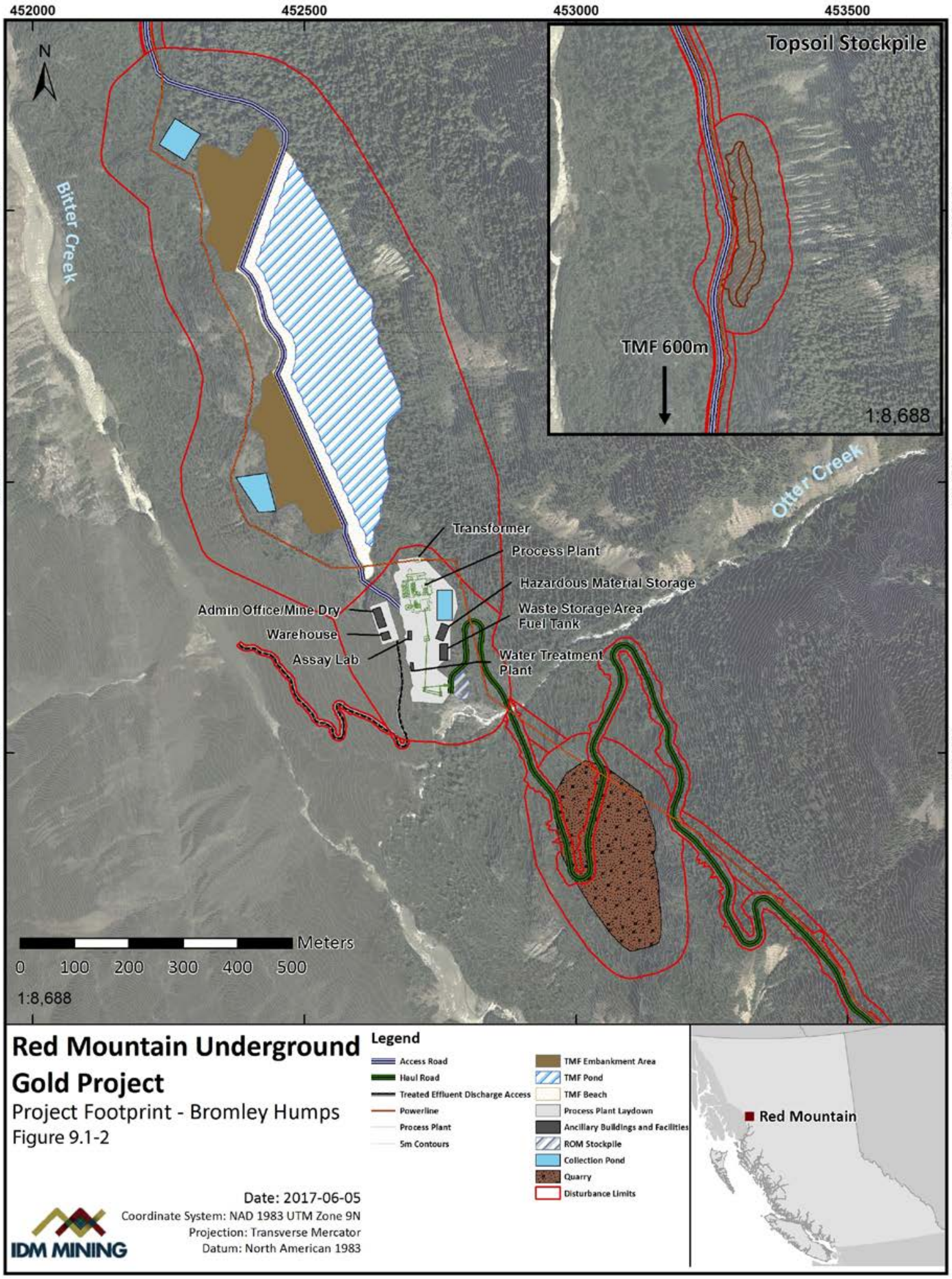
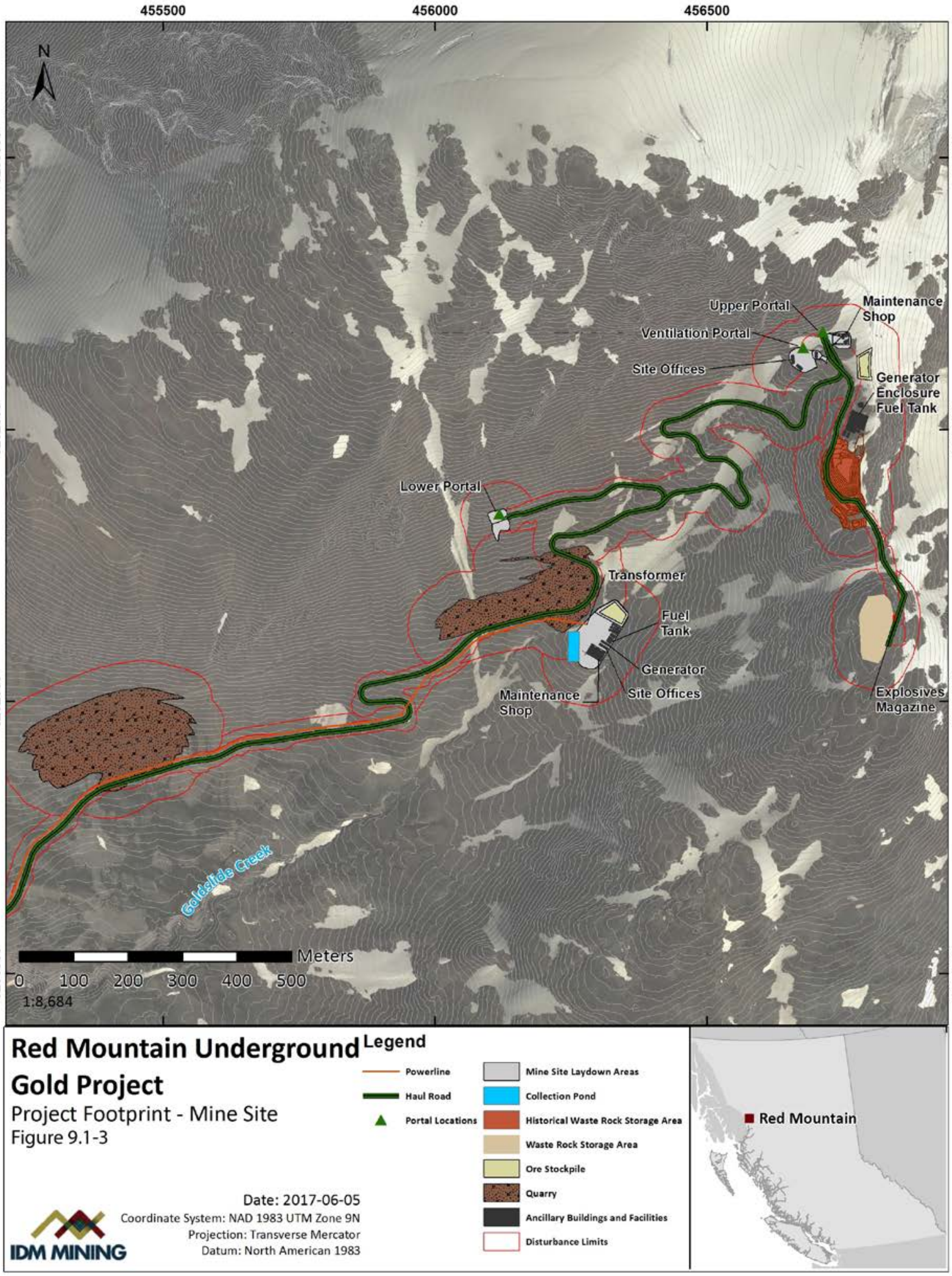


**Figure 9.1-3: Project Footprint – Mine Site**



## 9.2 Regulatory and Policy Setting

Under the *BC Environmental Assessment Act* (2002; BCEAA), the BC Environmental Assessment Office (EAO) issued an order under Section 11 of the BCEAA (the Section 11 Order) in February 2016. The Section 11 Order defines the process and procedure for the Project's environmental assessment (EA) under BCEAA. Under the Section 11 Order, EAO, jointly with the Canadian Environmental Assessment Agency (the Agency), convened a Working Group comprised of federal, provincial, and regional regulators, Aboriginal Groups, and government agencies whose mandates intersect with the proposed Project and its EA.

As per the Section 11 Order, IDM, in close collaboration with EAO, Working Group members, and Nisga'a Nation, as represented by Nisga'a Lisims Government (NLG), issued the Application Information Requirements (AIR) for the Project in March 2017. The AIR outlines the information required to be included in the Project's Application for an Environmental Assessment Certificate / Environmental Impact Statement (Application/EIS). This Application/EIS has been prepared to meet the requirements of the AIR.

Under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), the Agency issued Guidelines for the Preparation of an Environmental Impact Statement Pursuant to CEAA 2012 (the EIS Guidelines) for the Project in January 2016. This Application/EIS has been prepared to meet the requirements of the EIS Guidelines.

Mining activities in BC, including exploration, development, production, closure, and reclamation activities, are regulated under the British Columbia *Mines Act* (1996). Before conducting any mining activities, a project proponent must apply for a permit. As part of the permit application, a detailed Mine Plan and Reclamation Program must be submitted to the BC Ministry of Energy and Mines (BC MEM) for approval.

Under the *Mines Act* (1996), the Health, Safety and Reclamation Code for Mines in British Columbia (BC MEMPR 2008) requires that the applicant provide:

- Information on surficial geology, terrain mapping, soil survey and characterization, vegetation, wildlife, land capability, and present land use (which are located in Volume 8, Appendices 9-A, 9-B, 9-C, 16-A; Volume 3, Chapters 15, 20, and 21);
- Plans for salvaging and stockpiling of surface soils and overburden materials (see Volume 5, Chapter 29);
- An erosion and sediment control plan (see Volume 5, Chapter 29); and
- A reclamation plan (see Volume 2, Chapter 5).

The Fish Habitat Protection and Pollution Prevention provisions of the *Fisheries Act* (1985) describe measures required to avoid or minimize effects on the aquatic environment, shoreline, and riparian areas during development and operation of a project (s. 37), and regulate discharge of harmful substances, including sediment, into fish habitat (s. 34). Consideration of the above legislation is particularly important in cases when Project development is located near shorelines or riparian areas where sediment and chemical contaminants could migrate into the aquatic environment.

The Spill Contingency Plan (Volume 5, Chapter 29) and Waste Management Plan (Volume 5, Section 29) outline management of soils potentially contaminated by hazardous materials such as hydrocarbons and reagents.

The *Environmental Management Act* (EMA) establishes criteria under which sediment yield is considered a pollutant. BC's water quality guidelines recommend targets for acceptable sediment levels (turbidity and suspended, as well as benthic, sediments); these are used to determine performance of control measures while undertaking in-stream works (BC MOE 2001).

Unpaved roads can contribute significantly to soil erosion; adverse effects can be mitigated through use of best management practices (BMPs) that focus on erosion prevention and watercourse sedimentation resulting from accelerated soil erosion (see Volume 5, Section 29, Erosion and Sediment Control Plan). The *Forest and Range Practices A*ct (2002) governs road construction and maintenance within provincial forests and requires that these activities be carried out in accordance with the Forest Service Road Use Regulation (BC Reg. 70/2004). Guidance for development of roads (road design and field practices) is provided in the Forest Road Engineering Guidebook (BC MOF 2002).

The Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 2007) provide guidelines for contaminants in soil. These Canada-wide guidelines suggest maximum limits for substances such as pesticides, metals, and hydrocarbons in soil, and apply to residential, agricultural, industrial, and other land uses. The Contaminated Sites Regulation (BC Reg. 375/96) is part of the *Environmental Management A*ct (2003) and lists criteria for toxicity to soil invertebrates and plants. These criteria are used to define if a specific site is contaminated, to determine liability for site remediation, and to assess the effectiveness of remediation and reclamation efforts.

Terrain stability best management practices are derived from forestry practices. The Association of BC Forest Professionals and Association of Professional Engineers and Geoscientists have developed guidelines for terrain stability assessments (2010). The *Forest and Range Practices Act* (2002) sets out protections for riparian ecosystems.

Landforms and Natural Landscapes ICs will be managed according to applicable legislation and regulations and coordinated with management of relevant environmental, economic, heritage, health, and/ or social features (Table 9.2-1).

### Table 9.2-1: Relevant Legislation Applicable to Landforms and Natural Landscapes

| Legislation | Jurisdiction | Description |
|---|---|---|
| *BC Environmental Assessment Act* (BCEAA; 2002) | Provincial | An assessment of potential adverse environmental effects within provincial jurisdiction is required under the *Reviewable Projects Regulations* of BCEAA (2002) as the Project exceeds the annual ore production capacity of 75,000 tonnes (t). |

| Legislation | Jurisdiction | Description |
|---|---|---|
| *Canadian Environmental Assessment Act* (CEAA; 2012) | Federal | An assessment of potential adverse environmental effects within federal jurisdiction is required under CEAA (2012) because the Project exceeds the minimum daily ore production threshold of 600 t per day) (Section 16 of the *Regulations Designating Physical Activities*). |
| *Mines Act* (1996) | Provincial | Under the *Mines Act* (1996), the Health, Safety and Reclamation Code for Mines in British Columbia (BC MEM 2017) requires proponents to provide:<br>• Information on surficial geology, terrain mapping, soil characterization, vegetation, wildlife, and present land use;<br>• Salvage and stockpile plans of soil and overburden;<br>• Erosion control plan; and<br>• Reclamation plan.<br>This code specifies standards that must be achieved during mining activities and requires regular site inspections and annual reporting. |
| *Fisheries Act* (1985a) Recent amendments to *Fisheries Act* (2012) | Federal | The Fisheries Protection and Pollution Prevention within the *Fisheries Act* (1985) regulates activities that may cause serious harm to fish that are part of a commercial, recreational, or Aboriginal fishery, or to fish that support such a fishery. Under certain conditions, sediment from erosion in a waterbody or stream may cause serious harm to the abovementioned fish and fish habitat. A sediment control plan is needed for the Project to adhere to these regulations. |
| *Environmental Management Act* (EMA; 2003) | Provincial | Under the EMA (2003), the EPD sets criteria to define when "sediment yield" (i.e., sediment discharging into a watercourse) becomes a "pollutant," e.g., when received in concentration and/or duration beyond natural regimes (BC MOE 2015). Provincial water quality guideline documents, including BC MOE (2013) provide targets of acceptable levels of sediment in water.<br>Under the EMA (2003), the *Contaminated Sites Regulation* (BC Reg.375/96) provides soil criteria for toxicity to soil invertebrates and plants. These criteria define whether an applicable site is contaminated and aid in the assessment of reclamation success.<br>The technical guidance document, Developing a Mining Erosion And Sediment Control Plan (BC MOE 2015), guides mining companies to develop an erosion and sediment control plan that, when implemented, will contribute to compliance with the EMA (2003) and protection of the environment. |
| *Forest and Range Practices Act* (FRPA; 2002) | Provincial | Unpaved roads have potential to contribute to soil erosion, which can lead to sedimentation of watercourses. Road construction and maintenance within BC forests is governed by the FRPA (2002), which requires that road construction and maintenance conducted under Forest Act authority adhere to codes provided in the *Forest Service Road Use Regulation* (BC Reg. 70/2004), which focuses primarily on soil erosion prevention. |

The Project is also within the Nass Area and the Nass Wildlife Area, as set out in the Nisga'a Final Agreement (NFA). Pursuant to the NFA, Nisga'a Nation, as represented by NLG, has Treaty rights to the management and harvesting of fish, wildlife, and migratory birds within the Nass Wildlife Area and the larger Nass Area. The Project is also within the asserted traditional territory of Tsetsaut Skii km Lax Ha (TSKLH) and is within an area where Métis Nation BC (MNBC) claims Aboriginal rights.

At a regional scale, the Nass South Sustainable Resource Management Plan (NSSRMP) is a plan to promote and encourage long-term sustainable development in the southern parts of the Nass Timber Supply Area (TSA). The NSSRMP has five primary objectives (FLNRO 2012), including to:

- Assist in reaching a broad-based forestry accommodation agreement;
- Fulfill legal obligations of the Crown;
- Promote sustainable forest management in the Nass TSA;
- Assist in streamlining subsequent consultation processes; and
- Increased certainty for long-term access and sustainable development for Gitanyow, Nisga'a Nation (as represented by NLG), and all resource sectors (e.g., forestry, fisheries, tourism, and mining).

## 9.3 Scope of the Assessment

The scope of the assessment provides the framework for the evaluation of potential Project effects on Landforms and Natural Landscapes and includes the following steps:

- Review of the Project description (Volume 1, Chapter 2), relevant regulatory guidance documents, and consultation records from NLG, technical experts, and the Working Group;
- Select candidate ICs, sub-components, and ecological indicators based on issues raised during consultation and on the Project's potential to interact with the proposed ICs;
- Conduct field studies to collect information on the type, distribution, and extent of the potential ICs;
- Define assessment boundaries for the candidate ICs;
- Identify key potential Project interactions with candidate Landforms and Natural Landscapes ICs and identify potential pathways for interactions with other ICs/VCs;
- Determine potential mitigation, management, and follow-up measures to address potential Project effects on candidate ICs.

### 9.3.1 Information Sources

Information used in issues scoping and IC selection processes for the Application/EIS included:

- Project field data and mapping (see Ecosystems, Vegetation, Terrain, and Soils Baseline Report located in Volume 8, Appendix 9-A; and Red Mountain Geophysical Baseline, located in Volume 8, Appendix 9-B);
- Detailed terrain stability assessment for the access and haul roads (see Terrain Stability Assessment for the Project Footprint Study Area, located in Volume 8, Appendix 9-C);
- Recent, comparable project environmental assessments and related research conducted for comparable projects, especially in northwest BC;
- Consultation with provincial and federal regulators, Working Group members and organizations, Aboriginal Groups, local and regional stakeholders, and the public;
- Federal and provincial requirements;
- Publicly available spatial files, reports, land use plans, and background technical reports; and
- Expert knowledge and experience.

As outlined in Chapter 6 (Effects Assessment Methodology), IDM has not conducted primary traditional use or traditional ecological knowledge (TEK) surveys in support of the Project due to the preferences of Nisga'a Nation, as represented by NLG, and EAO's and the Agency's direction for comparatively low levels of engagement with the other Aboriginal Groups potentially affected by the Project. IDM has committed to using TEK where that information is publically available. As no TEK relevant to this effects assessment was publically available at the time of writing, no TEK has been incorporated.

### 9.3.2 Input from Consultation

IDM is committed to open and honest dialogue with regulators, Aboriginal Groups, community members, stakeholders, and the public.

IDM conducted consultation with regulators and Aboriginal Groups through the Working Group co-led by EAO and the Agency. Where more detailed and technical discussions were warranted, IDM and Working Group members, including sometimes NLG representatives, held topic-focused discussions, the results of which were brought back to EAO and the Working Group as a whole.

Further consultation with Aboriginal Groups, community members, stakeholders, and the public has been conducted as outlined by the Section 11 Order and EIS Guidelines issued for the Project. The results of those consultation efforts relevant to the assessment of potential effects of the Project on Landforms and Natural Landscapes have been summarized in the table below.

More information on IDM's consultation efforts with Aboriginal Groups, community members, stakeholders, and the public can be found in Chapter 3 (Information Distribution and Consultation Overview), Part C (Aboriginal Consultation), Part D (Public Consultation), and Appendices 27-A (Aboriginal Consultation Report) and 28-A (Public Consultation Report. A record of the Working Group's comments and IDM's responses can be found in the comment-tracking table maintained by EAO.

During consultation with stakeholders, government agencies, Aboriginal Groups, and the public, a preliminary list of proposed ICs and an IC-scoping exercise were conducted to explore potential Project interactions with candidate ICs (Table 9.3-1). A preliminary list of potential VCs was developed based on one or more of the following criteria:

- Issues or concerns raised during the EA Pre-Application Phase and through consultation activities;
- Input from TSKLH, MNBC, and Nisga'a Nation;
- A perceived likelihood that the IC will be affected by the Project based on scientific knowledge, past experience with other mining projects, and professional judgment regarding potential effects, thresholds, mitigation, and management measures;
- Policy guidance and/or relevance to regulatory requirements;
- Government management priorities;
- Sensitivity or vulnerability to disturbance; and
- Availability of data and analytical tools to measure effects on the VC (e.g., ecosystem mapping).

**Table 9.3-1: Summary of Consultation Feedback on Landforms and Natural Landscapes**

| Topic | Feedback by* | | | | Consultation Feedback | Response |
|---|---|---|---|---|---|---|
| | NLG | G | P/S | O | | |
| Soil Quality | | | | x | Identified as a key component of ecosystem development and function | Key potential Project effects on soils are assessed in the Vegetation and Ecosystems Effects Assessment (Volume 3, Chapter 15) and this Landforms and Natural Landscapes Effects Assessment. |

| Topic | Feedback by* | | | | Consultation Feedback | Response |
|---|---|---|---|---|---|---|
| | NLG | G | P/S | O | | |
| Soil Quantity | | | | x | Identified as a key component of ecosystem development and function | Key potential Project effects on soils are assessed in the Vegetation and Ecosystems Effects Assessment (Volume 3, Chapter 15) and this Landforms and Natural Landscapes Effects Assessment. |
| Terrain Stability | | | | x | Identified as a key component of ecosystem development and function, as well as a source of increased sedimentation | Key potential Project effects on terrain stability are assessed in this Landforms and Natural Landscapes Effects Assessment. |

*NLG = Nisg̱a'a Lisims Government;
G = Government - Provincial or federal agencies;
P/S = Public/Stakeholder - Local government, interest groups, tenure and license holders, members of the public;
O = Other

### 9.3.3 Intermediate Components, Assessment Endpoints, and Measurement Indicators

Intermediate components and measurement indicators are summarized in Table 9.3-2. The rationale for their selection was informed by input from Working Group members (including NLG, stakeholders, and government regulators), review of government guidelines, consideration of other relevant projects, grey literature, published research, and professional judgment. For this IC, the table provides a list of pathway VCs where significance will be determined, each with a unique assessment endpoint.

**Table 9.3-2: Sub-Components, Assessment Endpoints, and Measurement Indicators for Landforms and Natural Landscapes Intermediate Components**

| IC | Primary Measurement Indicators | VC Where Significance will be Determined | Rationale |
|---|---|---|---|
| • Landforms and Natural Landscapes<br>• Terrain Stability and Geohazards<br>• Soil Quantity<br>• Soil Quality | • Changes in terrain stability<br>• Changes in intensity and frequency of snow avalanches<br>• Changes to background surface erosion<br>• Changes to background rates of sedimentation of waterbodies<br>• Changes to soil quantity<br>• Change to soil quality<br>• Channel morphology lateral and vertical stability (i.e., bank erosion and scour) | • Wildlife<br>• Vegetation and Ecosystems<br>• Surface Water Quality<br>• Fish<br>• Fish Habitat<br>• Human Health | Terrain Stability and Geohazards<br>• It is important to understand the dynamic physical environment in order to mitigate through design and manage the risks that Project interactions with existing geohazards and potentially unstable terrain present to the environment and the Project.<br>Soil Quantity<br>• Soil quantity affects ecological function and quality of fish and wildlife habitat, quality of groundwater resources, and associated human and wildlife needs; affects Aboriginal and Treaty Interests; protection required by *Environmental Management Act* (2003) and *Mines Act* (1996).<br>Soil Quality<br>• Soil quality is necessary to maintain ecological function of ecosystems; has direct influence on wildlife habitat availability; affects Aboriginal and Treaty Interests, such as hunting, fishing, trapping, and gathering; protection required by *Mines Act* (1996). |

## 9.3.4 Assessment Boundaries

Assessment boundaries define the maximum limit within which the effects assessment and supporting technical studies are conducted. Boundaries encompass areas and periods of time during which the Project is expected to interact with Landforms and Natural Landscapes. The assessment boundaries account for constraints due to temporal, political, social, and economic circumstances, and technical limitations (i.e., known limitations in predicting or measuring changes to each IC).

### 9.3.4.1 Spatial Boundaries

#### 9.3.4.1.1 Regional Study Area

The regional study area (RSA; Figure 9.3-1) is the spatial area that encapsulates the Project and extends beyond to the height of land to include several watersheds within the region. The RSA boundary takes into consideration the predicted habitat of select wildlife over a season and/or over a lifetime, such as grizzly bears, mountain goats, martens, and wolverine (see Volume 3 Chapter 16). The RSA boundary provides context for the type, distribution, extent and prevalence of ecosystems within the region (Volume 3, Chapter 15). The RSA is 211,570 hectares (ha) in size.

#### 9.3.4.1.2 Local Study Area

The local study area (LSA; Figure 9.3-1) was established to provide a study area boundary for assessing the effects of the Project at the local watershed level. The LSA encompasses the full extent of the Bitter Creek watershed. It extends to the height of land on all sides of Bitter Creek, including the Roosevelt Creek drainage and a portion of Bromley Glacier to the south. The north end of the LSA includes the mouth of Bitter Creek where it passes Highway 37A and drains into Bear River, including an area of floodplain forest and Clements Lake. The LSA is 15,860 ha in size.

The LSA is the spatial area that extends to the height of land and includes the watersheds surrounding the Project. Watersheds represent a physical boundary within which ecological processes interact and shape the ecology of an area. For example, as water flows down from the height of land and interacts with elements of the receiving environment, such as parent material, soil type, soil drainage, and vegetation type, the water may be absorbed into the ground, contributing to groundwater flow; pooled at the surface creating wetlands over time; or contribute to an existing stream. These interactions over time and space result in distinct assemblages of vegetation types and ecosystems. The resultant vegetation and ecosystems provide the supporting landscape for wildlife and fish habitat and provide a variety of recreational services, such as skiing and hiking, within the watershed.

### 9.3.4.2 Project Footprint Study Area

The Project footprint study area (PFSA; Figure 9.3-1) is the spatial area within which development of temporary and permanent infrastructure is expected to occur. The Project Footprint is 247 ha and includes six main features: 1) the Mine Site (48 ha); 2) the Access Road (35 ha); 3) the Powerline (27 ha); 4) the TMF (48 ha); the 5) Process Plant (9 ha); and quarries, borrows, and stockpiles (81 ha). The Project footprint includes a 50 m disturbance buffer surrounding the proposed non-road infrastructure to accommodate for potential minor siting changes prior to the final design. This area is considered as "lost" for the effects assessment. The road lost area was the road footprint as determined by the road design. The PFSA includes a 150 metre (m) alteration buffer (encompassing an additional 714 ha) outside of the Project footprint to allow for the assessment of effects, including dust effects.

#### 9.3.4.3 Temporal Boundaries

Temporal boundaries encompass the periods during which the proposed Project is expected to interact with Landforms and Natural Landscapes. Temporal boundaries reflect those periods during which planned Project activities are reasonably expected to potentially affect an IC. The temporal boundaries are based on the timing of the different phases of the proposed Project as described in the Project Overview (Volume 2, Chapter 1).

**Table 9.3-3: Temporal Boundaries for the Effects Assessment**

| Phase | Project Year | Length of Phase | Description of Activities |
|---|---|---|---|
| Construction | Year -1 to Year 1 | 18 months | Construction activities and construction of: Access Road, Haul Road, Powerline, declines, power supply to the underground, water management features, water treatment facilities, TMF, Process Plant, ancillary buildings and facilities; underground lateral development and underground dewatering; ore stockpile and ore processing start-up; and receiving environmental monitoring. |
| Operation | Year 1 to Year 7 | 6 years | Ramp-up to commercial ore production and maintain a steady state of production, underground dewatering, tailings storage, water treatment, gold doré shipping, environmental monitoring, and progressive reclamation. |
| Closure and Reclamation | Year 7 to Year 11 | 5 years | Underground decommissioning and flooding; decommissioning of infrastructure at portals, Process Plant, TMF, ancillary buildings and facilities; reclamation, water treatment; removal of water treatment facilities. |
| Post-Closure | Year 12 - 21 | 10 years | Receiving environment monitoring. |

#### 9.3.4.4 Administrative and Technical Boundaries

The LSA is situated within the Regional District of Kitimat-Stikine (RDKS) and is partially within the District of Stewart (Figure 9.3-2). The RSA falls within two forest districts, the Kalum Forest District to the north and the North Coast Forest District to the south, within which forest resources are managed by the British Columbia Ministry of Forests, Lands and Natural Resource Operations. The LSA is fully within the Kalum Forest District.

The LSA and most northern portion of the RSA are within NSSRMP, while the southern portion of the RSA is in the North Coast (Great Bear Rainforest) Land Resource Management Plan (LRMP; BC Gov. 2004; BC Gov. 2008). The RSA is largely within the Nass Wildlife Area.

The RSA contains one protected area: Bear Glacier Provincial Park. Four legal Old-Growth Management Areas (OGMAs) are located within the LSA, three of which fall within 150 m of proposed Project infrastructure, with nine more OGMAs within the RSA. OGMAs are legally established and spatially defined areas that forest licensees are required to maintain. They are established through landscape-unit planning or operational planning to achieve biodiversity targets and retain representative old-growth forests (DataBC 2017).

**Figure 9.3-1: Landforms and Natural Landscapes Regional, Local, and Project Footprint Study Areas**

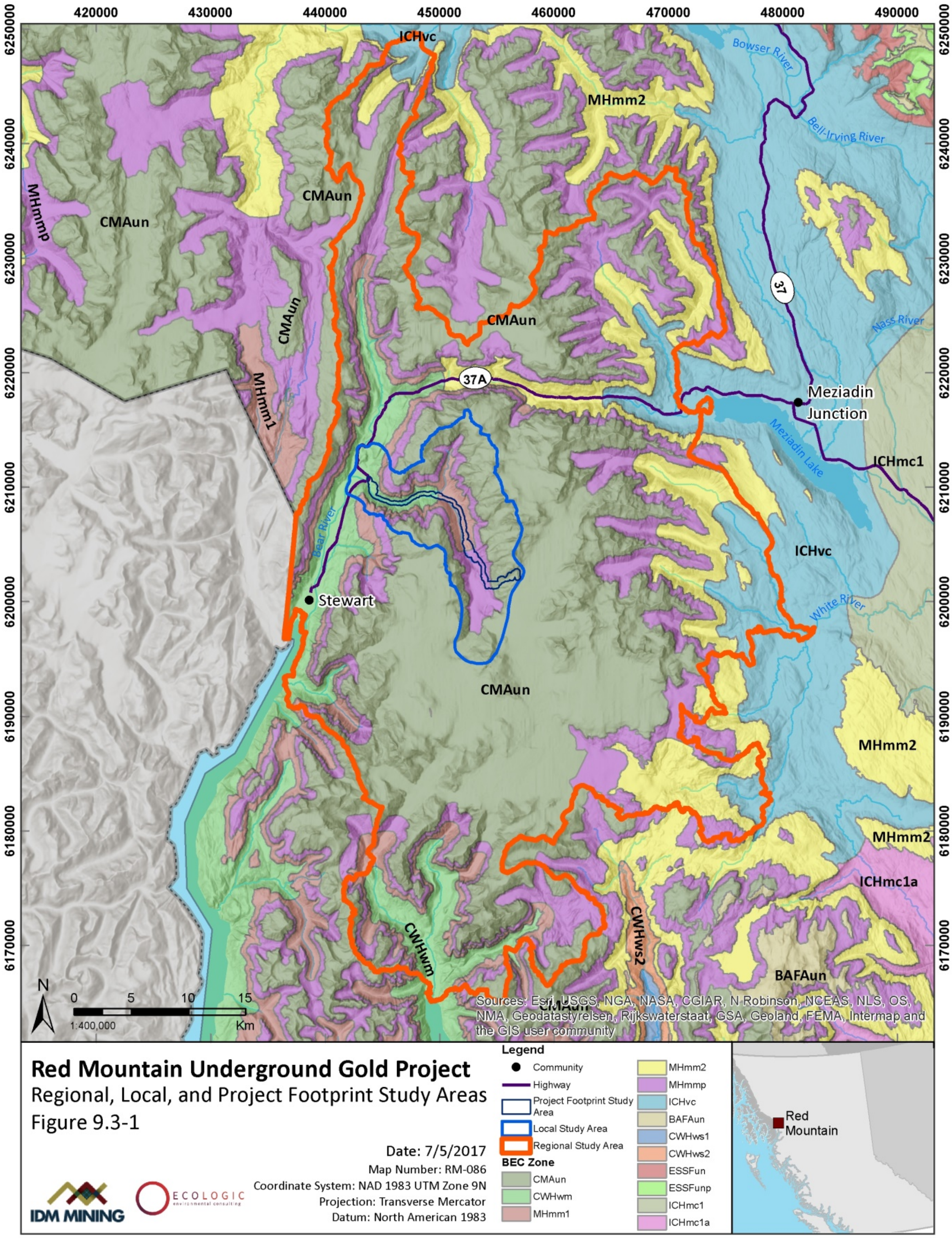
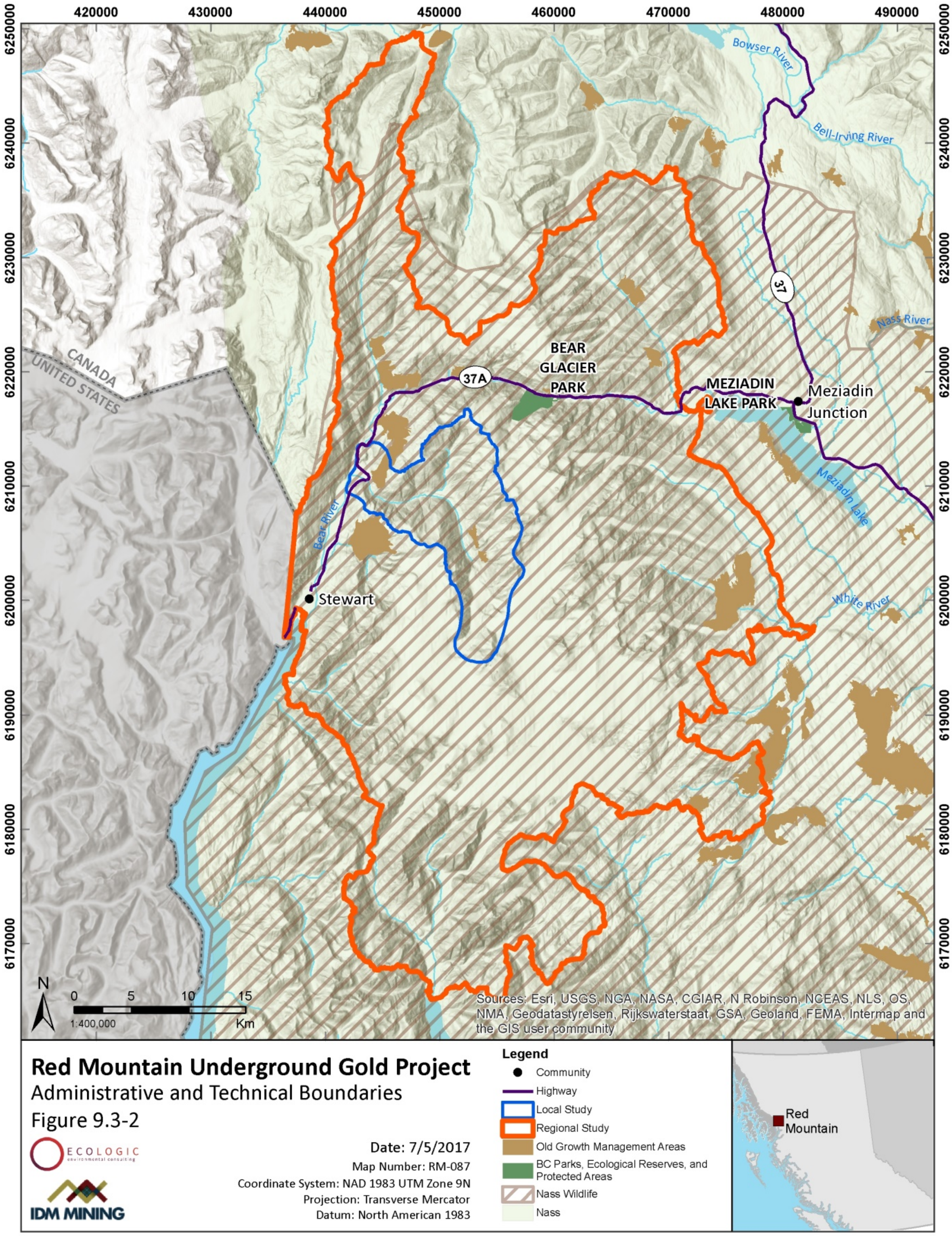


**Figure 9.3-2: Landforms and Natural Landscapes Administrative and Technical Boundaries**



# 9.4 Existing Conditions

## 9.4.1 Overview of Existing Conditions

### 9.4.1.1 Regional Setting Overview

The Project is located within the Boundary Ranges of the Coast Mountain Physiographic Subdivision, an area comprising primarily of rugged, northwest trending, granitic mountains along the Alaska, United States, panhandle and BC boundary. The range has been heavily glaciated and has a granitic core but is flanked in the east by sedimentary and volcanic bedrock (Holland 1976a in Appendix 9-A). The Boundary Ranges extend from sea level to approximately 3,090 metres above sea level (masl) at Mount Ratz, northwest of Red Mountain. The elevation in the RSA ranges from approximately 20 m to 2,700 m, with the majority occurring above 300 masl. The Project is split between the Boundary Ranges and Nass Ranges Ecoregions (Appendix 16-A). Ecoregions are areas that contain major physiographic and minor macroclimatic or oceanographic variation (Demarchi 1996). The 47 Ecoregions that occur in BC are further divided into Ecosections, based on minor physiographic, oceanic, and macroclimatic variation (Demarchi 1996).

The Boundary Ranges Ecoregion is characterized by rugged granitic and metamorphic-based mountains that are largely ice-capped (Demarchi 1996). The western half of the Project is situated within the Southern Boundary Ranges Ecosection, consisting of wet, rugged mountains that contain frequent remnant icefields and glaciers. Numerous rivers dissect the mountains, including Bear River, which drains into Portland Canal at the District of Stewart.

The Nass Ranges occur to the east, with roughly half of the RSA occurring in the Meziadin Mountains Ecosection, along with a small portion of the Nass Basin Ecosection to the southeast. The Nass Ranges are a transitional area from coast to interior, with western portions containing rugged, wet mountains similar to the Boundary Ranges, while eastern mountains are more subdued. The Meziadin Mountains Ecosection is comprised of rugged, granitic mountains that are located on the leeward side of the Boundary Ranges. White River and numerous small drainages flow from the LSA into Meziadin Lake and Meziadin River. Alpine areas make up a large portion of the Meziadin Mountains Ecosection, and range from large expanses of ice fields, multiple glaciers, and a variety of vegetated and sparsely vegetated areas (Demarchi 1996).

The Bitter Creek watershed is adjacent to the boundary of Intermontane and Coast belts of the Canadian Cordillera, along the southwest margin of the Bowser Basin and the western border of the Stikine Terrace. There are three primary stratigraphic elements in Stikinia and all are present in the Stewart area: Middle and Upper Triassic clastic rocks of the Stuhini Group, Lower and Middle Jurassic volcanic and clastic rocks of the Hazelton Group, and Upper Jurassic sedimentary rocks of the Bowser Lake Group. More specifically, well-bedded Jurassic marine clastic rocks of the Hazelton Group, circa (ca.) 157 to 174 mega-annum, or million years ago (Ma), overlay massive and competent Paleozoic to Lower Jurassic (ca. 174 to 201 Ma) oceanic arc, volcanic, and volcanoclastic basement rocks (Greig et al. 1994 in Appendix 9-A). These structures are exposed by Late Jurassic (ca. 157 Ma) and Early Cretaceous to Tertiary (ca. 147 to 165 Ma) structural folding within the Skeena Fold Belt, which are in turn intruded by Eocene and older (ca. 35 to 56 Ma) granite, granodiorite, and diorite intrusions of the Coast Plutonic Complex (Metcalfe, 2013). Much of the area has undergone metamorphic mineralization, associated with the arrival of island arc assemblages, which resulted in four significant magmatic episodes. These, each in duration of 5 to 10 Ma, are identified as the Red Mountain (Goldslide) Stock (Greig et al. 1994).

The Eocene (35 to 56 Ma) Coast Plutonic Complex dominates the western third of the Bitter Creek watershed. North past Roosevelt Creek, which enters Bitter Creek from the north, the rock formation changes to the Middle to Upper Jurassic Hazelton Group Undivided Sedimentary rocks. This transitions to Early Jurrasic to Triassic (174 to 251 Ma) Hazelton Group – Unuk River Formation andesitic volcanic rocks. The Early Jurrasic (174 to 201 Ma) Red Mountain (Goldslide) dioritic intrusive complex forms the area that contains the proposed Project.

The RSA encompasses four Biogeoclimatic (BGC) zones, 70% of which are alpine and parkland zones (Appendix 9-B):

- Coastal Mountain-heather Alpine (CMA), characterized by long, cold winters and short, cool growing seasons and dominated by dwarf shrubs, herbs, mosses, lichens, and rock;

- Coastal Western Hemlock (CWH), characterized by abundant rainfall and relatively warm temperatures, with forests dominated by western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*), with infrequent occurrences of western red cedar (*Thuja plicata*), yellow cedar (*Chamaecyparis nootkatensis*), and amabilis fir (*Abies amabilis*).

- Interior Cedar Hemlock (ICH), characterized by a deep persistent snowpack and cool, moist summers, and forests dominated by Roche spruce (*Picea glauca* x *sitchensis*) and subalpine fir (*Abies lasiocarpa*), with some western hemlock and mountain hemlock (*Tsuga mertensiana*).

- Mountain Hemlock (MH), characterized by high snowfall and a short growing season and with forests of mountain hemlock and amabilis fir and at upper elevations in the parkland, sparse, stunted trees with shrubland and alpine communities.

Precipitation ranges from approximately 500 millimetres (mm) in the summer to 1,300 mm during the winter months (Appendix 9-A).

The Pacific and North America plate boundary off of BC's west coast is a complex system of faults capable of producing large earthquakes (e.g., the 1949, 8.1 magnitude; Appendix 9-A). The best known active fault in the greater Stewart region is the Queen Charlotte Fault, a strike-slip (or transitional [left-right]) fault, located approximately 400 kilometres (km) southwest of Red Mountain. Historical records indicate five large earthquakes have been centred on the Queen Charlotte Fault area since 1920 (presented in Appendix 9-A), ranging in magnitude from 7.0 to 8.1. These data, along with other data, confirm the presence of a subduction system in the Haida Gwaii area (Goldfinger et al., 2013 in Appendix 9-A).

Though larger earthquakes are infrequent along the fault, magnitude 4.0 and lower energy events occur almost daily (NRC 2017 in Appendix 9-A). The effects of large earthquakes centered off the coast of Haida Gwaii are notable well inland of their epicenters (Appendix 9-A). Though over 400 km away, the 8.1 magnitude earthquake in 1949 registered as feeling like a magnitude 6.0 earthquake around Red Mountain (Lamontagne et al. 2007 in Appendix 9-A).

#### 9.4.1.2 Local Setting Overview

The proposed Project is situated in the Bitter Creek watershed, located within the Southern Boundary Ranges. The watershed is a largely north-south valley that drains Bromley Glacier into Bear River, off Highway 37A. Roosevelt Creek is a significant drainage occupying a hanging valley in the northeast portion of the watershed, while smaller watercourses frequently occur in deep gullies on the steep mountain slopes. The area is characterized by steep, wet slopes that contain frequent avalanche tracks. The north end of the Bitter Creek valley contains CWH forests along the lower and mid slopes, including large areas of mid-slope mature and old forests. The mouth of Bitter Creek, as it drains into Bear River, is characterized by flat floodplain forests and is dominated by deciduous stands adjacent to the rivers, grading into mixed forests on higher, less-active floodplains. Narrow fringes of floodplain forest extend up Bitter Creek, with most of the active creek floodplain area being highly scoured rock and gravel and occasional sparsely vegetated areas. MH forests occupy a narrow, steep band above (around 700 masl) the CWH, and replace the CWH at the valley bottom as elevation increases to the southeast of Roosevelt Creek. Parkland MH forests start around 900 masl in elevation and often contain old to very old forested stands before giving away to stunted krummholz around 1,200 masl as the CMA zone begins.

As Bitter Creek climbs in elevation towards Bromley Glacier, soil development is limited. At the southern end of the valley, the majority of the area is dominated by recently de-glaciated morainal deposits, along with colluvial slopes and barren alpine communities. Exposed higher elevations contain extensive sparsely-vegetated communities and barren rock outcrops before giving away to glaciers and icefields. Hillslopes at high elevations tend to be composed of veneers of colluvial or morainal material directly overlying bedrock, which is exposed on the steepest valley sides, such as the east-facing slopes opposite Goldslide Creek and in regions only recently uncovered by receding glacier (Appendix 9-A). The steep slopes, often in excess of 70%, and sparse vegetation can lead to high rates of mass wasting and large volumes of colluvial material. Therefore, many tributary valleys are supplied a functionally unlimited volume of sediment for transport and have the potential to generate debris flows or debris floods whenever critical climate thresholds are exceeded (Appendix 9-A and 9-B). Colluvial and fluvial fans resulting from this activity have formed at the mouths of many of these tributaries where they join Bitter Creek.

The last major glacial period to affect the LSA was the Fraser Glaciation with an onset approximately 25,000 to 30,000 years before present. In the Skeena Valley, Fraser deglaciation was complete sometime between 10,700 to 9300 years before present and the timing is assumed to be comparable for the Bear River and Bitter Creek valleys. During this time, lateral moraines from the Bromley Glacier were deposited along the hillslopes at elevations as high as 1,200 masl in the LSA (Appendix 9-A). More details on past and recent glaciation are provided in Appendix 9-A.

Till and glacial deposits were laid across the landscape at the onset of various glaciations. From the retreating alpine and Bromley Glaciers, large volumes of meltwater laden with sediment were released and transported to, and by, Bitter Creek (Appendix 9-A). Erosional reaches are more prevalent near the terminus of the Bromley Glacier, while downstream, the creek exhibits several sections of floodplain aggradation, such as near the mouths of Hartley Gulch and Roosevelt Creek.

In terms of a hazard rating for seismic activity near Stewart, the Geological Survey of Canada has created a relative seismic hazard rating map of Canada, which places Red Mountain in a moderately high hazard area (Appendix 9-A).

## 9.4.2 Past and Current Projects and Activities

The Bitter Creek watershed has a history of mines and mine explorations. Highway 37A and a BC Hydro transmission line cross the creek near the confluence with Bear River. Much of the area near Highway 37A has been, or is being, cleared or logged for various purposes. Small quarries and borrow pits associated with the highway or powerline construction occur along Highway 37A, and basic amenities have been developed for a recreation area at Clements Lake. An old, overgrown road runs parallel to much of Bitter Creek along the northern side on old floodplains and the toe of the slope. Several smaller old roads branch off up the slopes, and there are numerous old logged areas adjacent to the road. Additional roads occur around the vicinity of the old mine portal on Red Mountain.

Placer mining commenced in Bitter Creek at the base of Red Mountain at the turn of the 20$^{th}$ century. In 1989, gold mineralization was discovered and surface drilling was conducted from 1991 to 1994. Existing infrastructure on the Red Mountain Property includes an underground decline and drift development that was excavated in 1993 and 1994 for bulk sampling of the mineralized Marc zone, a 50,000 tonne (t) waste rock pile, a surface tote road network, temporary camp buildings, helipads, numerous temporary drill pads, and used mobile equipment (JDS 2016).

## 9.4.3 Project-Specific Baseline Studies

### 9.4.3.1 Data Sources

Data sources used to inform the evaluation of Project effects on Landforms and Natural Landscapes include information collected through field studies and published sources, including government planning documents, technical reports, peer-reviewed research, consultation records, spatial data, guidelines and protocols, and guidebooks.

#### 9.4.3.1.1 Field Studies

The following field studies informed the Landforms and Natural Landscapes Effects Assessment:

- 2014-201515 SNC Lavalin geophysical baseline studies;
- 2014 Triton vegetation and ecosystem surveys; and
- 2016 EcoLogic soils, terrain, vegetation, ecosystem and rare plant and lichen surveys.

#### 9.4.3.1.2 Existing Literature

Existing literature reviewed for this Landforms and Natural Landscapes Effects Assessment include:

- Nass South Sustainable Resource Management Plan (SRMP; FLNRO 2012);
- North Coast Land Resource Management Plan (LRMP);
- Nisga'a Final Agreement (Government of Canada 2012);
- Nisga'a Lisims Government website (NLG 2017);
- NatureServe Conservation Ranks (for provincially and globally rare plants and lichens);
- BC CDC, which provides information of the known occurrences of Red- and Blue-listed ecosystems and plants;
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC) for federally listed plants and lichens; and
- Publicly available data from other terrestrial ecosystems baseline studies conducted in the general vicinity of the Project (e.g., Brucejack Gold Mine Project, Kerr-Sulphurets-Mitchell Project, and Kemess Underground Mine Project).

#### 9.4.3.1.3 Spatial Data

Spatial data reviewed in support of this Landforms and Natural Landscapes Effects Assessment include:

- Base data (hydrology, glaciers, lakes, rivers, wetlands, roads, administrative boundaries, old growth management areas, protected areas, Predictive Ecosystem Mapping [PEM]; DataBC; Government of BC Data Distribution Service);
- Biogeoclimatic Ecosystem Classification (BEC) Zone/Subzone/Variant/Phase map (version 9, May, 2014; DataBC; Government of BC Data Distribution Service);
- Digital Elevation Models (GeoGratis; Natural Resources Canada);
- Landsat satellite imagery (GeoGratis; Natural Resources Canada);
- Terrain Resource Information Mapping (DataBC; Government of BC Data Distribution Service); and
- Digital 2013 colour air photos that were custom flown for the Project, and black-and-white 1994 air photos that were scanned from hard copy Provincial imagery.

##### 9.4.3.1.4 Guidelines and Protocols

The guidelines and protocols reviewed in support of this Landforms and Natural Landscapes Effects Assessment include:

- Biogeoclimatic Ecosystem Classification codes and names (BECdb version 8, Feb 2012);
- Standard for Terrestrial Ecosystem Mapping (TEM) in BC (1998);
- Standard for TEM Digital Data Capture in BC, Version 3.0 (2000);
- Terrain Classification System for BC, Version 2.0 (1997);
- Standards for Digital Terrain Data Capture in British Columbia, Version 1.0 (1998); and
- Standards and Guidelines to Terrain Mapping in BC (1996).

##### 9.4.3.1.5 Guidebooks

The guidebooks reviewed in support of this Landforms and Natural Landscapes Effects Assessment include:

- Biogeoclimatic Ecosystem Classification of Non-forested Ecosystems in British Columbia (MacKenzie 2012);
- Wetlands of British Columbia: a guide to identification (MacKenzie and Moran 2004);
- Field Manual for Describing Terrestrial Ecosystems; 2nd Edition (BC Min. of Forests and Range and BC Min. of Env. 2010);
- A Field Guide to Site Identification and Interpretation for the Prince Rupert Forest Region (Banner et al. 2004); and
- Canadian System of Soil Classification (SCWG 1998).

#### 9.4.3.2 Primary Data Collection and Analysis Methods

Baseline data collection and analysis occurred in the study areas described in Section 9.3.4. The exception to this is baseline data collected and analyzed in the SNC Geophysical Baseline (SNC 2017). The SNC RSA is roughly analogous to the LSA. It is noted that SNC Terrain Mapping was carried out according the boundaries of the LSA, but was not presented in SNC 2017 accordingly. Terrain mapping carried out by SNC is presented in this assessment according to the LSA boundaries.

##### 9.4.3.2.1 Field Surveys

Terrain and soil inspections (including profile descriptions) followed provincial methods using the *Field Manual for Describing Terrestrial Ecosystems* (BC MOFR and BC MOE 2010). Soil orders and horizon characterization follow the Canadian System of Soil Classification (SCWG 1998). Soils classification, to the order level, was inferred from soil morphologic observation interpretations and lab data. Soil samples were collected at 21 ground inspection sites, which were then analyzed for a suite of metals and soil parameters at Caro Labs in Richmond, BC (Section 9.4.3.2.3). Soil inspections used to inform the derivation of Soil Map Units (SMUs) were focused primarily in the PFSA. Terrain inspections used to inform the bioterrain mapping component were focused in the PFSA and LSA, with terrain information collected at survey locations in the RSA to support the PEM.

##### 9.4.3.2.2 Terrain Mapping and Geohazards

*Bioterrain and Terrain Stability Mapping*

Terrain mapping is a classification system that describes the characteristics and spatial distribution of surficial materials, landforms, and geomorphological processes. Bioterrain mapping is a modified method of terrain mapping that includes attributes useful to ecology, such as aspect and soil drainage, and is the base mapping used in TEM. Bioterrain mapping was performed for the Project using the standardized Terrain Classification System for British Columbia (Howes & Kenk, 1997) and provincial TEM (RIC 1998) in accordance with the Standard for Digital Terrain Data Capture in British Columbia (RIC 1998). Preliminary terrain mapping was conducted prior to field work and polygons were delineated and assigned attributes of surficial material, texture, surface expression, and geomorphic processes. Field data results were used to confirm and/or update the mapping.

Terrain mapping was conducted at 1:5,000 scale for the PFSA and at a 1:20,000 scale for the LSA (Appendix 9-B). A digital elevation model (DEM) with 1 m resolution was generated from July 2013 LiDAR data and used in the terrain mapping for the PFSA. For the LSA, some gaps in stereo image coverage occur at the edges of the study area. In these areas a DEM, created from the provincial Terrain Resource Information Management (TRIM) data, was used for elevational spatial input and analyses. The terrain mapping was incorporated and used as the basis for the TEM, having shared polygon line work.

Terrain stability mapping is an interpretation of terrain mapping that identifies areas currently unstable and susceptible to increased instability due to activities, such as road construction. Terrain stability mapping was conducted within the LSA at 1:20,000 scale and at 1:5,000 scale in the PFSA (Appendix 9-B). Terrain Stability Ratings were applied to terrain polygons following BC Ministry of Forests (1999) provincial guidelines, which were based on an assessment of the texture of surficial materials, thickness of materials, slope angle, slope configurations, drainage, regional climate, and the active geomorphic processes. The mapping was conducted using a five-class stability rating system (I to V). Further details of the methods, including the stability criteria for the Project, are provided in Appendix 9-B.

*Landslides*

A landslide inventory was undertaken in 2014 and 2016 as part of the Geophysical Baseline Studies by SNC-Lavalin (SNC 2017) to document the location, extent, type, terrain characteristics, and size of landslide processes (Appendix 9-B). This inventory occurred within the LSA, reported in Appendix 9-B as the Geohazard RSA (see Section 9.3.4.1). Landslide polygons were digitally delineated viewing three-dimensional aerial photographs and LiDAR data where it was available. Landslides were mapped at a scale of 1:20,000 within the majority of the LSA.

In 2017, terrain stability mapping was conducted by EcoLogic Consultants Ltd. at a 1:5,000 scale for the PFSA, of which the methods and results are presented in Appendix 9-A.

Two main categories of landslide types were used: 1) rapid mass movements (RMM); and 2) slow mass movements (SMM) and deformations. RMM refers to downslope movement by falling, rolling, or sliding of debris derived from surficial material and/or bedrock. When scale allowed, landslide unit areas were further subdivided into the initiation zone or main scarp, and the displaced mass run-out area or accumulation zone. Map units are rated for stability based on the most sensitive identified terrain component (i.e., there are no complexes of stability ratings as there are for terrain components).

*Snow Avalanches*

A snow avalanche inventory was conducted, delineating visible avalanche tracks, and categorizing them into four main classes using standardized Howes and Kenk (1997) geomorphic process symbols: i) active major avalanche tracks (Af); ii) zones of active minor avalanche tracks (Am); iii) zones of active mixed major and minor avalanche tracks (Aw); and iv) old avalanche tracks (Ao). Mapping was conducted using aerial photographs and LiDAR within the same spatial areas and scales as the landslide inventory (i.e., 1:5,000 scale for the majority of the PFSA and 1:20,000 scale for the majority of the LSA; Appendix 9-A and Appendix 9-B). The smallest polygon mapped for the avalanche inventory was approximately 2 ha.

*Fluvial Characterization and Channel Morphology*

Historical aerial photographs along with LiDAR imagery were used to inventory channel morphology and assess changes in Bitter Creek (Appendix 9-B). Fluvial mapping was completed, digitizing channel features for the years 1972, 1994, and 2013, within the Bitter Creek floodplain between the Highway 37A Bridge and the Bromley Glacier, referred to in Appendix 9-A as the Bitter Creek Study Area. A summary of the feature classifications and activity states are summarized in table format in Appendix 9-B. Fluvial change was assessed from 1994 to 2013, 1972 to 2013, and 1972 to 1994.

Each mapped fluvial unit is assigned a relative numeric value linked to its activity state (i.e., active or dormant) and relative elevation above or below bankfull depth. The numeric values allow the use of spatial mathematics to compare multiple years and detect meaningful change such as quantifying erosion and deposition over time. The results are then interpreted by the geomorphologist to describe the corresponding fluvial processes (Appendix 9-B).

Bitter Creek was split into seven reaches that share similar characteristics and trends in channel change over time (Appendix 9-B). In several locations, the rate of lateral erosion between years was extrapolated to provide estimated timelines for Bitter Creek to reach the Access Road.

*Water Crossings Risk-Based Assessment*

A multi-step water crossing risk-based methodology was applied to the proposed Access Road (as of November 1, 2016) as a screening tool to identify critical crossings for road construction and to evaluate sites for future site-specific assessments and monitoring. The risk-based assessment involved the identification of potential hazards (e.g., hydrogeomorphic processes) and the estimation of the likelihood that a hazard event will occur, effect the road, and cause some type of damage. Four priority levels (i.e., low, moderate, high, and very high) were classified based on relative risk and potential implications for risk management identified (Appendix 9-B).

#### 9.4.3.2.3 Soil Mapping and Laboratory Soil Analyses

*Soil Mapping*

The SMU is the basic map unit used to describe the soil types within a polygon. The identification and description of SMU types includes a description of general characteristics and soil conditions for each general soil type. Common characteristics, such as soil texture, parent material, drainage, general soil nutrient and moisture regime, depth to water table or seepage, soil colour, and percent coarse fragment volume (%), are used to derive the SMU. Soil classification abbreviations common to each SMU are described in the Canadian System of Soil Classification (SCWG 1998). Project-specific soil maps were developed using ArcMap 10 by combining and/or incorporating information from the bioterrain mapping and field survey data (from soil and terrain site inspections and TEM; Appendix 9-A).

SMU mapping was conducted at 1:5,000 scale for the PFSA. A SMU legend was applied to SMU maps and described the general attributes of the SMUs as assessed for each polygon shown on the soil map. The GIS database included a polygon number, the surficial material type, soil drainage (as interpreted by SMR), soil salvage potential (SSP; see next section), soil erosion potential (SEP), as well as subgroup information where considered relevant to further interpretation. Soil phase information (e.g., shallow soils to rock) is accounted for by a unique unit. SMUs were sorted into Soil Groups reflecting their general soil management issues such as reclamation potential, salvage depth, and suitability.

*Soil Erosion Potential*

Soil erosion potential (SEP) refers to the potential for the initiation, transportation, and deposition of mineral soil material to occur (Appendix 9-A). Conditions that influence surface runoff, such as slope steepness, slope morphology, and material type and texture, form the criteria used to assess soil erosion potential.

A five-class SEP rating was developed for the LSA at 1:20,000 scale based on surficial sediment texture, slope, and local climate (Appendix 9-A): Very Low, Low, Moderate, High, and Very High. These ratings were used to establish the likelihood of soil erosion occurring after disturbance. Local information on climate, slope, topography, and sediment texture is gathered and a SEP rating is derived. Polygons containing sediments consisting of highly erodible and transportable silt and/or fine sand have a higher SEP rating than sediments consisting predominately of coarser, less mobile fragments or rock.

In the PFSA, surface erosion potential was assessed for each SMU at 1:5,000 scale (Appendix 9-A). Each bioterrain polygon was assessed and attributed for SEP. The method for assigning SEP followed the provincial standard used in the forest industry (BC Ministry of Forests 1999). SEP classes range from VL (very low) to VH (very high), and refer to in situ, unvegetated surficial materials that are exposed as a result of development activities. The ratings do not apply to undisturbed, vegetated terrain, and they do not apply to future development-related deposits such as stockpiles, tailings, and waste rock. Combination categories were employed in complex or variable SMU polygons.

*Soil Lab Analysis*

Twenty-one mineral soil samples were collected from separate locations, representing various soil parent materials from across the various soil climates in the LSA with focus of sampling in the PFSA (Appendix 9-A). Organic wetland soils were not included in this sampling/testing program owing to their sparsity in the PFSA.

Samples were kept cool and sent to the Caro Labs as soon as practical for subsequent drying, sieving, and subsampling prior to lab work by standard BC methodology for soil analysis. Generally, the 0 to 15 centimetre (cm) surface layer of mineral soil was sampled.

Soil lab analytical results were used to characterize soil development and rate suitability for reclamation. Appendix H, Soil Analytical Lab Results in Appendix 9-A, provides the 2016 Caro Labs analytical methods and results, respectively.

The interpretation of baseline data included comparing analytical results to the industrial guidelines provided for 19 metals by the Canadian Council of Ministers of the Environment (CCME 2007; Table 9.4-7). Additional parameters, including pH, carbon, texture, calcium carbonate ($CaCO_3$) equivalence, and cation exchange capacity were analyzed to provide information on potentially significant characteristics relative to reclamation suitability and soil management (Appendix 9-A).

#### 9.4.3.2.4 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) was carried out throughout each phase of the Project data collection, mapping, and analyses. Initial polygon delineation for TEM mapping was checked for slivers and other errors by senior GIS staff. Once polygons were attributed, image interpretation and data entry were assessed by a senior external ecologist. Field data forms were assessed for entry and interpretive errors. In addition, lab analytical QA/QC was conducted by Caro Labs. More detail on the QA/QC process is provided in Appendix 9-B.

## 9.4.4 Baseline Characterization

### 9.4.4.1 Terrain Mapping and Geohazards

#### 9.4.4.1.1 Surficial Geology and Terrain Distribution

The Project's terrain mapping within the LSA and PFSA is presented in Volume 8, Appendices 9A and 9B. Volume 8, Appendix 9-C (Terrain Stability Assessment for the Project Footprint Study Area) shows the detailed results of the terrain stability assessment carried out within the PFSA in 2016. A summary of surficial materials mapped in the LSA and PFSA is presented in Table 9.4-1 and their distribution by dominant surficial material is displayed in Figure 9.4-1. Results are based on two different scales of mapping for the LSA and PFSA. The larger scale (1:5,000) in the PFSA resulted in some surficial materials being identified that were not identified in the LSA at 1:20,000 scale.

The majority of the LSA is moraine (34%) and colluvium (21%) with a relatively large proportion of ice and bedrock (each comprising 15% of the LSA). Approximately 11% of the LSA is missing imagery and therefore was not mapped; however, all of the unmapped area is far removed from proposed Project infrastructure and predominately high elevation landforms and glaciers. The majority of the surficial material in the PFSA is comprised of colluvium (37%), moraine (23%), and fluvial (17%). Glaciofluvial materials occur in isolated terraces and at the confluence of creeks feeding into the north side of Bitter Creek, such as Roosevelt and Radio Creeks.

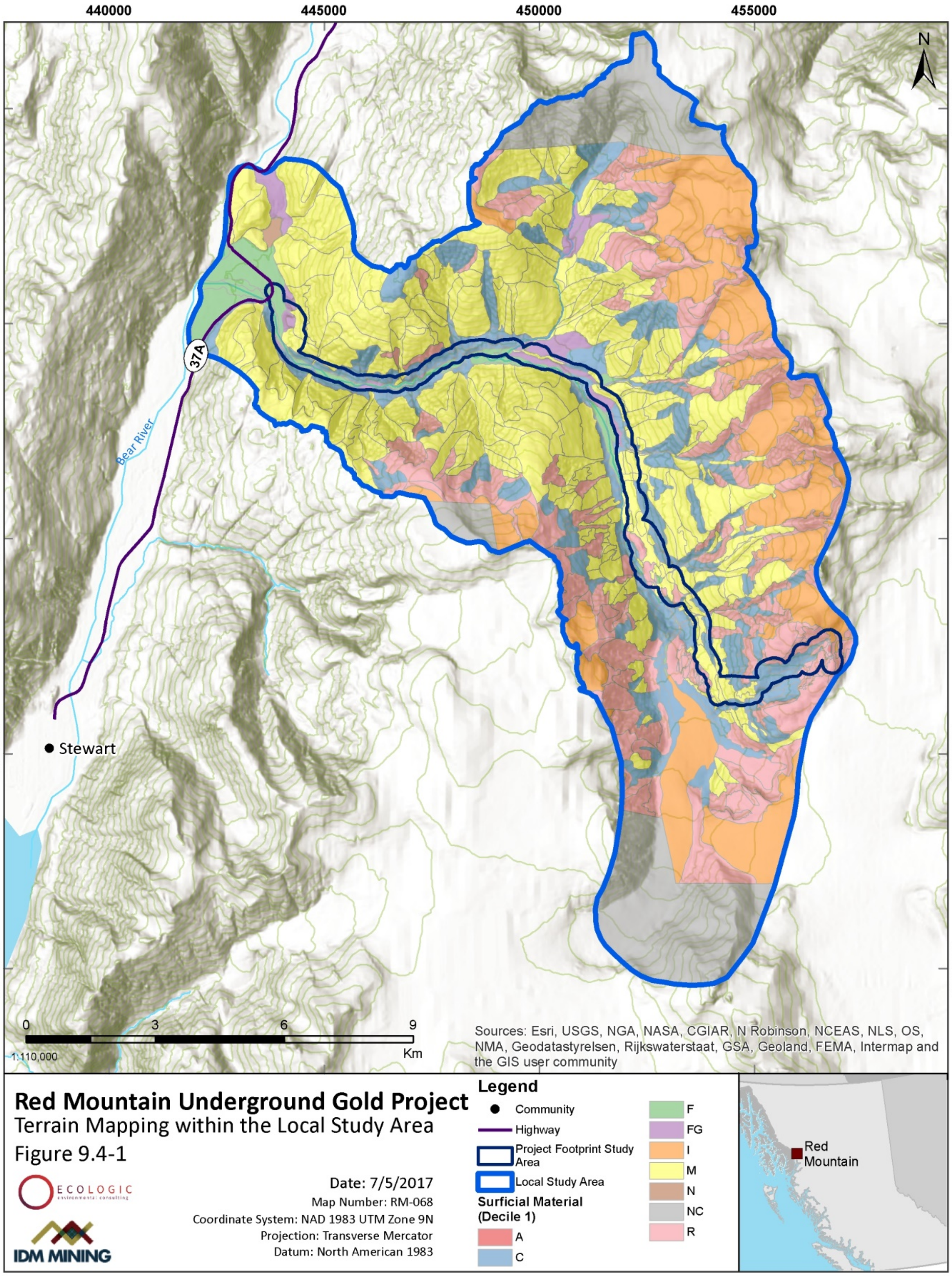
At some point during deglaciation, a glacial lake formed in the Bitter Creek valley bottom depositing glaciolacustrine sediments. This may have occurred when valley bottom ice temporary blocked flow from the Bitter Creek valley. Glaciolacustrine sediments are mapped beneath younger colluvial sediments in some areas of the Bitter Creek valley bottom. Because these sediments were not mapped at the ground surface, they do not appear in Table 9.4-1. However, it is important to highlight the presence of glaciolacustrine sediments, as they make unstable foundations, fail at low angles, and are highly erodible.

### Table 9.4-1: Summary of Surficial Materials Mapped in the LSA and PFSA

| Surficial Material | Map Code | LSA | | PFSA | |
|---|---|---|---|---|---|
| | | Area (ha) | Proportion (%) | Area (ha) | Proportion (%) |
| Anthropogenic | A | 1.5 | 0.0 | 24.1 | 2.5 |
| Bedrock | R | 2,346.1 | 14.8 | 96.5 | 10.0 |
| Glaciocolluvial | CG | 0.0 | 0.0 | 48.0 | 5.0 |
| Colluvium | C | 3,255.2 | 20.5 | 358.7 | 37.3 |
| Fluvial | F | 488.8 | 3.1 | 161.4 | 16.8 |
| Glaciofluvial | FG | 251.1 | 1.6 | 41.2 | 4.3 |
| Ice | I | 2,360.2 | 14.9 | 6.9 | 0.7 |
| Moraine | M | 5,342.5 | 33.7 | 221.1 | 23.0 |
| Not Classified | NC | 1,793.5 | 11.3 | 0.0 | 0.0 |
| Organic | O | 0.0 | 0.0 | 0.5 | 0.1 |
| Undifferentiated materials | U | 1.5 | 0.0 | 0.0 | 0.0 |
| Water Features (small) | OW,PO,N | 19.5 | 0.1 | 2.3 | 0.2 |
| **Total** | | **15,859.9** | **100.0** | **960.7** | **100.0** |

Note:
Values may not sum to total shown because of rounding.
Areal extents reported are based on 1:20 000 scale for the entire LSA and 1:5 000 scale for the entire PFSA.

**Figure 9.4-1: Terrain Mapping within the Landforms and Natural Landscapes Local Study Area**



#### 9.4.4.1.2 Terrain Stability and Geohazards

*Terrain Stability*

The recently glaciated nature of the area has resulted in oversteepened materials along the sidewalls of the recently deglaciated valley, which is actively eroding in many areas as it finds an angle of repose. All five stability classes were mapped within the LSA and PFSA and the mapped distribution is presented in and near Red Mountain (Appendices 9-A and 9-B). The activity state of these features is not currently known.

Within the PFSA, 123 (22%) of the polygons contain the initiation zones of one or more RMM. These geohazards are spread throughout the PFSA and tend to occur on slopes steeper than 60%. Polygons containing the initiation zones of SMM processes occur in 39 (7%) of the PFSA polygons. A bedrock slump is mapped near the mouth of Rio Blanco Creek. Most of the polygons mapped with slow mass movement are located in the alpine area of Red Mountain and areas associated with permafrost processes, such as solifluction and larger lobate features created by creeping ground ice.

Figure 9.4-2 and Figure 9.4-3 present terrain stability mapping at 1:20,000 for the LSA and at 1:5,000 for the PFSA (Appendices 9-A and 9-B). Most the proposed Project infrastructure occurs in classes I and II. Details regarding terrain stability within the PFSA are also presented in Appendix 9-C, which presents the results of the Onsite Engineering detailed terrain stability and mitigation assessment conducted in 2016.

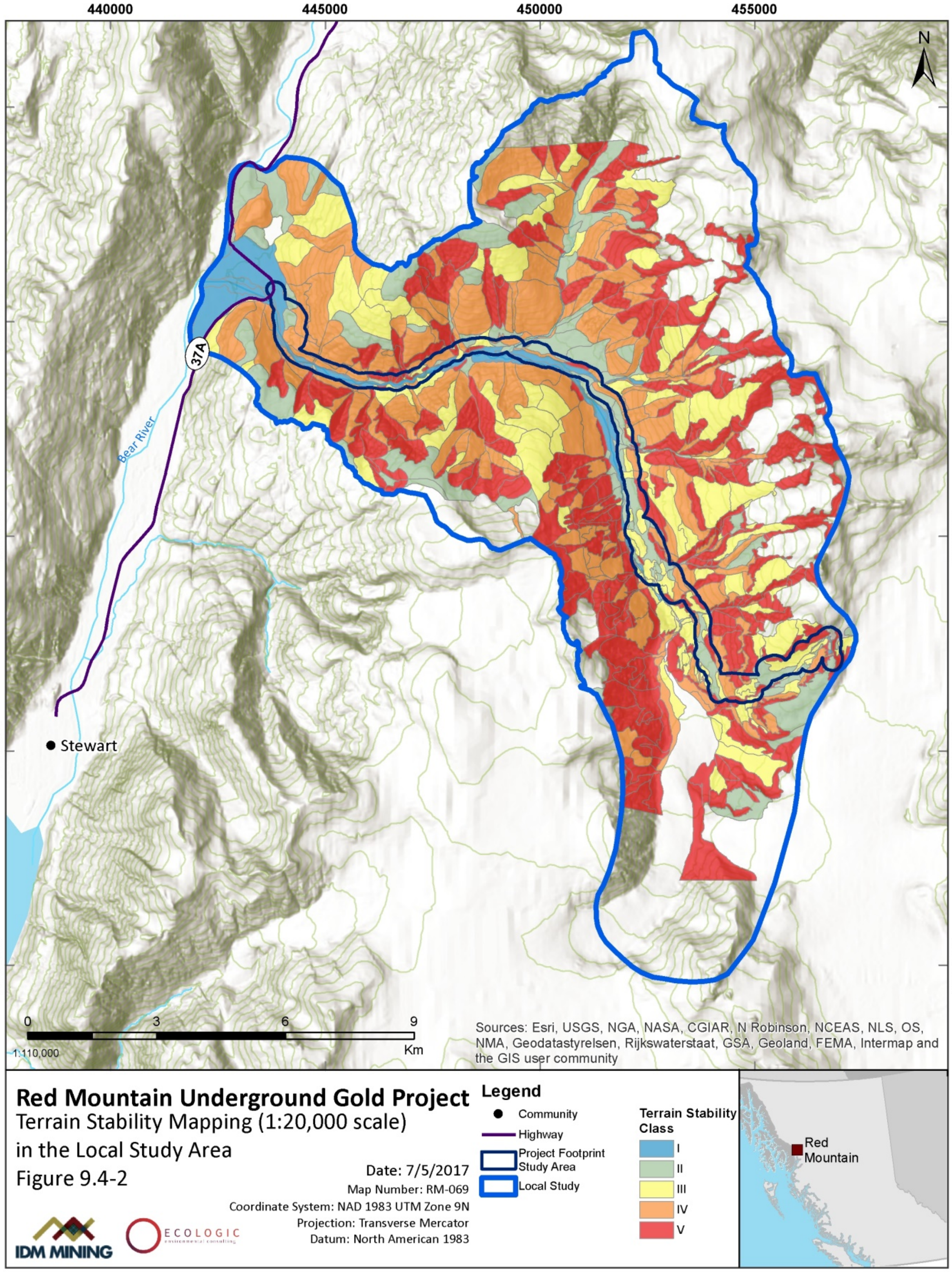
Table 9.4-2 shows the spatial extent by terrain stability class in the LSA and PFSA. Within the PFSA, the majority is negligible (class I) terrain stability (slopes less than 60%); however, approximately 21% was mapped as class V (unstable).

### Table 9.4-2: Terrain Stability Class Mapped in the LSA and PFSA

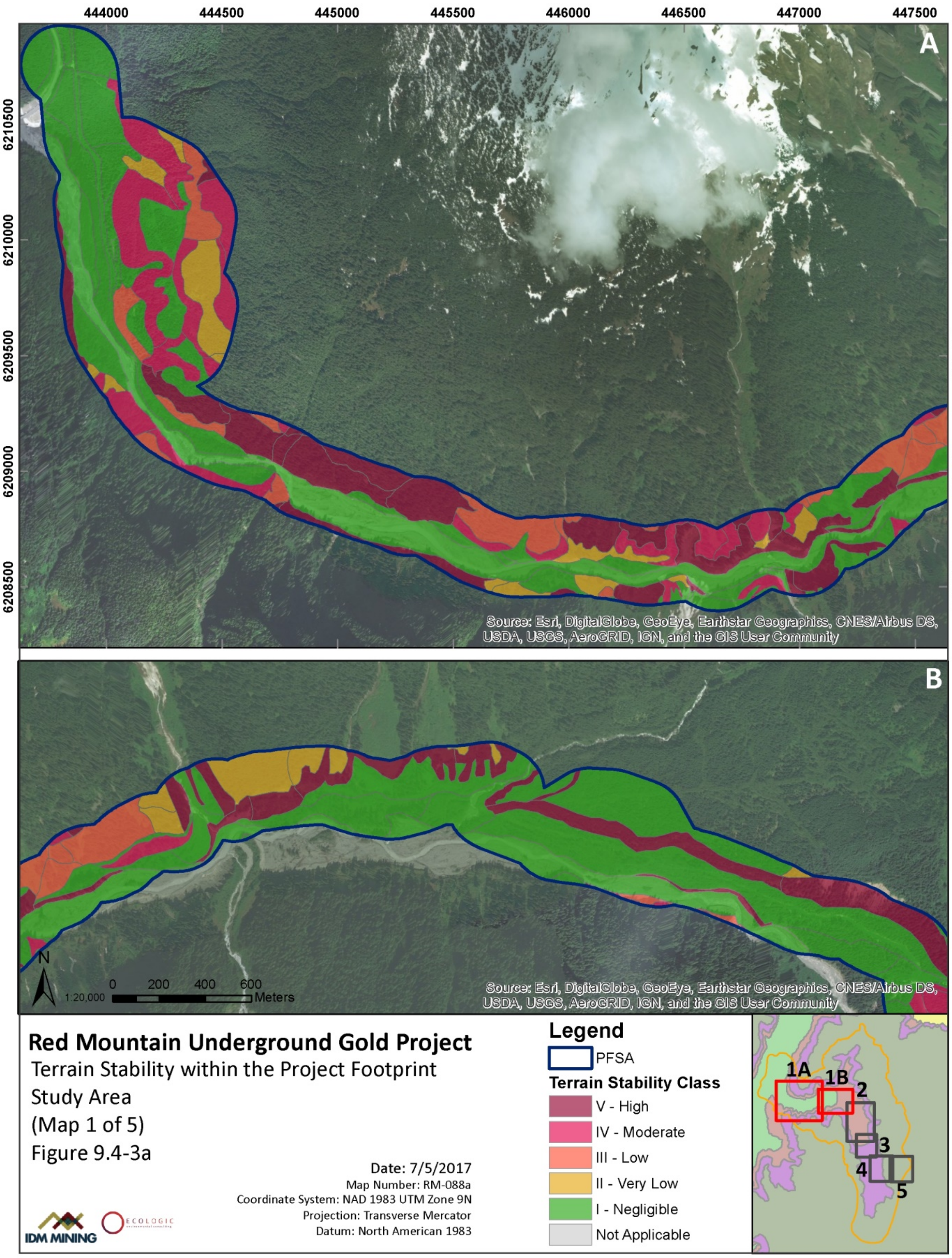
| Terrain Stability Class | Map Code | LSA | | PFSA | |
|---|---|---|---|---|---|
| | | Area (ha) | Proportion (%) | Area (ha) | Proportion (%) |
| Negligible | I | 516.9 | 3.3 | 272.4 | 28.3 |
| Very Low | II | 1,521.4 | 9.6 | 193.3 | 20.1 |
| Low | III | 2,197.9 | 13.9 | 159.2 | 16.6 |
| Moderate | IV | 3,345.5 | 21.1 | 124.3 | 12.9 |
| High | V | 4,104.6 | 25.9 | 203.8 | 21.2 |
| N/A | - | 4,173.6 | 26.3 | 7.9 | 0.8 |
| **Total** | | **15,859.9** | **100.0** | **960.7** | **100.0** |

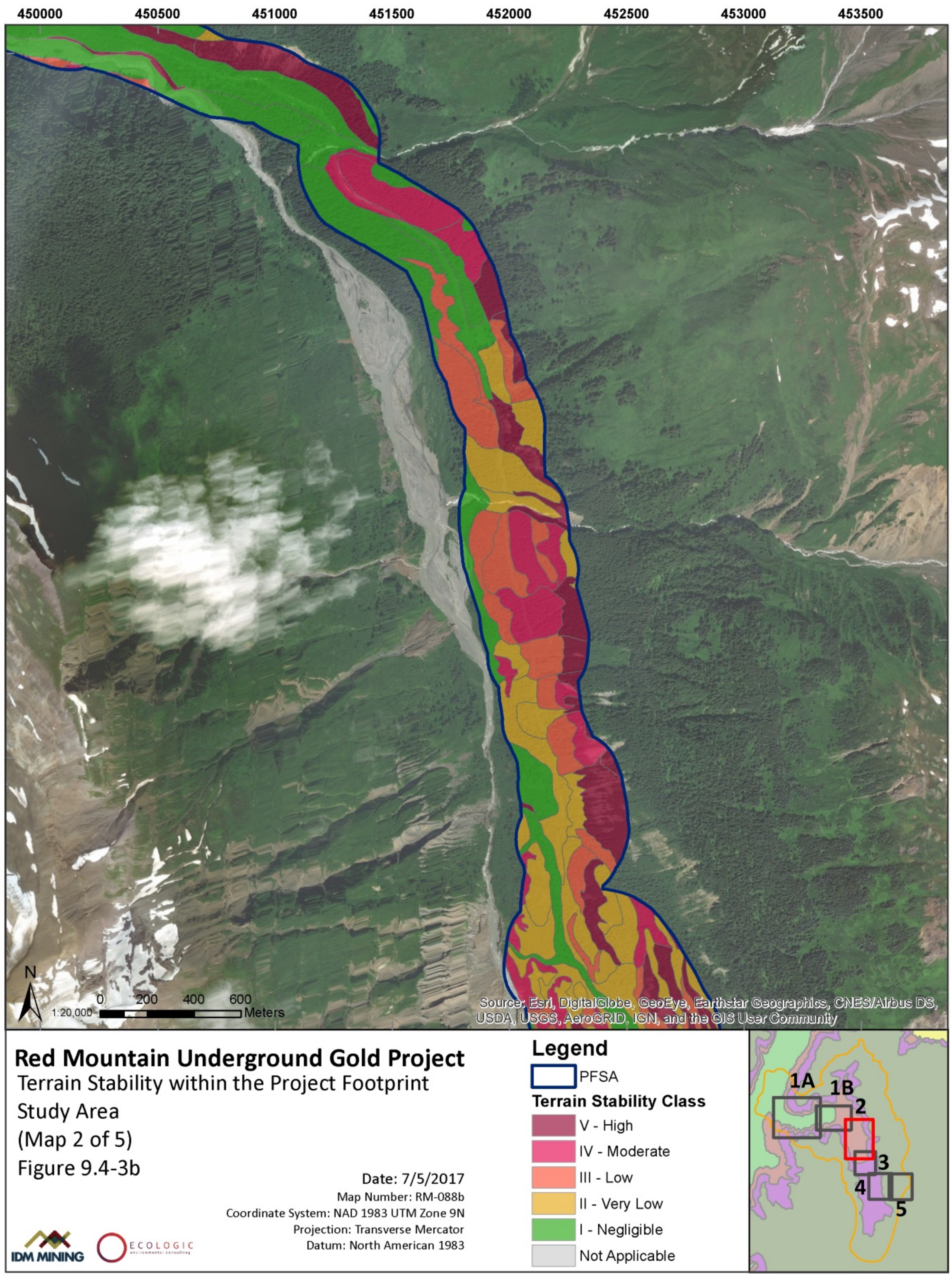
Note:
Values may not sum to total shown because of rounding.
Areal extents reported are based on 1:20,000 scale for the entire LSA and 1:5,000 scale for the entire PFSA.

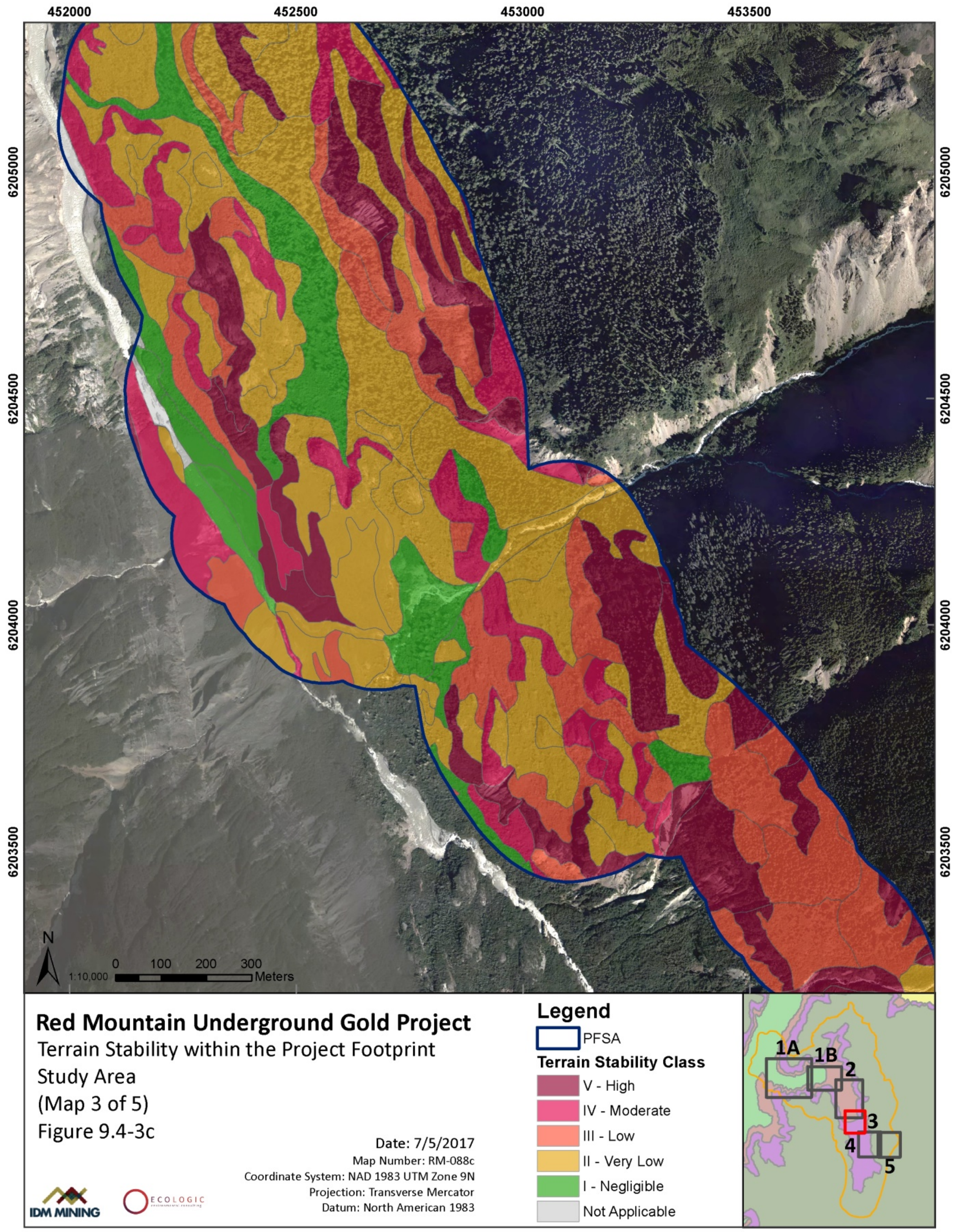
**Figure 9.4-2: Terrain Stability Mapping (1:20,000) in the Landforms and Natural Landscapes Local Study Area**



## Figure 9.4-3: Terrain Stability Mapping (1:5,000) in the Project Footprint Study Area




450000
450500
451000
451500
452000
452500
453000
453500
6209000
6208500
6208000
6207500
6207000
6206500
6206000
6205500
6205000
N
1:20,000
0 200 400 600
Meters
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Red Mountain Underground Gold Project
Terrain Stability within the Project Footprint Study Area
(Map 2 of 5)
Figure 9.4-3b
Date: 7/5/2017
Map Number: RM-088b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
3
4
5


452000
452500
453000
453500
6205000
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6204000
6203500
N
1:10,000
0 100 200 300
Meters
Red Mountain Underground Gold Project
Terrain Stability within the Project Footprint Study Area
(Map 3 of 5)
Figure 9.4-3c
Date: 7/5/2017
Map Number: RM-088c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
3
4
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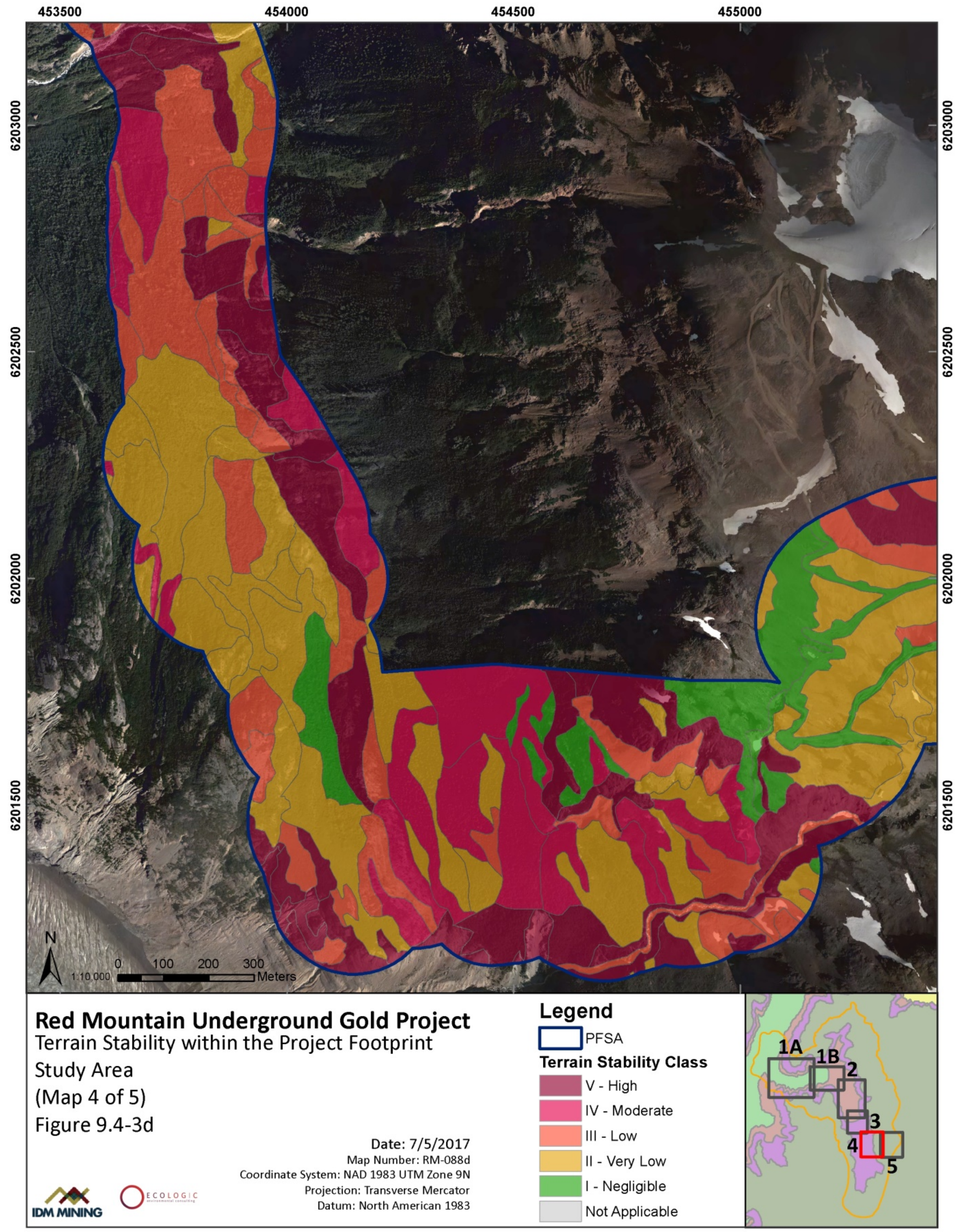
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Red Mountain Underground Gold Project
Terrain Stability within the Project Footprint
Study Area
(Map 4 of 5)
Figure 9.4-3d
Date: 7/5/2017
Map Number: RM-088d
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
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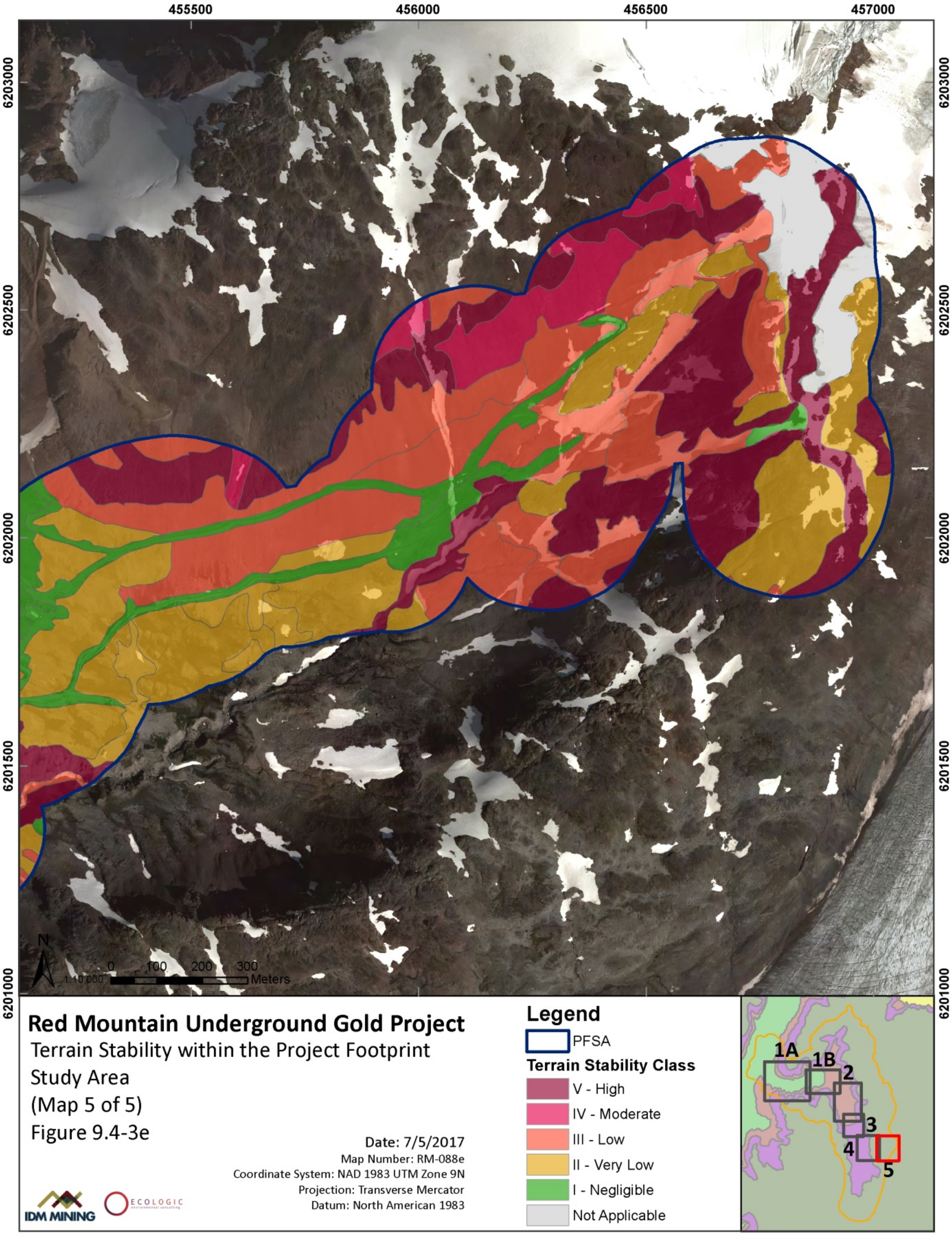



**Red Mountain Underground Gold Project**
Terrain Stability within the Project Footprint Study Area
(Map 5 of 5)
Figure 9.4-3e

Date: 7/5/2017
Map Number: RM-088e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

*Landslides*

Quaternary deposits and bedrock in the LSA have been altered and modified by a diverse range of landslides (Appendices 9-A and 9-B). A total of 251 landslide polygons were identified within the terrain stability mapping portion of the LSA (Appendix 9-B). The most common landslide types observed (all RMMs) include rockfalls, debris avalanches, debris flows, and debris falls. In general, the majority of RMM are distributed among the steep colluvial, bedrock, and morainal slopes in the alpine and major tributary valleys. Failures are also more densely concentrated within recently deglaciated terrain, such as near the area near the Bromley Glacier and other high alpine glaciers. Movements in this class tend to be unvegetated or partially vegetated, and show indicators of recent activity.

The type and incidence of RMMs present in the PFSA are presented in Table 9.4-3. Within the PFSA, 123 (22%) of the polygons contain the initiation zones of one or more RMM. These geohazards are spread throughout the PFSA and tend to occur on slopes steeper than 60%. These polygons comprise the TSC V terrain presented in Figure 9.4-3. Polygons containing the initiation zones of SMM processes occur in 39 (7%) of the PFSA polygons. A bedrock slump is mapped near the mouth of Rio Blanco Creek. Most of the polygons mapped with slow mass movement are in the alpine area of Red Mountain and areas associated with permafrost processes, such as solifluction and larger lobate features created by creeping ground ice.

*Snow Avalanches*

Mapped avalanches (92) encompass an area of approximately 2,615 ha within the LSA (Appendix 9-B):

- 29 Major Avalanches (Af), covering approximately 509 ha;
- 45 Mixed Major and Minor Avalanches (Aw), covering approximately 1,719 ha; and
- 18 Minor Avalanches (Am), covering approximately 388 ha.

Snow avalanche processes are common along the steep hillslopes of the Bitter Creek valley, valley sides, and channels of the major tributary creeks. Avalanche tracks are observed to run to valley bottoms and intersect the proposed Access Road in numerous locations between Unnamed Creek 4 and the portal at Red Mountain. No avalanche tracks were observed between Unnamed Creek 4 and the western edge of the LSA.

Within the PFSA, snow avalanche is a common geomorphological process throughout the steep slopes of the PFSA existing in 106 (19.1%) of the polygons (Appendix 9-B). Polygons with snow avalanche are often located in polygons with rapid mass movement processes (Table 9.4-3).

Bitter Creek presents a number of hazards to the proposed Access Road primarily due to lateral erosion and flood events (Appendix 9-B). Channel change detection has identified several locations where Bitter Creek is migrating towards the Access Road and actively eroding into the right bank.

*Fluvial Characterization and Channel Morphology*

Perhaps the most hazardous section of the Access Road lies between Radio Creek and Unnamed Creek 3 (Appendix 9-B). In this location, the pre-existing road (primarily aligned with the proposed Access Road) has been washed out in a few places due to lateral erosion by Bitter Creek. At Radio Creek, the right bank is underlain by glaciolacustrine silts and clays which are actively failing as material is removed by the river at the toe of the slope.

**Table 9.4-3: Summary of Geohazards and Snow Avalanches Mapped for the PFSA**

| Mass Movement Type | Geohazard Type | Map Code | No. Polygons | Percent of Polygons |
|---|---|---|---|---|
| Rapid Mass Movement | Rockfall | -R”b | 123 | 22.2 |
| | Debris flow | -R”d | | |
| | Debris slide | -R”s | | |
| | Debris flood | -R”t | | |
| Slow Mass Movement | Bedrock Slump | -F”m | 39 | 7.0 |
| | Solifluction | -S | | |
| | Rock/ground ice creep | -F”g | | |
| Snow Avalanche | Snow Avalanche | -A | 106 | 19.1 |

*Water Crossings Risk-Based Assessment*

Assessment of the 15 Access Road crossings resulted in 4 crossings being classified as low priority, 6 crossings classified as moderate priority, 1 crossing classified as high priority, and 4 crossings as very high priority (Appendix 9-B).

### 9.4.4.2 Soil Mapping and Analytical Results

#### 9.4.4.2.1 Soil Map Units

Soil formation in the LSA is limited by the cold climate (limiting soil-forming processes) and natural disturbance (such as steep terrain with regular downslope movement through soil creep, surface erosion, and mass movement). Soils that develop in colluvial and morainal surficial materials dominate the LSA; soils derived from fluvial, glaciofluvial, glaciocolluvial (combination of glacial till and downward postglacial material movement) are common. Poorly drained organic materials, shallow weathered bedrock materials (saprolite), and shallow open water (ponds) have limited distribution.

The dominant mineral soils described in the LSA are weakly to moderately developed and include moderately developed brown coloured Brunisols and weakly developed Regosols. Less common mineral soils include Humo-Ferric Podzols (CSSC 1998) occurring in higher elevation areas with coarse gravelly sandy textures; poorly drained Gleysols in lower/toe slope positions and riparian areas; and rarely-occurring Organics in valley bottoms and depression slope positions. The latter are primarily moderately decomposed Mesisols of varying thickness.

A total of 22 SMUs were established within the PFSA and are presented in Table 9.4-4 and Figure 9.4-4. Details are presented in Appendix 9-A.

### Table 9.4-4: Summary of Soil Map Units Mapped in the PFSA

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 1a | 85.3 | 8.9 | Mesic Site, Average Mid-Slope Soils | • Well- to rapidly drained, coarse-textured deep soils often of sandy, silty (dominantly loamy sand) and gravelly texture and derived from glacial till and colluvium materials.<br>• Commonly found on mesic or average sites with average to below-average nutrients and fresh or moist soil moisture.<br>• Typically occur on mainly glacial till blankets (>1 m depth) with slope gradients ranging from gentle to steep (e.g., 15-50% slope gradient) and occur in all slope positions.<br>• Coarse fragment content ranges from 20-50%. Typical soil classification (CSSC 1998) for this type includes O.HFP, EL.DYB, O.DYB, and O.EB. |
| 1b | 24.3 | 2.5 | Mid-Lower Slope positions | • Soil textures range from loamy (L-SL) - SiL tills on 5-40% slope gradient.<br>• Soils of this type mainly on lower-toe slope position, and as such, have slightly higher organic matter content (i.e., are medium-brown in colour). Ah horizons <0-5cm in depth and can include somewhat richer intermixed soil materials owing to slope movement. Soils are moist but not saturated for long duration, thus gleying and intense mottling are uncommon. Typical soil classification is variable for this SMU include: O.HFP, O.DYB, GL.DYB, O.EB, and GL.EB |
| 1c | 11.1 | 1.2 | Fine Silt Loam Veneer at Surface of Till | • Mesic, well drained Podzols and Brunisols with a veneer of silt loam at surface of glacial till.<br>• Surface mineral material prone to surface water erosion.<br>• Difficult to discern from imagery and needs on-site ground assessment. Slightly more productive forests. More common gullying evident. |

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 4 | 33.4 | 3.5 | Fine-Textured Soils | • Finer mineral textures and often overlying compact clay-enriched in mineral soils (e.g., SiCL, L, CL) occur in conjunction with gentle sloping glacial till or lacustrine-type environments forming in lower/toe to undulating slope positions.<br>• Weak mottling and subsurface compacted soil layers (weak compacted clay pans) are common.<br>• Soil gullying and failures are relatively common, particularly on slope gradients from 40 to $\geq$70+%. Soils can include solifluction" (-S) process in deeper deposits in colder alpine or subalpine environments.<br>• Common soil subgroups include O.EB, O.DYB, O.MB, BR.GL (weak), GLBR.GL, and GLD.GL. Soils are generally >1 m in depth.<br>• These soil types are potentially valuable soil materials for construction of containment facilities or settling ponds. |
| 4a | 44.0 | 4.6 | Fine Texture Soils, Evidence of Erosion or Movement | • Moist, fine-textured glacial till (Mb) and glaciolacustrine materials (LG) (often L to SiCL texture).<br>• Moderately well to imperfectly drained soil materials with common seepage but no prominent mottling.<br>• Commonly occur on lower- to toe-slope positions and often near the vicinity (i.e., side slopes) of creek draws.<br>• Soil Subgroups include GL.MB, O.MB, and O.SB. Variable coarse fragment content. Potentially unstable soil materials as evidenced by tree buttressing or surface tension fractures, and requiring careful management during construction phases.<br>• Very good soil types to salvage for construction or reclamation activities requiring finer soil textures and moisture retention but caution required owing to high compaction potential, especially during wet periods. |

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 4b | 13.0 | 1.4 | Dark, Finer Texture Soils | • Generally, includes dark colours, till, colluvium or glaciolacustrine soils that look "rich" in nutrients often containing silt loam textures in the upper 30 cm.<br>• Occurs most often on moist to wet seepage sites in lower/toe to near-level slope positions. Also found alongside creek draws or beside avalanche tracks.<br>• Rooting depth is often >60 cm, most often contain organic-enriched brown to black surface horizons (Ah and Bm horizons) of SiL to SiCL texture and are often underlain by coarser sandy gravelly till or colluvium surficial materials.<br>• Soil drainage ranges from well- to imperfectly-drained and with common seepage.<br>• Common in the vicinity of unstable "moving" soil material as evidenced by butressed trees and soil pedoturbation (i.e., mixed up soil layers).<br>• Soil subgroups include O.MB and GL.EB (with darker brown colours). |
| 5 | 25.5 | 2.7 | Glaciofluvial sands and gravel-gentle to level | • Occurs on flat- to gently undulating Glaciofluvial sand and gravel terraces.<br>• Relatively loose soils with high coarse fragment content, commonly >50% clast volume; shallow main rooting zone, often <25 cm from surface.<br>• Main soil types include bright coloured Humo-Ferric Podzols and Dystric Brunisols (O.HFP, E.DYB, and O.DYB).<br>• Can be moisture- and nutrient-deficient for part of the growing season. |

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 5a | 29.5 | 3.1 | Glaciofluvial-Steep | • Glaciofluvial materials on steeper 30 to 60% slope gradients.<br>• May include hummocky eskers type terrain with well to rapid drainage and sandy/gravely soils.<br>• Depth soil usually 30 to 60 cm.<br>• Soils are often have nutrient poor conditions and are prone to brief periods of summer drought, especially in warm aspects.<br>• Rapid debris failures (dry ravelling) common down to a creek feature.<br>• Main soil types include bright coloured Podzols and Brunisols (O.HFP, E.DYB, and O.DYB). |
| 6 | 122.5 | 12.8 | Shallow Soils | • Shallow soil deposits of colluvium, saprolite (rotten rock) or morainal veneers over bedrock.<br>• Often high coarse fragment content (>50%).<br>• May be derived from decaying bedrock or failures or thin glacier deposits over bedrock outcrops and common on steep slopes (often >50-75% slope gradient).<br>• Very common to upper and crest slope positions and moisture shedding. Soil types include acidic Podzols and Brunisols.<br>• Main soil types include O.HFP, E.DYB, O.R, and Non-Soil (NS). Lithic and Shallow Soil Phase common in forested and alpine areas where bedrock is <50 cm. |
| 6a | 12.0 | 1.3 | Rubbly Talus | • Rubbly/bouldery talus materials, often with >65 to 90% coarse fragment volume derived from varied local bedrock types.<br>• Slope gradient 50-100%.<br>• Soil types commonly include O.R, O.DYB, and O.MB . Mostly <30-75 cm to bedrock contact. |

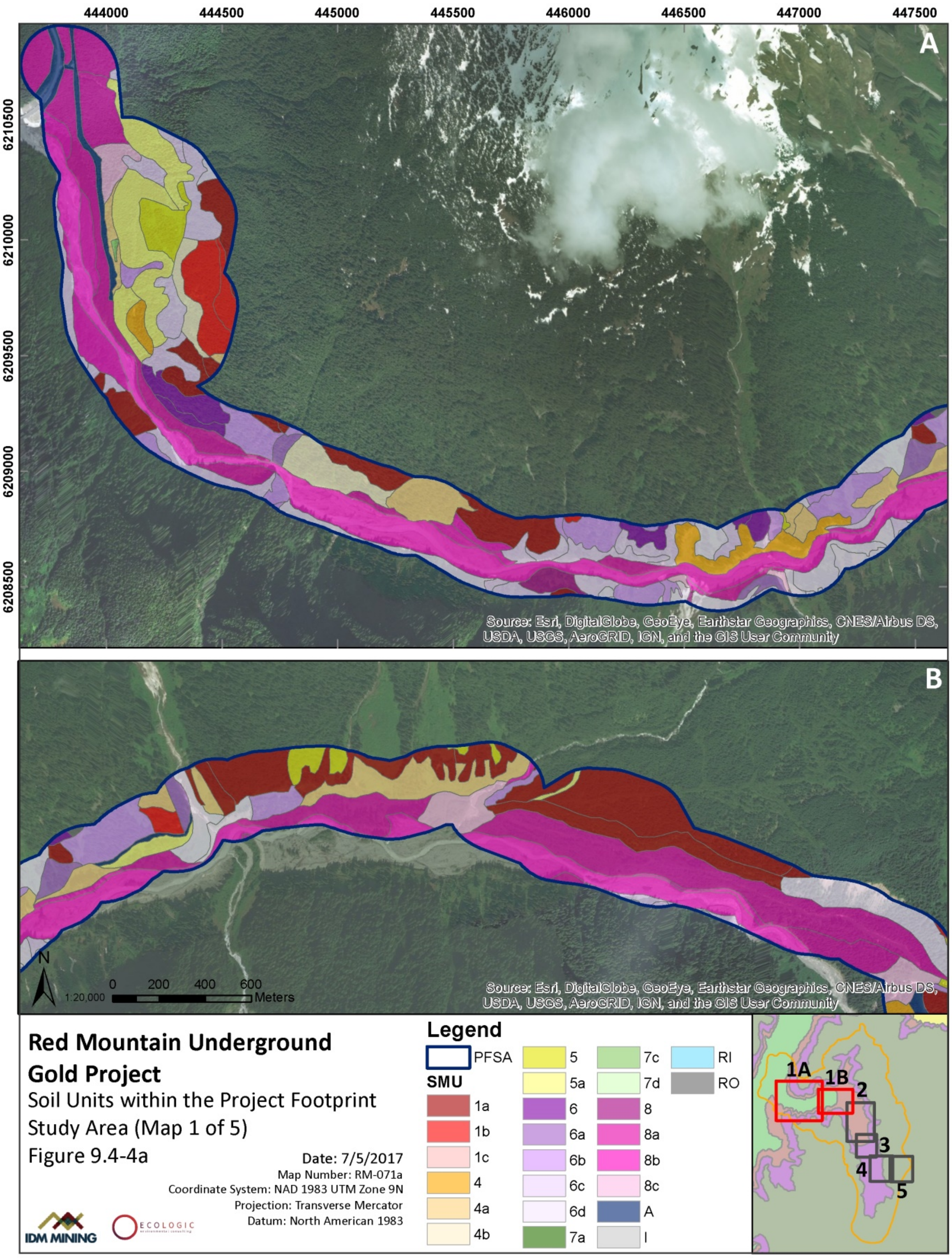
| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 6b | 73.2 | 7.6 | Loose Moderately Deep Colluvium | • Moderately deep colluvium (>45 to 60% gradient), relatively deep (zsCwks) and loose soils with angular coarse fragments.<br>• Surficial material depth to bedrock often 50-100 cm.<br>• Main soil types include O.HFP, EL. DYB, and O.DYB.<br>• Often submesic moisture and nutrient regime (i.e., slightly drier and poorer). Common evidence of soil movement. |
| 6c | 81.0 | 8.4 | Colluvium in Lower/Toe Slope Positions | • Shallow colluvial toe and lower slope position, soils moist to wet for majority of growing season.<br>• Common presence of soil mottles suggesting very brief periods of soil saturation.<br>• Soils often dark colours at surface and commonly have seepage but generally soils are well-aerated conditions. Soil types commonly include GL.MB, GL.EB, and O.EB and often <50 cm to bedrock. |
| 6d | 60.1 | 6.3 | Active and Older Snow Avalanche Scars | • Active snow avalanche terrain (and older unstable terrain subject to previous disturbance.<br>• Areas subject to failures, flash channel/draw flooding, gullying, and continuous seepage.<br>• Areas at toe of slope subject to wind-shear, blow-down events, and pedoturbation.<br>• Common soil types include GL.MB, GL.EB, O.RG, and O.HG. |
| 7a | 20.8 | 2.2 | Alpine Soils | • Alpine/subalpine moist meadows and brown to black soils common.<br>• Mostly till (Mv/R) and saprolite veneers (Dv/R) over rock with seepage common in receiving positions or in close proximity to springs.<br>• Soils classification includes O.HFP, O.EB, O.DYB; O.MB, and O.SB (Lithic Phases common). |

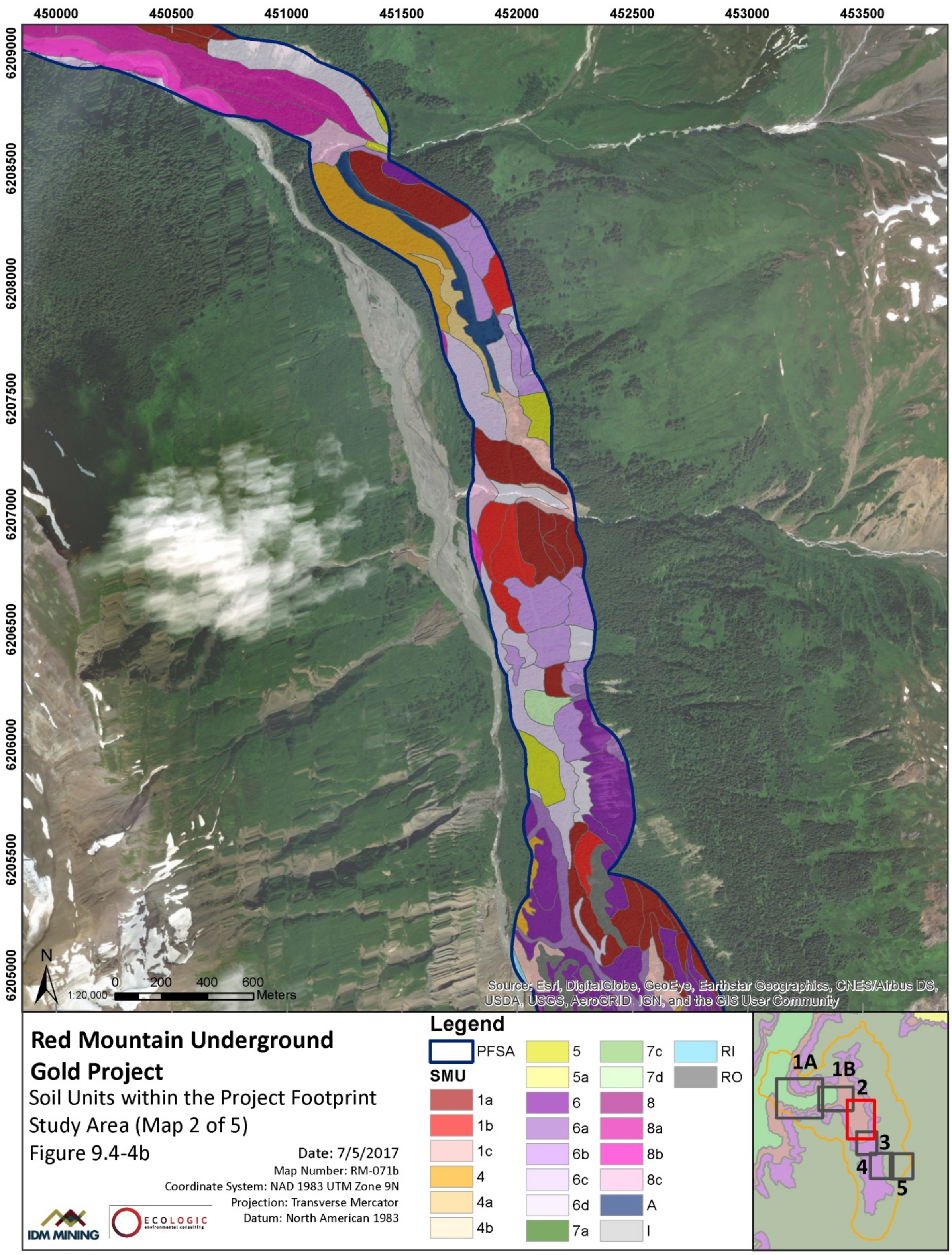
| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 7b | 4.6 | 0.5 | Wetlands (Fens, Swamps, Marshes) | • Shrubby fens swamp or marshes in alpine/ subalpine and forested areas.<br>• This SMU is uncommon and limited in extent, usually <0.5 ha.<br>• Generally, these soil materials form as thin veneers (<1 m) of organic material (Ov), mostly derived from saturated conditions and sedge vegetation in depression slope positions.<br>• Spring flooding common.<br>• Soils often less than 30 cm depth to bedrock or compact till/lacustrine. Soils typically include TE.M and TE.FI.<br>• Water table and seepage is usually <25 cm from the surface. |
| 7c | 0.2 | 0.0 | Carex-Dominated Wetlands and Organic Soils | • Sedge-dominated wetlands in depression or toe slope position in subalpine, alpine and forested locations. These sites and soils are very rare and limited in extent.<br>• Soil types expected include moderately decomposed Mesisols (T.M and TY.M).<br>• Water table and seepage is usually <10 cm from the surface. |
| 7d | 77.4 | 8.1 | Alpine Tundra, Shallow Soils | • Alpine/subalpine drier exposed alpine tundra with heathers, sparse grasses lichens; shallow to broken rock or saprolite.<br>• Most commonly brown Brunisolic soils with some minor Ah horizons (3-10 cm depth).<br>• Deeper Ah horizons can occur on long open slopes >30-45% gradient common where “flowing lobes of soils” or “Solifluction” geomorphic process occurs in frozen/thaw environments on moderate to strong slopes (i.e., near to glacier interface).<br>• Texture of mineral material often gravelly, fine, sandy loam. Relatively rare or unique soil type in vicinity of the PFSA. |

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 8 | 7.4 | 0.8 | River, Fluvial Soils | • Soils forming in moist to wet creek draws and channels and subject to annual or semi-annual flooding.<br>• These are newly deposited surficial materials often with minimal soil development (Regosols) and are laid down in highly erosive environments often with a finer sand or silt capping over coarser gravelly, cobbly materials.<br>• Creek channels usually <10 m width occur in steep mountainous areas. |
| 8a | 71.6 | 7.4 | High Bench Fluvial | • Inactive and older mid- to high-bench fluvial terraces.<br>• Relatively older fluvial terraces, often well drained.<br>• Not necessarily rich, but can be rich.<br>• Soil types include O.EB, O.MB, GL.R, and O.R (in very coarse dry sands).<br>• Can be very sensitive soils/sites to compaction and water erosion depending on soil texture. |
| 8b | 71.2 | 7.4 | Active Fluvial | • Active fluvial deposits and floodplains.<br>• Annual flooding is common (e.g., Bitter Creek) and includes some low-bench fluvial and active river deposits with prolonged periods of water inundation.<br>• Subsurface seepage is usually present (depth of 20 to 50 cm) for most of year and at the surface in early spring freshet.<br>• Most of these soils have high erosion potential, especially where fine sand and silt layers exist at the surface.<br>• Common soil types O.R, GL.R, CU.R, and GLCU.R. |

| Soil Mapping Unit | Project Footprint Study Area | | Soil Mapping Unit Name | Soil Mapping Unit Description |
|---|---|---|---|---|
| | Area (ha) | Proportion (%) | | |
| 8c | 9.9 | 1.0 | Fluvial Fans | • Fluvial fans forming on and gentle slopes (5 to 30%) and often richer than average and potentially subject annual fluvial sediment input, erosion and gullying.<br>• Subsurface seepage common and rich vegetation includes alder and ferns.<br>• Common soil types include O.EB and GL.MB. Often high coarse fragment content >50%. |
| A | 21.1 | 2.2 | Low Bench Active Fluvial | • Active fluvial deposits and floodplains.<br>• Annual flooding common (e.g., Bitter Crekk) and includes some low bench fluvial and active river deposits with prolonged periods of water inundation.<br>• Subsurface seepage usually 20-50 cm most of year and at the surface in early spring freshet.<br>• Most of these soils have high erosion potential, especially where fine sand and silt layers exist at the surface.<br>• Common soil types O.R, GL.R, CU.R, and GLCU.R |
| RO | 42.4 | 4.4 | Bedrock-dominated materials | • Bedrock outcrops, very common in upper slope positions and high elevation areas.<br>• Can include very thin saprolite or till veneers of <10 cm mineral soil to rock.<br>• Soil types include Non-Soil and RO. |
| I | 16.9 | 1.8 | Ice-dominated Materials | • Ice materials at or near the glacier ice.<br>• Snow often persists late in the growing season in depression slope positions or areas of cold air drainage.<br>• Frozen soils and soil-forming processes can exist under or near the ice margins and undergo cryoturbation soil-forming processes, such as solifluction. |
| Total | 960.3 | 100.0 | | |

## Figure 9.4-4: Soil Map Units in the PFSA

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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Red Mountain Underground Gold Project
Soil Units within the Project Footprint Study Area (Map 2 of 5)
Figure 9.4-4b
Date: 7/5/2017
Map Number: RM-071b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
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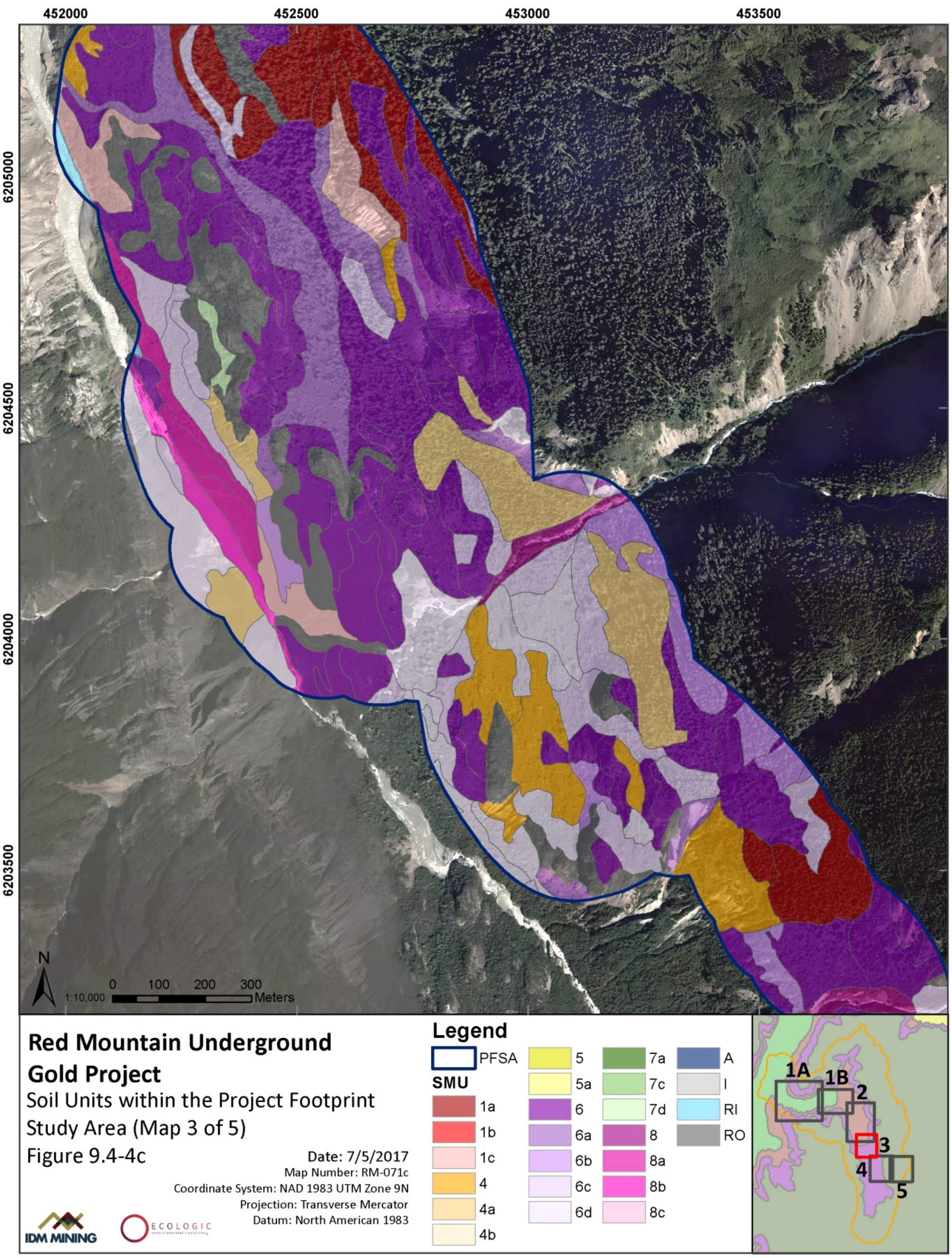
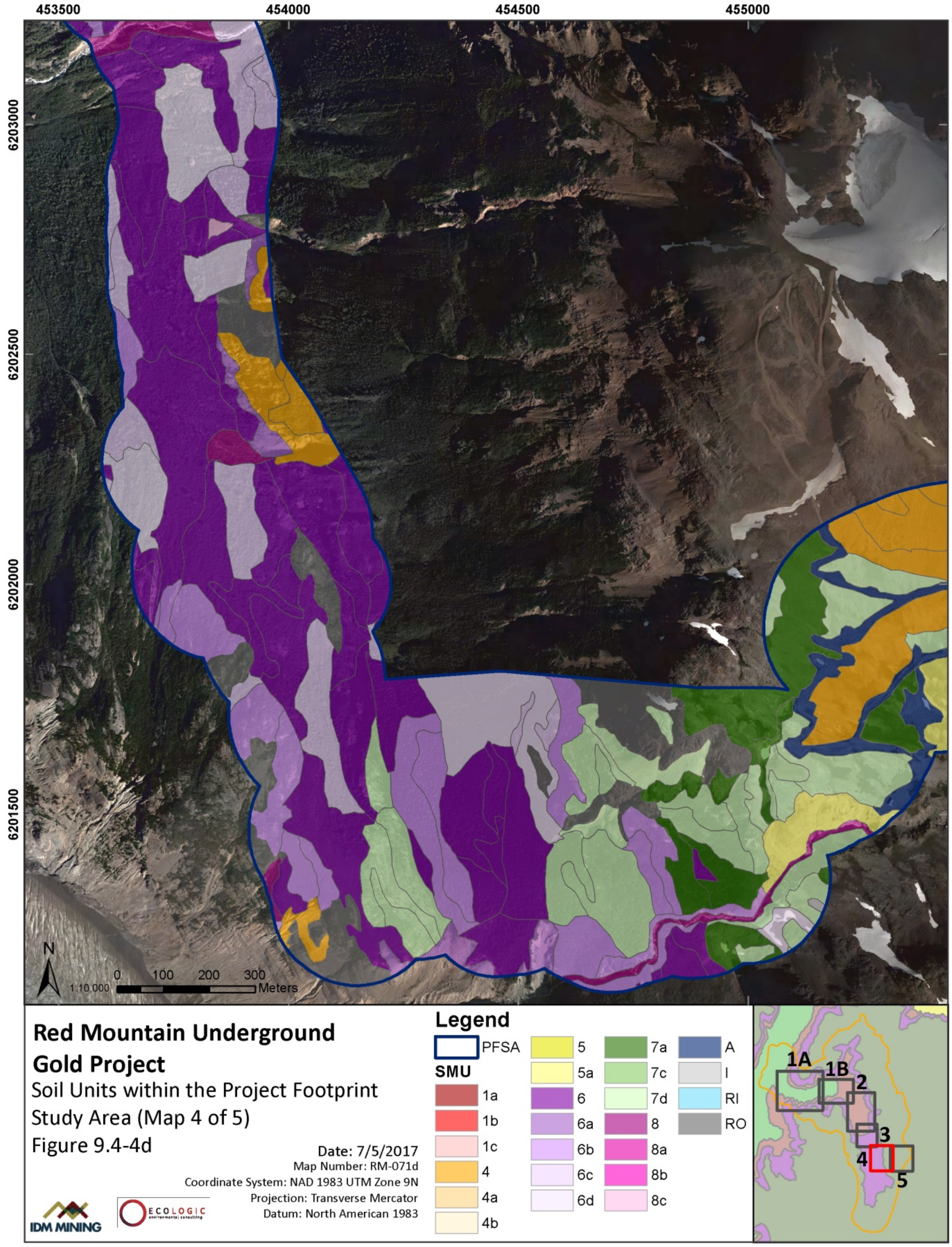



**Red Mountain Underground Gold Project**

Soil Units within the Project Footprint Study Area (Map 3 of 5)

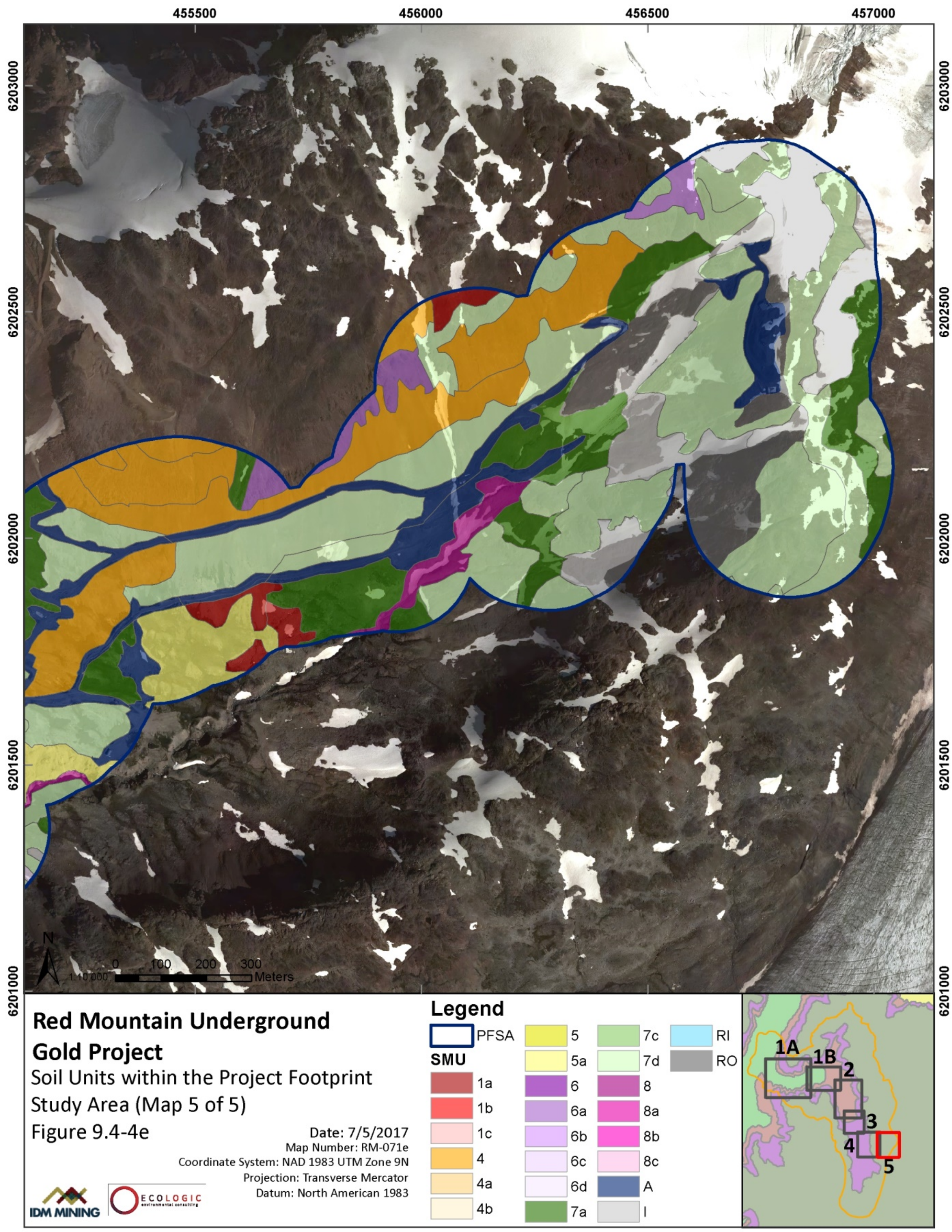
Figure 9.4-4c

Date: 7/5/2017
Map Number: RM-071c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983




**Red Mountain Underground Gold Project**
Soil Units within the Project Footprint Study Area (Map 4 of 5)
Figure 9.4-4d

Date: 7/5/2017
Map Number: RM-071d
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983




**Red Mountain Underground Gold Project**

Soil Units within the Project Footprint Study Area (Map 5 of 5)

Figure 9.4-4e

Date: 7/5/2017
Map Number: RM-071e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

#### 9.4.4.2.2 Soil Erosion Potential

The distribution (Figure 9.4-5) and spatial extent (Table 9.4-5) of the SEP vary within the PFA. The SEP classification ratings, by particle size, and slope, are outlined in tabular format and their estimated distribution throughout the LSA are spatially presented in Appendix 9-A.

**Table 9.4-5: Summary of Soil Erosion Potential mapped in the PFSA**

| Soil Erosion Potential Class | Map Code | Project Footprint Study Area (ha) | Proportion of Project Footprint Study Area (%) |
|---|---|---|---|
| Very Low | VL | 86.3 | 9.0 |
| Low | L | 454.3 | 47.3 |
| Moderate | M | 175.1 | 18.2 |
| High | H | 107.5 | 11.2 |
| Very High | VH | 129.7 | 13.5 |
| Not Applicable (N/A) | - | 7.9 | 0.8 |
| | **Total** | 960.7 | 100.0 |

Note: Values may not sum to total shown because of rounding.

#### 9.4.4.2.3 Soil Analytical Results

*Soil Reaction (pH)*

The range of mineral soil pH in the 0 to 15 cm soil layer is relatively wide: 4.8 (extremely acidic) to 8.0 (moderately alkaline [Appendix 9-B]). Just over half (11 of 21 soil samples tested) had pH values less than 5.5. No horizon–specific pH testing was completed.

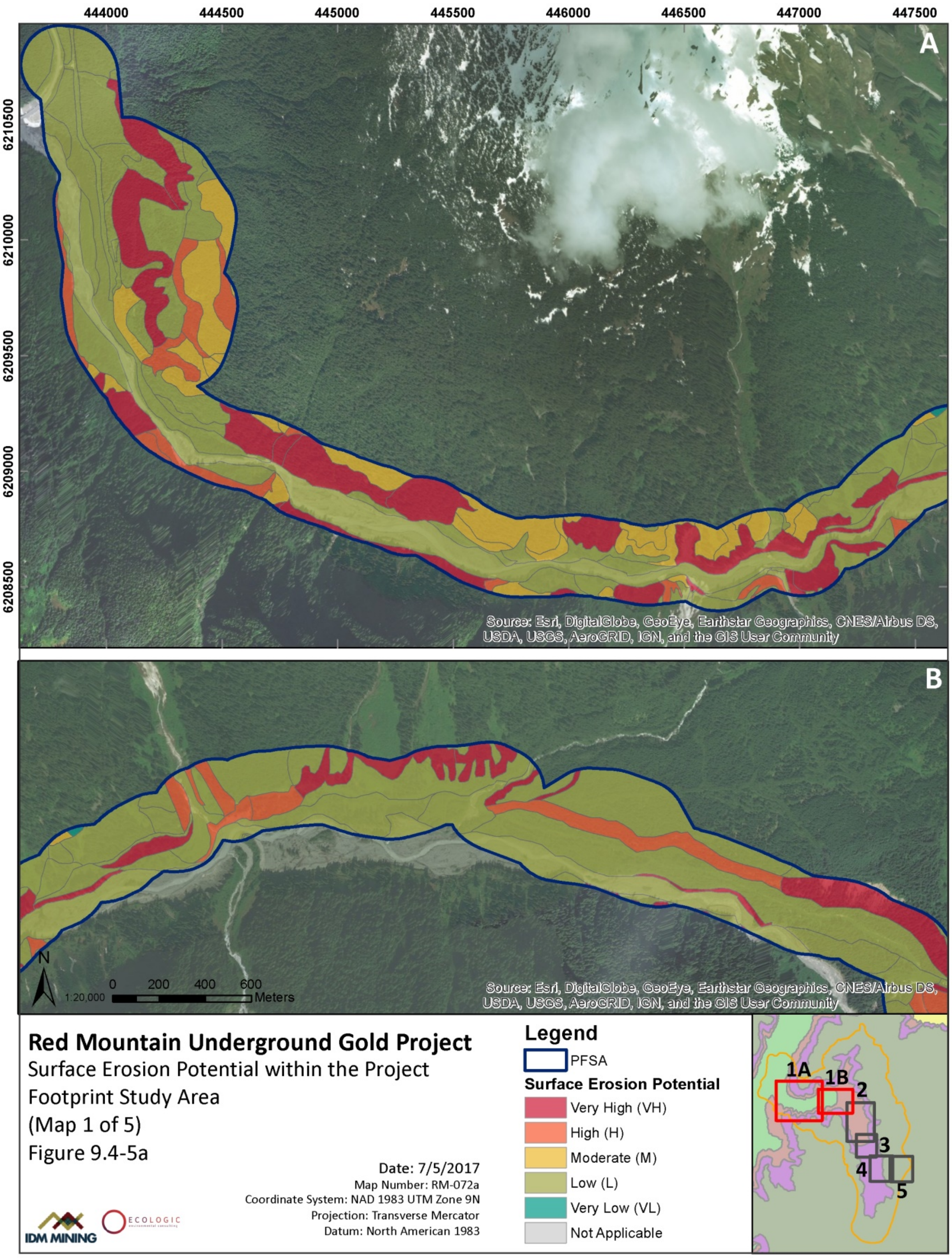
*Free Carbonates*

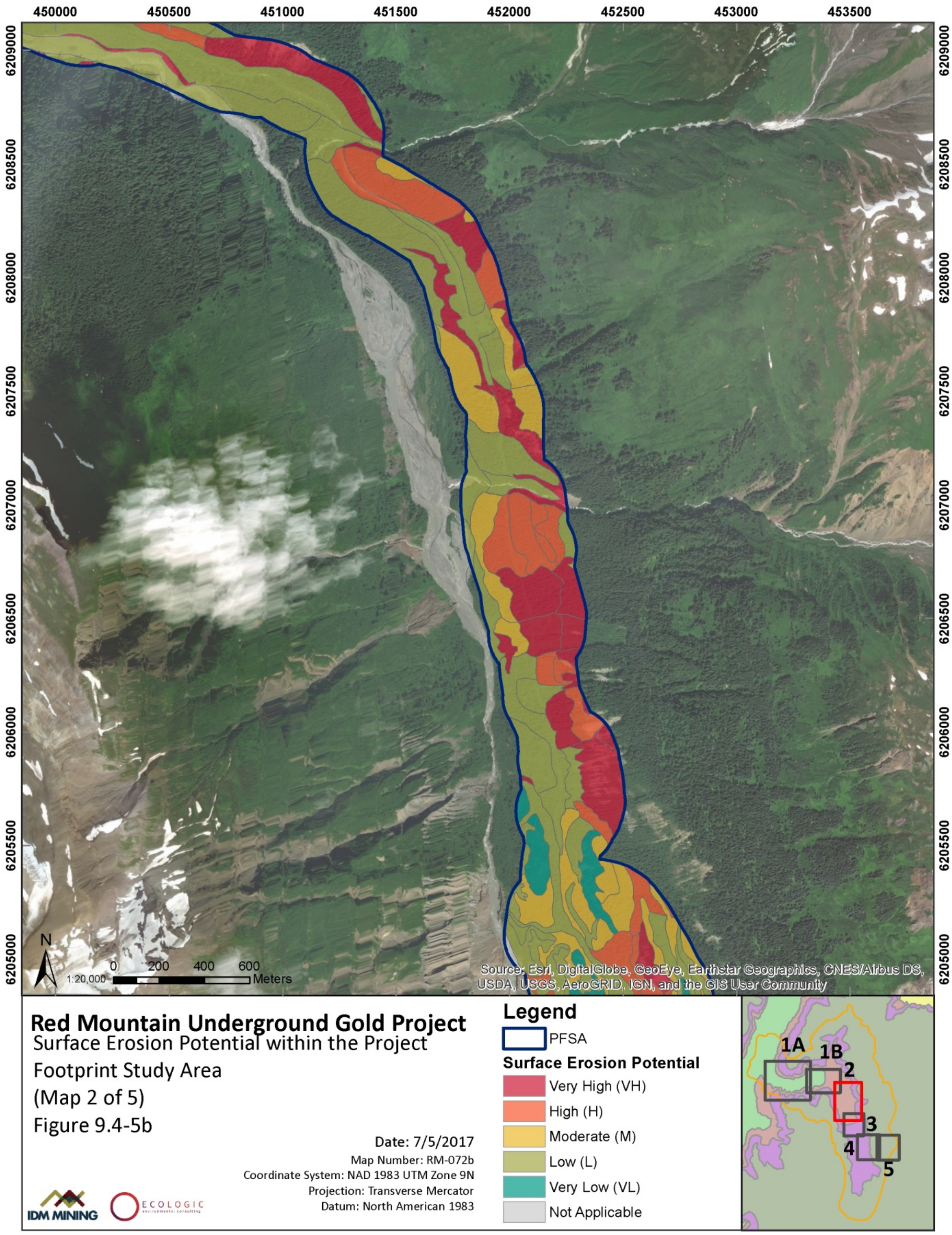
No testing for free carbonates was conducted owing to relatively low pH (4.5 to 6.5) and no visible calcium precipitates were noticed on the soil or coarse fragments in the sample area. Results of lab testing confirm the near total absence of free carbonates samples with a pH of 6.6 or less (Appendix 9-B).

*Soil Carbon*

In the absence of mineral carbon (typically found as carbonates), total carbon content is used as a proxy for organic carbon accumulation. The median value of total carbon content (by combustion) for the 21 mineral samples was 2.0%, and values ranged from 0.2% to 7.7% (Appendix 9-B). The presence of organic matter strongly influences the cation exchange capacity (CEC) of local soils as increasing carbon content shows a positive relationship with increasing CEC. CEC ranged from 0.5 to 7.5 milliequivalents of cations per 100 grams of soil (meq/100 g), normal when compared to soils of this general area (e.g., Brucejack Mine).

## Figure 9.4-5: Soil Erosion Potential in the PFSA





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6205500
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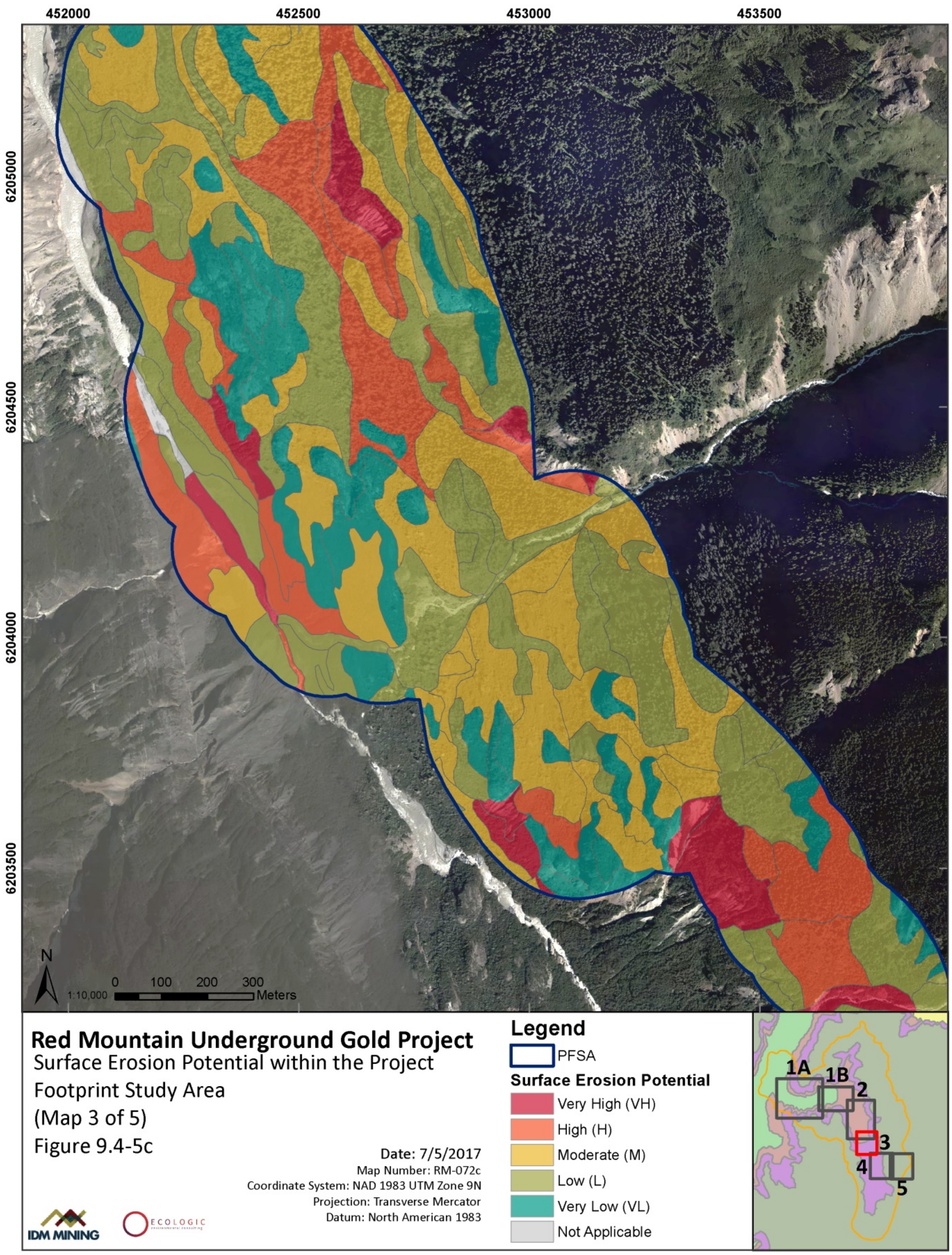
1:20,000
Meters
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Red Mountain Underground Gold Project
Surface Erosion Potential within the Project Footprint Study Area
(Map 2 of 5)
Figure 9.4-5b
Date: 7/5/2017
Map Number: RM-072b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Surface Erosion Potential
Very High (VH)
High (H)
Moderate (M)
Low (L)
Very Low (VL)
Not Applicable
1A
1B
2
3
4
5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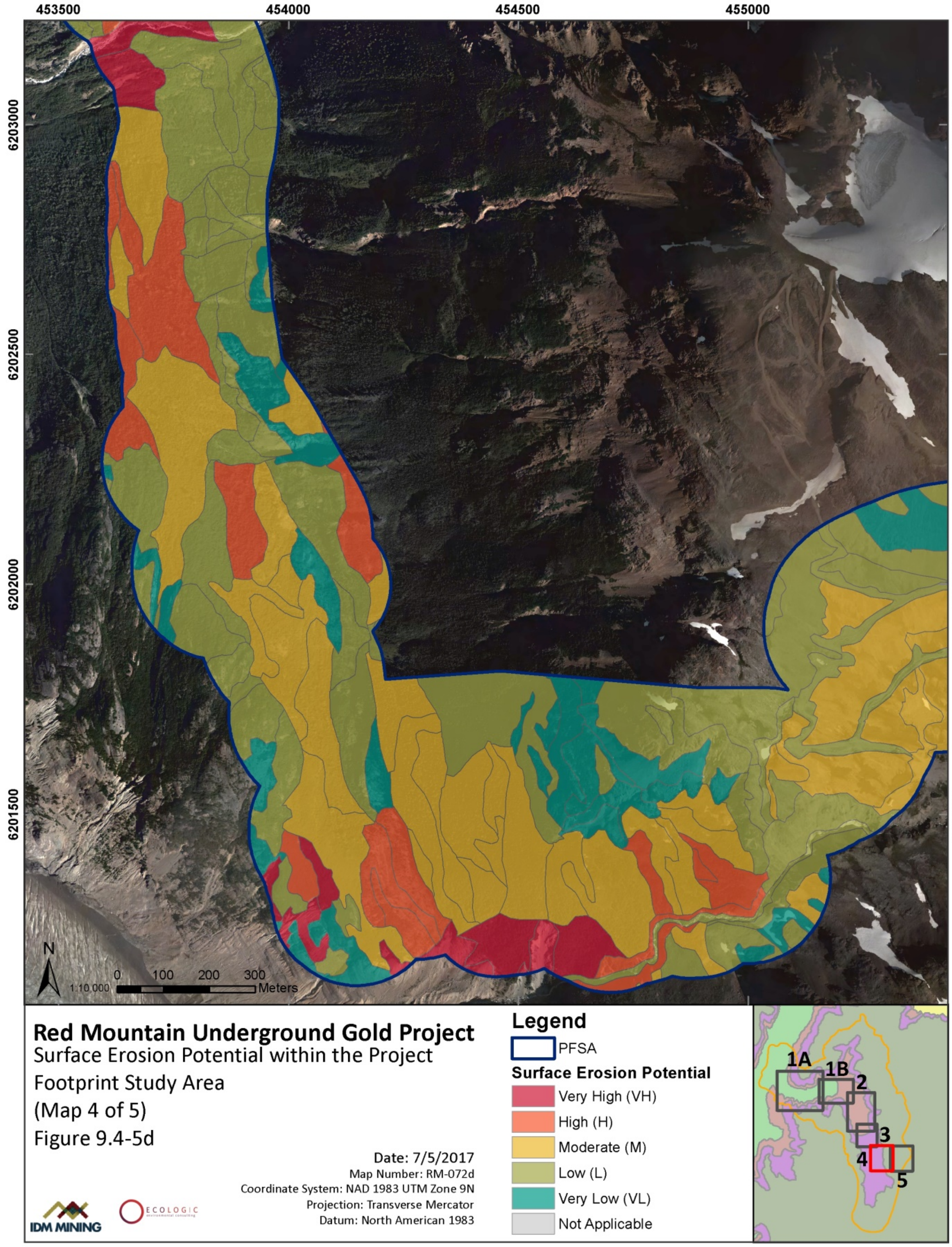
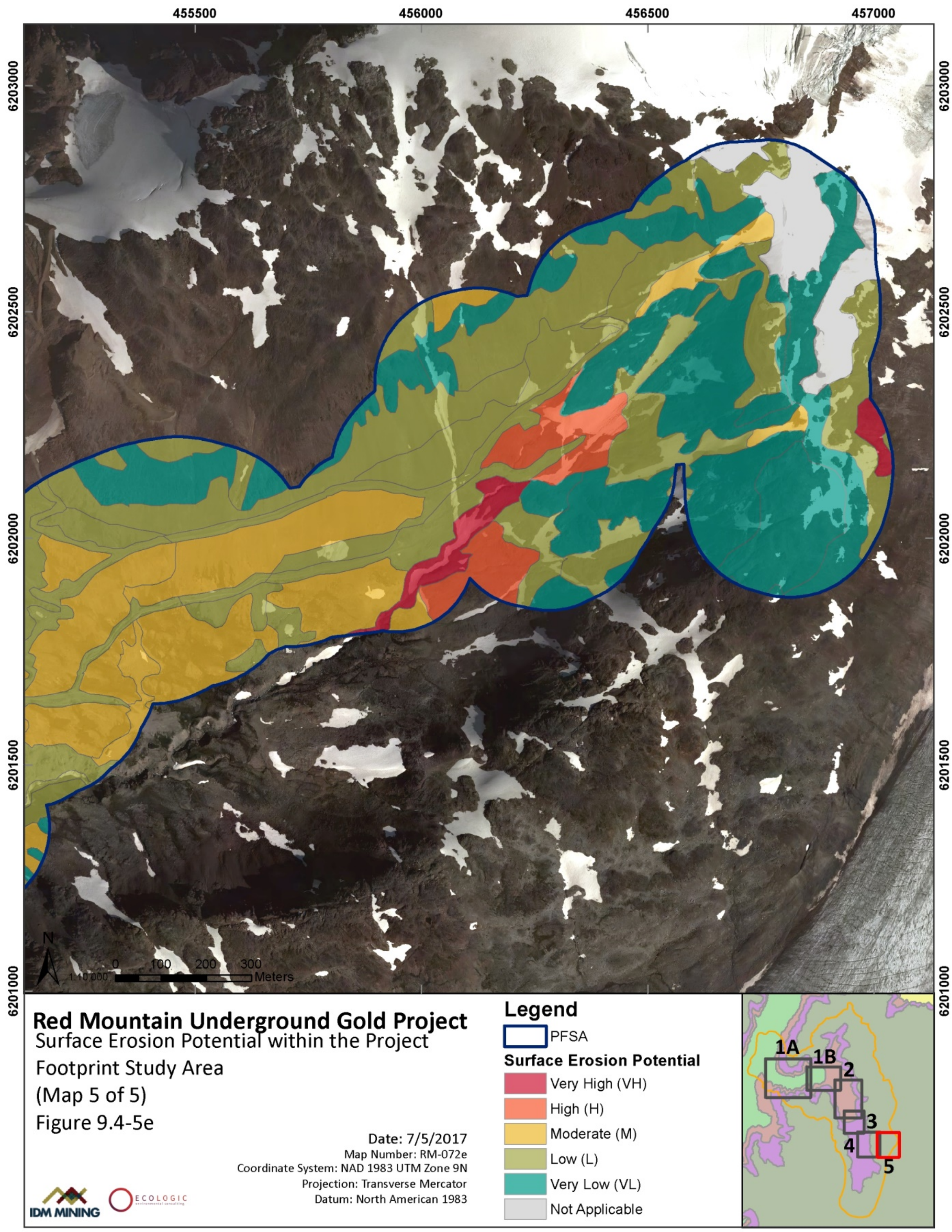
Red Mountain Underground Gold Project
Surface Erosion Potential within the Project Footprint Study Area
(Map 3 of 5)
Figure 9.4-5c
Date: 7/5/2017
Map Number: RM-072c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Surface Erosion Potential
Very High (VH)
High (H)
Moderate (M)
Low (L)
Very Low (VL)
Not Applicable
1A
1B
2
3
4
5




**Red Mountain Underground Gold Project**
Surface Erosion Potential within the Project Footprint Study Area
(Map 4 of 5)
Figure 9.4-5d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Red Mountain Underground Gold Project
Surface Erosion Potential within the Project Footprint Study Area
(Map 5 of 5)
Figure 9.4-5e
Date: 7/5/2017
Map Number: RM-072e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
PFSA
Surface Erosion Potential
Very High (VH)
High (H)
Moderate (M)
Low (L)
Very Low (VL)
Not Applicable
1A
1B
2
3
4
5

*Soil Texture*

Soil textures assessed in the field by hand texturing indicated soils in the PFSA to be coarse (sandy and loamy sand), moderately coarse (sandy loam), medium (loam and silty loam), or moderately fine (sandy clay loam and silty clay loam). Samples for lab testing were selected for particle size analyses to reflect a range of field textures, from fine to coarse, as found in areas associated with proposed development. Lab results confirm that soils in the Project area display a range of texture classes from medium to very coarse and mostly key out to sandy loam to loam texture class (Appendix 9-B). Based on the lab data, the moderately fine rated (Sandy Clay Loam) field textures may overestimate the clay content and may actually include slightly coarser, loam-textured materials. This is indicated by the median clay content of the 18 samples, tested as moderately low (8.6%), though it ranges from 1% to 17%C.

*Cation Exchange Capacity (CEC)*

The CEC is the total capacity of a soil to retain exchangeable cations. It influences the soil's ability to hold onto essential nutrients, buffer against soil acidification, and is an important characteristic for root zone fertility. CEC reflects the presence of colloidal materials, typically humus and clay-size mineral material, within the soil. Samples were selected to typify local soil conditions, especially near surface. Lab results show the CEC ranged from 0.5 to 7.5 meq/100 g of soil. Further information, such as a summary of sample variation and possible overestimation of soil types based in the CEC results, is provided in Appendix 9-B.

*Soil Metal Concentrations*

Metal concentrations that exceed acceptable threshold levels under CCME standards were identified for seven metals listed in Table 9.4-6: arsenic, molybdenum, silver, selenium, copper, nickel, and chromium (additional details in Appendix 9-B). Eight metals exceed the concentration criteria levels set for the most stringent land use, Agricultural Land Use. Using the less stringent Industrial Land Use criteria, the list of metals of concern is decreased from eight to three, namely arsenic, selenium, and copper. Nine samples exhibit exceedance of industrial criteria for two or more metal species (seven are acidic soils, two are alkaline soils). Arsenic and selenium exceedance occurred across all soil reaction classes (acidic and alkaline). Copper exceedance of Industrial limits was only observed in the acidic soils.

Elevated soil metal species appear generally like those noted for local geologic materials (waste rock, ore, and talus) as determined for static testing as part of metal leaching/acid rock drainage (ML/ARD) investigations (SRK 2017).

#### 9.4.4.2.4 Soil Salvage Potential

Most of the PFSA SSP is characterized as poor, good, or moderate (Table 9.4-7). All soil horizons were rated based on available data, which includes morphological and lab data (Appendix 9-A). Constraints (e.g., steep terrain, limited road access, moisture excess, unstable soils) in a particular area may limit soil use for salvage.

Organic soils are considered potentially useful as amendments to organic-poor materials. They may also be a significant source of 'refugia' and used in direct replacement in constructed wetland areas, if the receptor areas are available at the time of disturbance. The organic LFH layers, typical of many upland forested soils, are generally thin (less than 10 cm thick). Forest floor materials are considered to be suitable and assumed to be incorporated with the underlying mineral soils at the time of salvage. Upland organic soils (Folisols) were rarely observed in the field survey (except near isolated bedrock outcrops near Bromley Humps.

### Table 9.4-6: Number of Samples Exceeding CCME Soil Metal Concentration Thresholds

| Metal | Number of Samples Exceeding CCME Criteria Concentration Thresholds | | | Maximum Exceedance Level in Samples Compared to the Threshold | |
|---|---|---|---|---|---|
| | Acceptable CCME Threshold Levels | Agricultural Land Use | Industrial Land Use | Agricultural Land Use | Industrial Land Use |
| Arsenic (As) | 21 | 21 | 21 | 10 times | 10 times |
| Molybdenum (Mo) | 5 | 10 | 0 | 7 times | Not applicable |
| Silver ( Ag) | 5 | 0 | 0 | Not applicable | Not applicable |
| Selenium (Se) | 4 | 17 | 7 | 5 times | 1.6 times |
| Copper (Cu) | 5 | 14 | 4 | 3 times | 2.1 times |
| Nickel (Ni) | 3 | 4 | 0 | 1.1 times | Not applicable |
| Chromium (Cr) | 2 | 4 | 0 | 1.2 times | Not applicable |
| Uranium | 1 | 1 | 0 | slightly above 1 time | Not applicable |
| Zinc | 1 | 1 | 0 | 1.2 times | Not applicable |

### Table 9.4-7: Soil Salvage Potential Categories

| Soil Salvage Potential Category | Soil Salvage Potential Category Abbreviation | Project Footprint Study Area (ha) | Proportion of Project Footprint Study Area (%) |
|---|---|---|---|
| Good | G | 210.6 | 21.9 |
| Moderate to Good | M-G | 56.5 | 5.9 |
| Moderate | M | 202.1 | 21.0 |
| Moderate to Poor | M-P | 69.6 | 7.2 |
| Poor | P | 309.8 | 32.2 |
| Poor to Nil | P-N | 2.4 | 0.3 |
| Nil | N | 109.8 | 11.4 |
| | **Total** | 960.7 | 100.0 |

Note: Values may not sum to total shown because of rounding.

## 9.5 Potential Effects

The evaluation of Project effects on Landforms and Natural Landscapes takes into consideration the interconnections that occur across the landscape, information from key stakeholders, and the guiding principles outlined in the NSSRMP (FLNRO 2012).

### 9.5.1 Methods

Key Project-related interactions with Landforms and Natural Landscapes were determined through a screening evaluation of proposed physical works and activities in relation to the Landforms and Natural Landscapes ICs within the RSA, LSA, and PFSA. Key Project-related interactions and the likelihood of the interaction were determined by overlaying the spatial layers of the Project footprint on the terrain and soils mapping products to determine where soil loss, alteration and terrain stability effects were likely to occur (Table 9.5-1).

### 9.5.2 Project Interactions

The Project will interact with soil quantity, soil quality, and terrain stability during the Construction, Operation, and Closure and Reclamation Phases of the Project (Table 9.5-1). The potential effects and pathways of interaction include the following:

1. Loss and alteration of soil quality and quantity through soil stripping, handling, stockpiling, and dust and acidification effects;
2. Loss of soil quantity due to excavation during construction;
3. Loss of soil quality due to compaction;
4. Destabilization of terrain due to construction and maintenance of Project infrastructure;
5. Metal leaching acid rock drainage due to exposure of potentially acid generating (PAG) material; and
6. Increases of sediment being discharged into waterbodies.

Based on the results of the screening evaluation, any possible interactions between the Project and Landforms and Natural Landscapes were carried forward into the assessment to determine the effects of the interaction on Landforms and Natural Landscapes.

### Table 9.5-1: Landforms and Natural Landscapes Interaction Matrix

| Project Component / Activity | Landforms and Natural Landscapes | | |
|---|---|---|---|
| | Terrain Stability and Geohazards | Soil Quantity and Quality | Potential Effect / Pathway of Interaction |
| **Construction Phase** | | | |
| Construct Access Road and Haul Road Hwy 37a to the Upper Portal | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (ML / ARD and dust) |
| Install powerline from substation tie-in to the Lower Portal laydown area | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (from dust deposition) |
| Excavate and secure Lower Portal entrance and access tunnel | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (ML / ARD and dust) |
| Construct Mine Site water management infrastructure including talus quarry and portal collection ponds, dewatering systems, and water diversion, collection and discharge ditches and swales. | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; erosion, compaction, contamination (ML / ARD and dust) |
| Install and fill Fuel Tanks at Mine Site | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (dust) |
| Construct Explosives Magazine | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (dust) |
| Construct other Mine Site ancillary buildings and facilities | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (from dust deposition) |
| Discharge of water from underground workings at the Mine Site | - | X | Changes in soil moisture regime, contamination (discharge) |
| Initiate underground lateral development and cave gallery excavation | - | X | Erosion, compaction, contamination (ML / ARD, blasting) |

| Project Component / Activity | Landforms and Natural Landscapes | | |
|---|---|---|---|
| | Terrain Stability and Geohazards | Soil Quantity and Quality | Potential Effect / Pathway of Interaction |
| Temporarily stockpile ore at the Mine Site | X | X | Stockpile instability; loss of soil under component footprint; erosion and sedimentation, and contamination (ML / ARD and dust) |
| Install construction and permanent ventilation systems and underground water pumps | - | X | Soil loss under component footprints; erosion and sedimentation |
| Transport and deposit waste rock to Waste Rock Storage Area(s) | - | X | Loss of soil under waste rock stockpile; contamination (ML / ARD and dust) |
| Clear and prepare the TMF basin and plant site pad | X | X | Temporarily increased slope instability, erosion and sedimentation; erosion, compaction, contamination (dust) |
| Excavate rock and till from the TMF basin and local borrows / quarries for construction activities (e.g. dam construction for the TMF) | X | X | Temporarily increased slope instability erosion and sedimentation; compaction, contamination (ML / ARD and dust) |
| Establish water management facilities including diversion ditches for the TMF and Process Plant | X | X | Temporarily increased slope instability, erosion and sedimentation; compaction, contamination (ML / ARD and dust) |
| Construct the TMF | X | X | Temporarily increased slope instability, erosion and sedimentation; compaction, contamination (dust) |
| Construct the Process Plant and Run of Mine Stockpile | X | X | Loss of soil under Plant Site and Ore Stockpile area; temporarily increased slope instability, erosion and sedimentation; erosion, compaction, contamination (ML / ARD and dust) |
| Construct water treatment facilities and test facilities at Bromley Humps | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; erosion, compaction, contamination (dust) |
| Construct Bromley Humps ancillary buildings and facilities | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; compaction, contamination (from dust deposition) |
| Commence milling to ramp up to full production | - | X | Contamination from dust deposition |

| Project Component / Activity | Landforms and Natural Landscapes | | |
|---|---|---|---|
| | Terrain Stability and Geohazards | Soil Quantity and Quality | Potential Effect / Pathway of Interaction |
| **Operation Phase** | | | |
| Use Access Road for personnel transport, haulage, and delivery of goods | - | X | Contamination from dust deposition |
| Maintain Access Road and Haul Road, including grading and plowing as necessary | - | X | Contamination from dust deposition |
| Continue underground lateral development, including dewatering | - | X | Contamination from dust deposition |
| Discharge of water from underground facilities | - | X | Changes in soil moisture regime , contamination (discharge) |
| Haul waste rock from the declines to the Waste Rock Storage Area(s) for disposal (waste rock transport and storage) | - | X | Loss of soil under waste rock stockpile; contamination from dust deposition |
| Extract ore from the underground load-haul-dump transport to Bromley Humps to Run of Mine Stockpile (ore transport and storage) | X | - | Slope instability / subsidence |
| Temporarily store hazardous substances including fuel, explosives, and mine supplies | - | X | Soil quality effects from the use of chemicals and fuel |
| Progressively reclaim disturbed areas no longer required for the Project | X | X | Slope instability; loss of soil due to erosion / slope failure; soil quality effects from soil erosion, compaction |
| **Closure and Reclamation Phase** | | | |
| Use and maintain Access Road for personnel transport, haulage, and removal of decommissioned components until road is decommissioned and reclaimed. | - | X | Contamination from dust deposition |
| Decommission underground infrastructure | X | X | Terrain instability / subsidence; loss of soil due to erosion / slope failure |
| Flood underground | - | X | Effects on soil moisture regime |
| Install bulkhead(s) in the declines and ventilation exhaust raise | - | X | Effects on soil moisture regime |

| Project Component / Activity | Landforms and Natural Landscapes | | |
|---|---|---|---|
| | Terrain Stability and Geohazards | Soil Quantity and Quality | Potential Effect / Pathway of Interaction |
| Decommission and reclaim Lower Portal Area and Powerline | X | X | Slope instability; erosion and sedimentation, and compaction |
| Decommission and reclaim Haul Road | X | X | Slope instability; erosion and sedimentation, and compaction |
| Decommission and reclaim all remaining mine infrastructure (Mine Site and Bromley Humps, except TMF) in accordance with the final Closure Plan | X | X | Slope instability; erosion and sedimentation and compaction |
| Construct the closure spillway | X | X | Temporarily increased slope instability, erosion and sedimentation; loss of soil under component footprint; soil compaction |
| Remove discharge water line and water treatment plant | X | X | Temporarily increased slope instability, erosion and sedimentation; soil erosion and compaction |
| Decommission and reclaim Access Road | X | X | Slope instability; erosion and sedimentation, and compaction |

#### 9.5.2.1 Construction

Construction activities are associated with loss of soil quantity and potential increases in terrain instability as well as some minor potential for alteration. Construction activities are expected to interact with Landforms and Natural Landscapes through surface disturbance that will include clearing vegetation and removing topsoil, stockpiling overburden and topsoil, and constructing roads and infrastructure. Construction activity has the potential to decrease terrain stability, particularly along road cut slopes and overburdened fill slopes. Specifically, Project infrastructure and activities will interact with Landforms and Natural Landscapes through development of the following Project components:

- Re-activation of the 5 m wide, 14 km Access Road from Highway 37A to Bromley Humps;
- Construction of the TMF and the Process Plant at Bromley Humps;
- Construction of the 5 m wide Haul Road that will extend 12.5 km from the Process Plant at Bromley Humps to the underground mine;
- Clearing associated with the creation of the right-of-way (ROW) for the 138-kilovolt (kV) Powerline from Highway 37A to the underground mine; and
- Clearing and installation of the Powerline poles along the full length of the line.

The Access Road ROW will be cleared, grubbed, and stripped prior to construction. Trees will be cleared to a distance 3 m upslope of the road prism. Timber within the ROW is non-merchantable and will be piled and burned locally along the ROW. In areas of steep terrain, the stripped soil will be end-hauled to a stable location for storage. Sediment and erosion control strategies will include limiting the disturbance areas to the minimum practicable extent, installing sediment controls prior to construction activities, and progressively rehabilitating disturbed land and constructing drainage controls to improve the stability of rehabilitated land.

A starter dam will be constructed using local borrow materials. It will provide approximately 12 months of tailings storage, with an embankment raise during the first year of operations.

The Haul Road is designed with a 25 m ROW in sections of the alignment where the Powerline will run parallel to the road, and the disturbance limit will be reduced to 20 m where the line deviates from the road alignment. Site-specific conditions may necessitate a wider ROW where cut and fill slopes extend beyond the typical ROW. In these locations, the right-of-way will be optimized, but can be considered to increase 3 m beyond the typical toe of the fill or crest of the cut.

Borrow pits primarily target organic-free surficial materials that are to be excavated with an excavator, loader, or bulldozer. They will be stripped of the organic soil layer (stripped topsoil and organics are to be stored for later use in reclamation at the edge of the borrow site) before use and are to be established by working into the cut slope. Once the site has been stripped, the targeted material will be excavated, sorted (if required), and hauled to the required location.

Once use of the borrow pit has concluded, the cut slopes will be reduced to match the cut slope specifications applicable to the ground type at the site to provide long-term stability of the site.

#### 9.5.2.2 Operation

Potential effects during operations are primarily associated with the loss of soil quality due to dust effects, alteration of soil chemical properties in stockpiles, and ongoing potential for erosion and contamination (fuel and fluid spills). The following Operation Phase activities will interact with Landforms and Natural Landscapes:

- Ongoing use of the Access and Haul Road;
- Deposition of material into the TMF; and
- Surface storage stockpiles from waste rock generated from mine development.

Much of the anticipated operational alteration will be due to dust produced by Access and Haul Road use as well as the potential for ongoing erosion.

The TMF embankments will be progressively raised during operations following the downstream method of construction. Local borrow materials will be used to construct the expansions. The TMF (basin and upstream faces of the embankments) will be lined with a geomembrane to minimize the potential for seepage from the facility. A system of collection ditches, ponds, and pumps/pipelines will collect runoff and seepage from the TMF.

#### 9.5.2.3 Closure and Reclamation

Closure and Reclamation activities will interact with Landforms and Natural Landscapes through:

- Decommissioning of the Process Plant, TMF, ancillary buildings and facilities;
- Land reclamation and removal of water treatment facilities; and
- Soil handling and revegetation of proposed reclaimed areas.

#### 9.5.2.4 Post-closure

There are no anticipated interactions between Post-Closure Phase activities (i.e., flooding of the underground workings and post-closure environmental monitoring) and Landforms and Natural Landscapes. There will be no road access to the Project; all access will be via helicopter.

### 9.5.3 Discussion of Potential Effects

This assessment identifies key potential effects of the Project on Landforms and Natural Landscapes. These are represented by changes to soil quantity, soil quality, and terrain stability. The severity of effect is categorized as either loss or alteration. Areas that fall within the direct Project footprint are considered lost, while areas that could potentially be affected by the Project are considered altered. Loss leads to negative effects on soil quantity, while alteration results in reductions of soil quality. Alteration can, in certain situations, also lead to soil loss (reductions in soil quantity). Terrain stability can be affected by the Project through alteration of landscapes so that they are more prone to landslides, including rapid mass movements and slow mass movements, as well as snow avalanches. Terrain effects can also include increased rates of sedimentation of waterbodies (i.e., due to increased mass movement as well as surface erosion) and bank scour. As it is not possible to separate out discrete terrain effects in a predictive manner, terrain instability, sedimentation, and bank scour effects are captured under terrain alteration (i.e., decreases in terrain stability).

Potential Project effects on Landforms and Natural Landscapes were identified through reviews of relevant literature (e.g., Project description and baseline results, information made available from public consultation, scientific literature, government documents, and publicly available data associated with relevant adjacent projects), professional judgement, and experience with other mine EAs in northwest BC.

Measurement indicators are used to determine the overall effect of the Project on Landforms and Natural Landscapes (Table 9.5-2).

**Table 9.5-2: Measurement Indicators for Landforms and Natural Landscapes Intermediate Components**

| Intermediate Component | Measurement Indicator | Potential Effect Related to Measurement Indicator |
|---|---|---|
| Soil Quality | Changes to quality of soil | • Soil compaction<br>• Soil contamination<br>– Spills<br>– Fugitive dust<br>– Acidification and eutrophication<br>• Soil Alteration |
| Soil Quantity | Changes to quantity of soil | • Direct loss of soil during construction<br>• Surface soil erosion |
| | Changes to background rates of soil erosion | • Surface soil erosion<br>• Increases in rapid and slow mass movements |
| | Changes to terrain stability | • Increases in rapid and slow mass movements |
| | Changes to background rates of sedimentation of waterbodies | • Surface soil erosion<br>• Increases in rapid and slow mass movement |
| Terrain Stability | Changes to terrain stability | • Increases in rapid and slow mass movement |
| | Changes to background rates of soil erosion | • Surface soil erosion<br>• Increases in rapid and slow mass movement |
| | Changes to background rates of sedimentation of waterbodies | • Surface soil erosion<br>• Increases in rapid and slow mass movement<br>• Channel morphology lateral and vertical stability |
| | Changes in intensity and frequency of snow avalanches | |

### 9.5.3.1 Key Effects on Soil Quantity

#### 9.5.3.1.1 Direct Soil Loss during Construction

Soil loss (i.e., direct removal of soils) occurs during construction of mine infrastructure, including the construction of the TMF, the Access and Haul Roads, borrow pits, and stockpiles. Soil can be lost via erosion (both water and wind) and admixing (incorporating soils with less productive materials, such as coarse woody debris and subsurface horizons).

#### 9.5.3.1.2 Soil Erosion

Soil erosion rates within the Bitter Creek valley are elevated due to recent glacial retreat. Glacial retreat leaves behind un-vegetated sediments and oversteepened side slopes that continue to erode until the natural angle of repose is achieved and vegetation cover is established. The greatest potential for Project-related increases in soil loss will occur during construction and closure and reclamation due to the amount of ground disturbance and exposed soil surfaces. Once vegetation is removed, soil erosion and slope failure are more likely, as vegetation roots contribute to soil strength, and leaves and coarse woody debris reduce the energy of rainfall (splash erosion) and break up the surface so running water does not obtain an erosive velocity.

#### 9.5.3.1.3 Admixing

Admixing occurs when less or non-productive soil horizons are mixed with the more productive surface tiers, resulting in reduced soil quality. Sub-surface tiers often have characteristics that do not suit reclamation, such as elevated $CaCO_3$, anoxic reaction by products, and massive structures.

#### 9.5.3.1.4 Increases in Rapid and Slow Mass Movement

Increases in terrain instability can lead to loss of surface soils. These potential effects are discussed in detail in Section 9.5.3.3.

### 9.5.3.2 Key Effects on Soil Quality (Soil Alteration)

Soil alteration occurs when soil is subject to some manner of deleterious influence that results in a reduction of its functions, usually expressed in terms of parameters such as metal availability, pH, base cations, aeration and porosity, and $CaCO_3$ content. Typical pathways to soil alteration involve compaction and contamination, including spills, dust effects, acidification, and erosion.

#### 9.5.3.2.1 Soil Compaction

Soil compaction is the compression of soil material and subsequent loss of pore space, which leads to alteration of soil fertility. It is caused primarily by the use of heavy equipment during construction activities. Alteration associated with soil compaction is dependent on both innate characteristics of soil (e.g., texture, coarse fragment, degree of aggregation, organic matter) and edaphic conditions at the time of disturbance (soil moisture content, presence of frozen layers; Gomez, Powers and Singer 2002). Soil compaction can have numerous effects, including reduced plant growth due to restrictions in root growth and reduced water absorption and nutrient availability (Kozlowski 1999). As water is not easily adsorbed into the soil matrix, surface runoff can increase over compacted soils, leading to losses of soil (Luce and Black 1999). Key ecological functions, such as site stability, productivity, nutrient cycling, carbon storage, water regulation, and wildlife habitat may also be affected depending on the severity of the compaction and the soil type affected.

#### 9.5.3.2.2 Soil Contamination

Soil contamination can occur during mining operations from a number of pathways. These include spills of fluids, such as fuel, aerial deposition of metals in dust, soil acidification due to emissions from diesel engines, and transportation of metals by surface and groundwater, often in association with the weathering of acid-generating competent bedrock and surficial materials. Miscellaneous spills or accidents involving the release of fuel or chemicals are discussed separately as waste management and spill prevention in Volume 5, Chapter 29 (Spill Contingency Plan).

*Fugitive Dust*

Rock material present in the LSA and PFSA contains metals that could be liberated during mining operations and cause potential contamination issues. Dust-releasing mining operations include blasting, crushing, and road use. As the milling operations will be conducted inside buildings, the primary potential source of dust contamination of soils from mining operations is from road use. This dust is referred to as "fugitive dust" to distinguish it from dust that comes out of a vent or stack (i.e., not a by-product of burning). Deposition of dust is also expected to be one of the pathways of potential alteration of vegetation.

Fugitive dust arises when fine granular material is propelled into the air and is transported and deposited at some other locale. How far dust travels depends on the magnitude of the disturbance force and the characteristics of the granular material. Depending on the source, deposition of dust can lead to increased soil contamination with metals, changes in soil salinity, or ecosystem eutrophication with nutrients. Sulphide-containing rocks can contribute to the deposition of sulphides on surface soil tiers, which can result in the acidification of the soils.

Fugitive dust can contain heavy metals if those metals are present in the material used in construction, especially road construction. Heavy metals constitute an ill-defined group of inorganic chemical hazards, but commonly include lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni; GWRTAC 1997). Vehicle traffic can result in the mobilization of these metals which can then settle on soil and vegetation. The behavior of these metals in soils is highly dependent on both the metal speciation and the soil environment. Unlike organic contaminants, which are oxidized to carbon oxide by microbial activity, most metals do not undergo microbial or chemical alteration. As a result, their total concentration in soils increases with additional inputs and persists for extended periods.

The detailed discussion of dust emission, distribution, and deposition patterns within the LSA and the assessment of dust effects on air quality are presented in Volume 3, Chapter 7 (Air Quality Effects Assessment).

*Soil Acidification and Eutrophication*

Atmospheric deposition of substances capable of causing soil acidification can occur during mine operations. Mining operations, when involving the use of diesel engines, will emit nitrogen oxides ($NO_x$) and sulfur dioxide ($SO_2$), which can be carried in precipitation (wet deposition) or fall as dry deposition. Direct effects on soils include reductions in pH, loss of base cations ($Ca^{2+}$, $Mg^{2+}$, and $K^{+}$) and mobilization of metals.

Nitrogen compound deposition results in temporary eutrophication of the soil (fertilization), which induces short-term increases in productivity and changes in vegetation community, often resulting in increases in invasive species establishment (Stephens 2010). If, upon deposition, nitrate ($NO_3^-$) is not taken up by plants, it can leach through and out of the rooting zone. As nitrate is negatively charged, it takes a base cation with it, which reduces the buffering capacity of the soil, further decreasing the soil pH. Sulphate compound deposition contributes to soil acidification, as it is a proton donor ($H^+$) to the soil environment. If the soil is base deficient and cannot neutralize the added proton, a buildup of $H^+$ will occur, lowering the soil pH.

Alterations of soil pH leads to changes in soil biochemical function and can result in the liberation of metals that were previously immobile. This can result in changes to the bioavailability of toxic chemicals and affect the overall ability of the ecosystem to function. The rate of acidification is highly dependent on both the rate of input and soil characteristics, including surface soil pH, $CaCO_3$ equivalence, clay content, soil organic matter content, coarse fragment content, and native rock characteristics, which determine soil buffering capacity (Reuss, Cosby, and Wright 1987; Galloway 1995).

#### 9.5.3.3 Loss of Terrain Stability

The effects of the Project on terrain stability include the potential for decreased stability and increased frequency and magnitude of geohazards. Movement of sediment due to geohazards, especially debris slides and debris flows, are effective agents of erosion, commonly increasing the volume of material as it progresses downslope. In particular, rapid mass movements are:

- Potential sources of stream sediment and alteration of fish habitat and water quality;
- Potential hazards to Project personnel and Project infrastructure; and
- Pathways to loss of soil quantity.

Debris flows and debris slides are triggered by heavy rain, water from snow melt, and/or rain on snow events and result from loss of soil strength due to high pore water pressure. In logged areas, debris slides that occur several years after logging can be due to changes in the amount of soil moisture and the loss of soil strength that results from root decay. Some reasons cited for failures initiating from roads, fill, and cutslopes include (Pike et al., 2010):

- Weak fill slopes;
- Inadequate or poor site or road drainage;
- Failure from cutslope;
- Culvert water discharge, including rerouting and/or concentration of flow, onto an unstable slope;

- More water is intercepted by the cutslopes (i.e., daylighting near-surface seepage) than was anticipated during site or road design; and
- Water is redirected due to blocked culvert or cross-ditch downslope onto potentially unstable terrain.

A debris flow may move downslope for several hundred metres or more before it is arrested by gentler terrain or by de-watering, or it may enter a trunk stream.

Solifluction/gelifluction lobes are common in the alpine area of the mine site (mapped as –S). Larger lobes of creeping ground ice in talus slopes (mapped as –F"g) are present on the south facing slopes of Red Mountain above the Haul Road. From air photo interpretation alone, it is unknown if these slopes are still experiencing creep or if these are relict features from a colder climate. If these are currently active processes, there is a possibility that excavations in the affected soils will alter the active zone of the soil and cause an increase in the slow mass movement of sediments.

#### 9.5.3.4 Snow Avalanches

Snow avalanche is a common naturally occurring process within the LSA and parts of the PFSA. There is the potential for increased avalanche activity following forest removal. The presence of forest influences the microclimate, such as wind, interception of precipitation, incoming shortwave radiation, and outgoing longwave radiation (Pike et al, 2010). Steep slopes where forest is removed are exposed to stronger winds, increased precipitation, and sun exposure, combined with reduced snow-pack strength. The net result can be an increase in avalanche activity (Pike et al, 2010) in areas where avalanche activity did not previously occur. Unmitigated effects or consequences could include damage or destruction of access roads, transportation vehicles, mining equipment, and mine infrastructure, as well as injury to personnel. Also, logging of slopes directly below snow avalanche terrain could result in longer avalanche run-out paths.

### 9.5.4 Quantification of Potential Effects – Soil Quality and Quantity

The PFSA is the area that will be subject to direct and indirect Project effects, resulting in loss and alteration of soils and potential effects on terrain stability. Figure 9.5-1 shows the results of analysis for loss and alteration of soils, expressed in hectares per SMU. Table 9.5-3 shows this same information with spatial loss and alteration, while Table 9.5-4 shows SMU alteration and loss delineated for each infrastructure unit. These tables show loss and alteration for all soil types and do not distinguish between the relative valuable functions of each SMU with respect to ability to support ecologically development. Such soils are referred to as Ecologically Valuable Soils and are a VC in Volume 3, Chapter 15 (Vegetation and Ecosystems Effects Assessment).

Table 9.5-3 and Table 9.5-4 will be referred throughout the discussion of quantification of potential effects. Generally, loss refers to effects related to losses of soil quantity, such as direct loss, erosion, and mass wasting, while alteration refers to those effects that can result in the alteration of soils, such as compaction and contamination (spills, fugitive dust deposition, and acidification). In reality, alteration can lead to soil loss, as soils can become altered to such a point that they no longer can perform soil functions.

In summary, it is expected that the area directly affected by Project development will result in the loss of 219.5 ha (1.3 % of the LSA) and alteration of 625.7 ha (3.9% of the LSA) of soils. The level of soil alteration will vary depending on the severity of soil compaction, erosion, contamination, acidification, and the soil type affected. Reclamation may reduce the area of lost soil, and soil handling, stockpiling, and redistribution will reduce alteration effects to soil quality.

### Table 9.5-3: Loss and Alteration of Soil for each Soil Management Unit

| SMU | Loss Area (ha) | Alteration Area (ha) |
|---|---|---|
| 1a | 16.1 | 64.1 |
| 1b | 8.3 | 16.0 |
| 1c | 2.7 | 8.4 |
| 4 | 9.5 | 23.9 |
| 4a | 8.8 | 35.2 |
| 4b | 4.2 | 8.8 |
| 4c | 0.2 | 0.2 |
| 5 | 5.9 | 19.5 |
| 5a | 14.4 | 15.1 |
| 6a | 10.5 | 11.7 |
| 6 | 36.1 | 81.3 |
| 6b | 9.4 | 63.8 |
| 6c | 21.5 | 59.5 |
| 6d | 7.5 | 52.6 |
| 6e | 0.1 | 1.5 |
| 7 | 0.0 | 0.1 |
| 7a | 6.6 | 14.2 |
| 7b | 0.0 | 4.5 |
| 7c | 0.2 | 0.0 |
| 7d | 27.2 | 50.2 |
| 8 | 0.7 | 6.6 |
| 8a | 20.0 | 51.6 |
| 8b | 4.8 | 66.4 |
| 8c | 2.2 | 7.6 |
| A | 12.3 | 8.8 |

| SMU | Loss Area (ha) | Alteration Area (ha) |
|---|---|---|
| I | 3.9 | 13.1 |
| RI | 0.0 | 0.4 |
| RO | 13.4 | 29.0 |
| Total | 219.5 | 625.7 |

**Table 9.5-4: Loss and Alteration of Soil per Infrastructure Unit**

| Infrastructure | Loss | Altered |
|---|---|---|
| Access Road | 34.9 | 339.6 |
| Gravel Borrow | 17.2 | 20.6 |
| Haul Road | 37.8 | 201.6 |
| Lower Portal | 3.2 | 6.5 |
| Process Plant Site | 8.2 | 10.6 |
| Rock Quarry | 42.3 | 29.4 |
| Talus Quarry | 14.2 | 16.2 |
| TMF | 47.8 | 44.1 |
| Powerline | 26.6 | 22.5 |
| Upper Portal | 6.5 | 6.2 |
| Bitter Creek Site Road | 0.5 | 4.9 |
| Temporary Waste Rock Storage Area | 2.6 | 5.7 |
| Topsoil Storage Area | 4.6 | 6.4 |

### 9.5.4.1 Soil Quantity

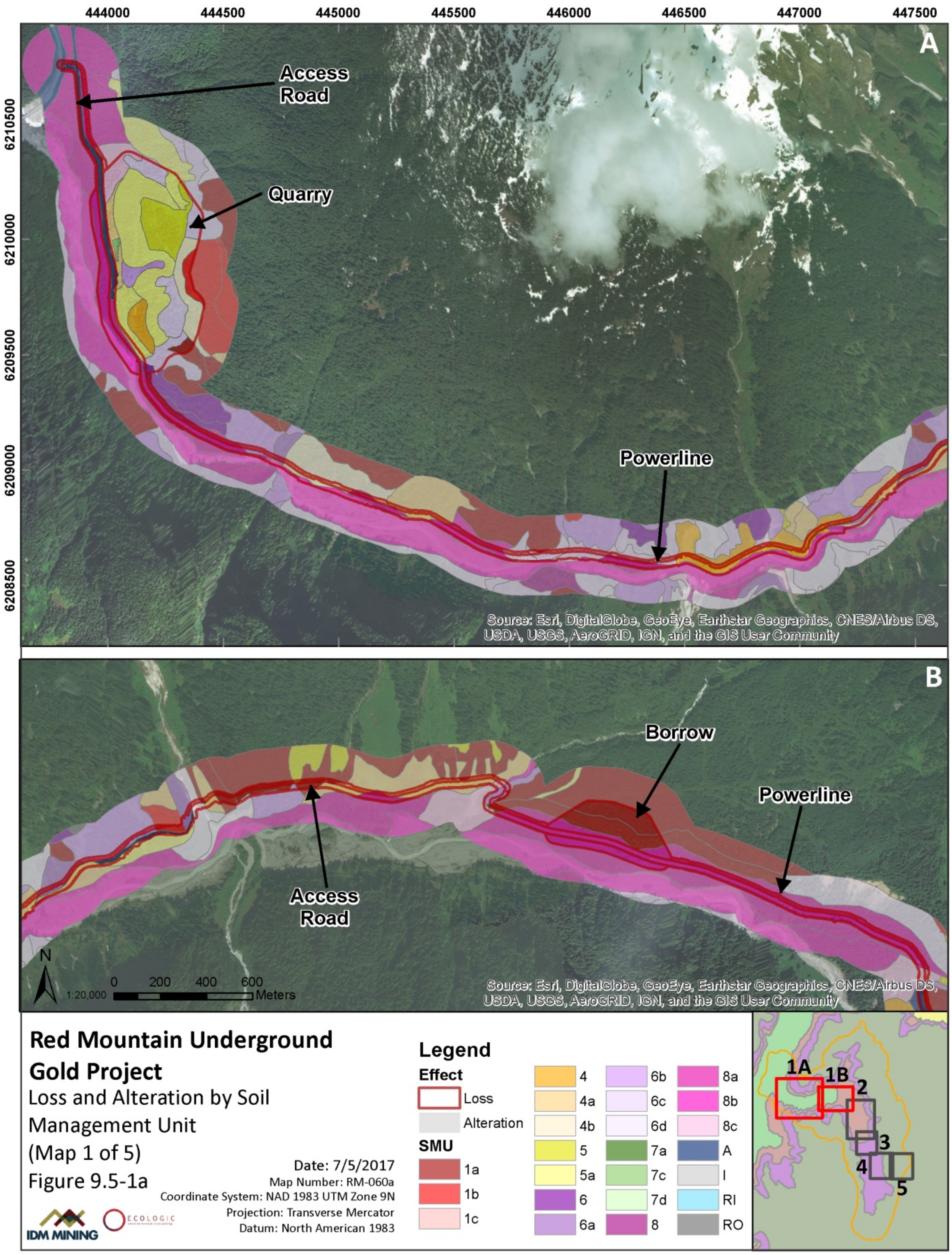
#### 9.5.4.1.1 Direct Soil Loss

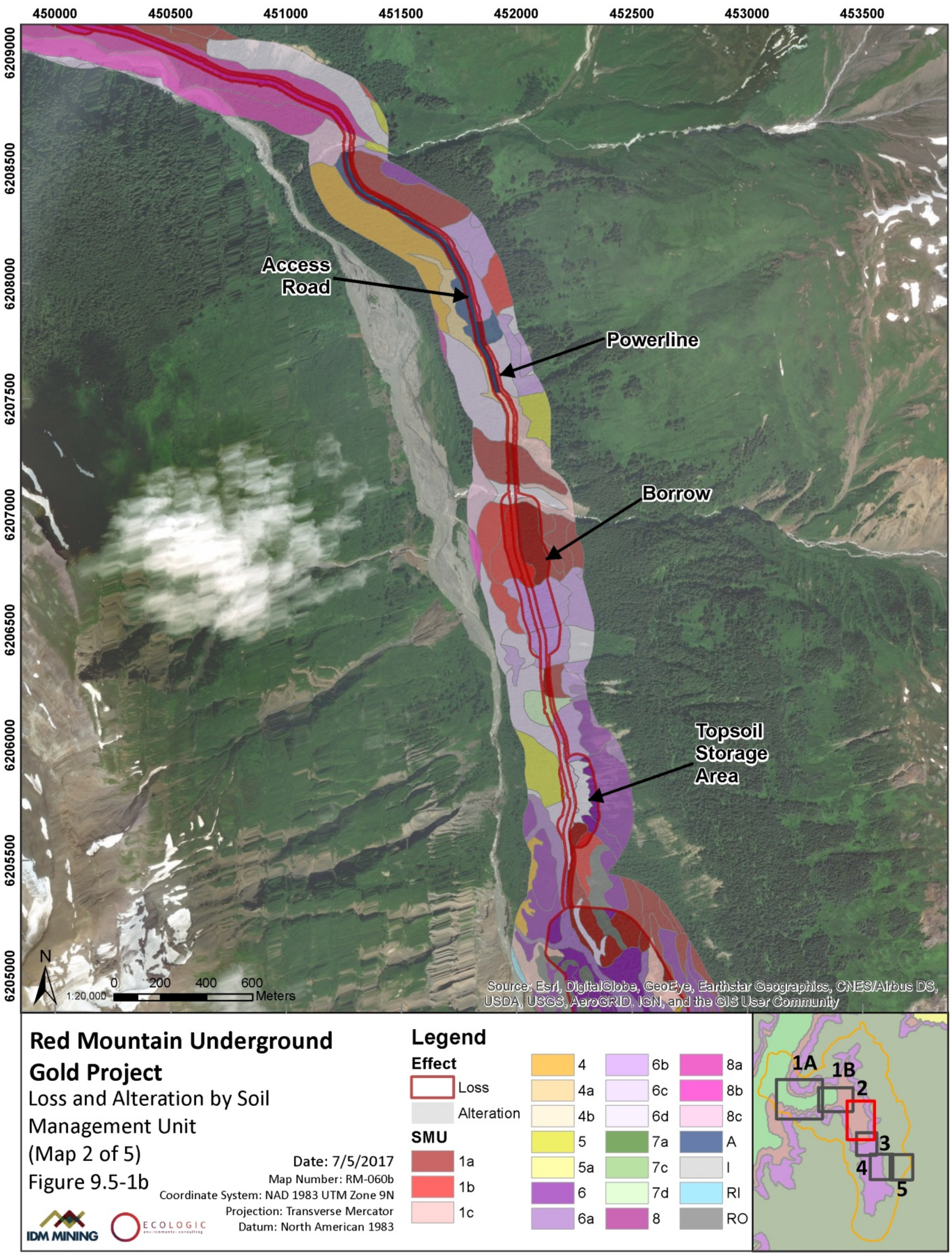
Direct soil loss refers to the soil associated with the direct Project footprint with the addition of a 50 m buffer on non-road infrastructure to account for changes in orientation, laydown areas, and other variances that may occur. The assessment assumes that any soil associated with the direct Project footprint is lost. Direct soil loss due to the Project is 219.5 ha (Table 9.5-3). The majority of this is associated with the Access Road (34.9 ha), Haul Road (37.8 ha), rock quarry (42.8 ha), and Powerline (26.6 ha) (Table 9.5-4).

This is considered a conservative estimate of soil loss, as some of this soil may be eligible for salvage (Section 9.6.1). As well, some of the material considered “soil” has little ecological value (Table 9.4-4). As an aggregate, these ecologically valuable soil SMUs are considered a VC in Volume 3, Chapter 15 (Vegetation and Ecosystems Effects Assessment), where additional analysis and quantification of effects for these soils is undertaken. Finally, the 50 m buffer around infrastructure and the delineated road footprint may not be subject to full soil loss due to the Project.

Mitigation measures for Direct Soil Loss are discussed in Section 9.6.

**Figure 9.5-1: Loss and Alteration by Soil Management Unit**



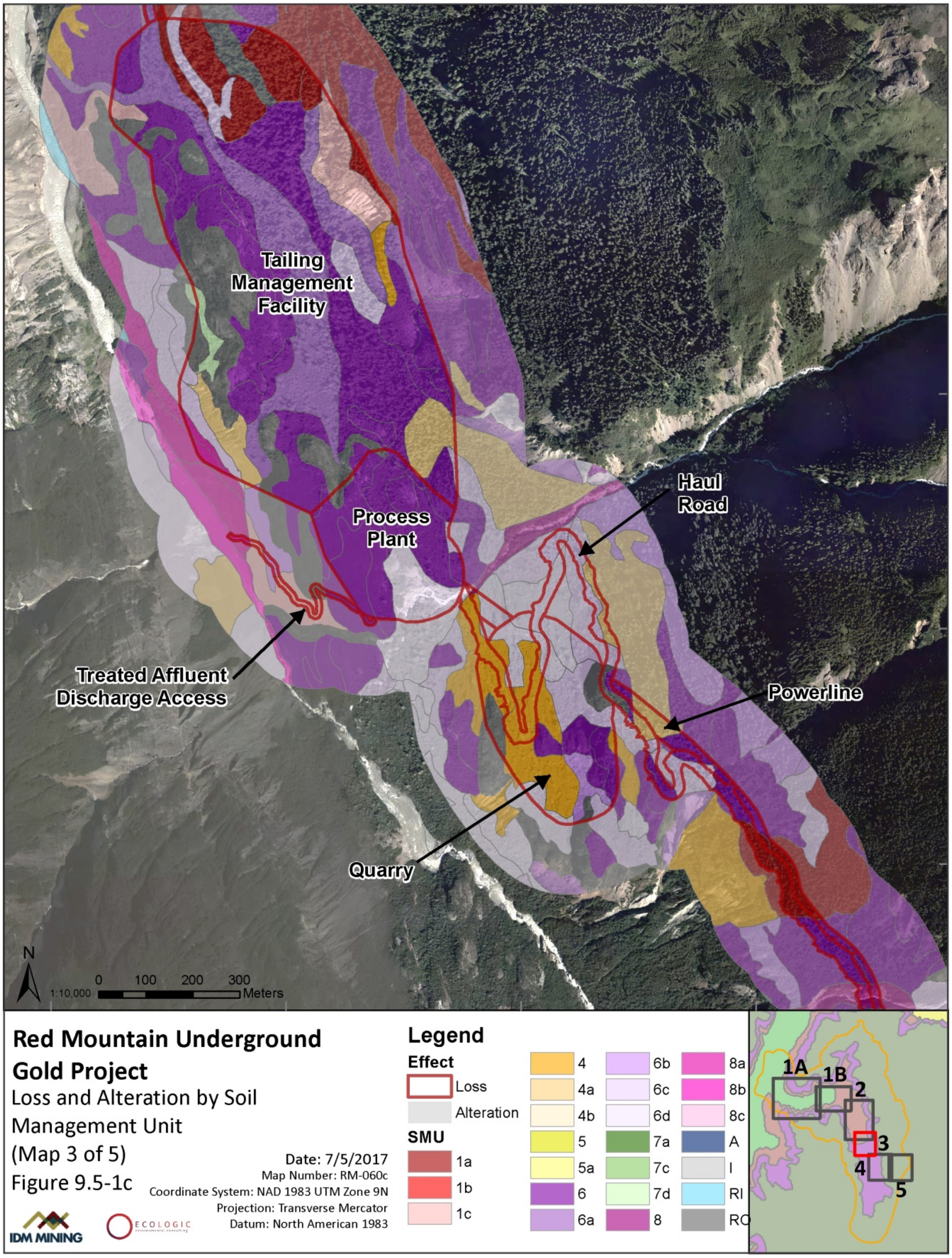



**Red Mountain Underground Gold Project**

Loss and Alteration by Soil Management Unit (Map 2 of 5)

Figure 9.5-1b

Date: 7/5/2017
Map Number: RM-060b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983


452000
452500
453000
453500
6205000
6204500
6204000
6203500
Tailing Management Facility
Process Plant
Haul Road
Treated Affluent Discharge Access
Powerline
Quarry
N
1:10,000
0 100 200 300 Meters
Red Mountain Underground Gold Project
Loss and Alteration by Soil Management Unit
(Map 3 of 5)
Figure 9.5-1c
Date: 7/5/2017
Map Number: RM-060c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
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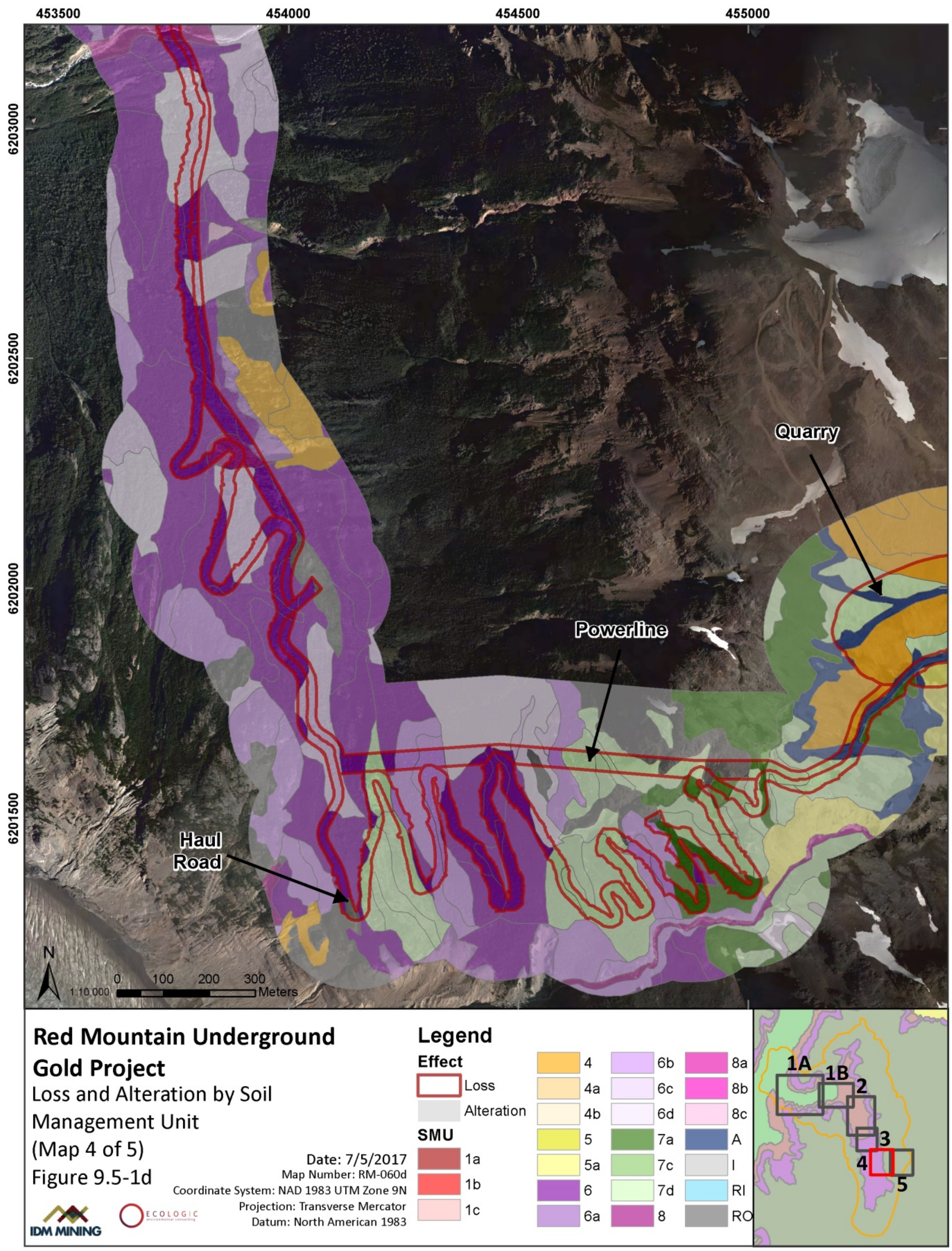
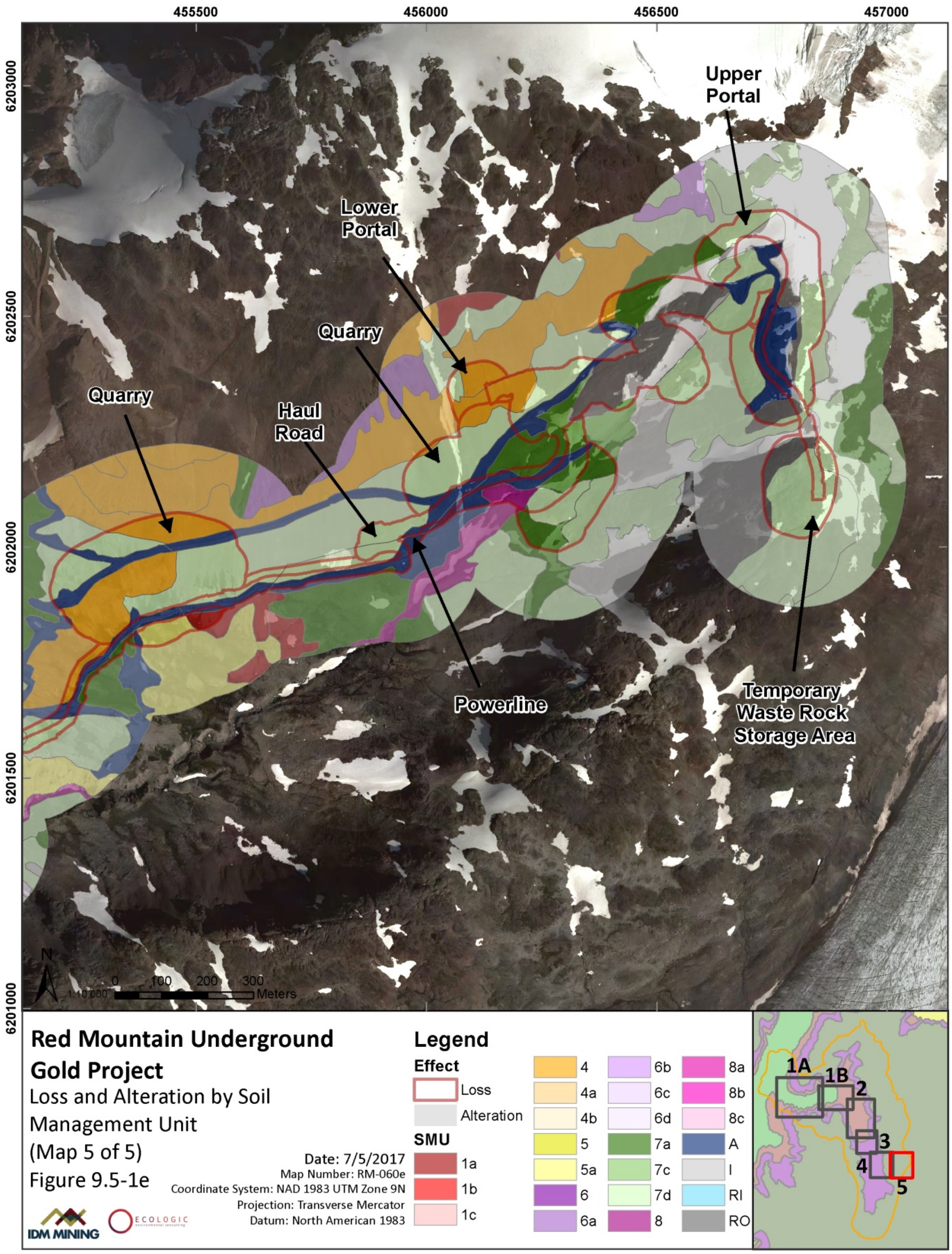
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5


453500
454000
454500
455000
6203000
6202500
6202000
6201500
Quarry
Powerline
Haul Road
N
0 100 200 300
1:10,000 Meters
Red Mountain Underground Gold Project
Loss and Alteration by Soil Management Unit
(Map 4 of 5)
Figure 9.5-1d
Date: 7/5/2017
Map Number: RM-060d
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
8
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5


455500
456000
456500
457000
6203000
6202500
6202000
6201500
6201000
Upper Portal
Lower Portal
Quarry
Quarry
Haul Road
Powerline
Temporary Waste Rock Storage Area
N
0 100 200 300 Meters
1:10,000
Red Mountain Underground Gold Project
Loss and Alteration by Soil Management Unit
(Map 5 of 5)
Figure 9.5-1e
Date: 7/5/2017
Map Number: RM-060e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
8
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5

#### 9.5.4.1.2 Soil Erosion

Soil erosion can lead to additional soil loss, especially in areas beyond the direct Project footprint that have been cleared. The greatest potential for soil erosion will occur during the Construction and Closure and Reclamation Phases due to the amount of ground disturbance and exposed soil surfaces. Given that a buffer for loss has been established around the Project infrastructure, it is not anticipated that soil erosion will result in losses of soils not accounted for in Section 9.5.4.1.1.

#### 9.5.4.1.3 Increase in Mass Wasting Events

Quantification of losses of soil due to increases in mass wasting events is not possible to undertake, as it is the goal of the Project that no increases in mass wasting occur due to consequences to the environment, Project infrastructure, and worker safety. A full discussion of mitigation strategies to achieve this goal is presented in Section 9.6.1.

### 9.5.4.2 Soil Quality

#### 9.5.4.2.1 Soil Compaction

The greatest potential for soil compaction is also associated with construction and closure and reclamation activities because soil is most extensively moved and disturbed during these phases. These are also the times when earth-moving machinery is most likely to travel over the soil storage berms and in areas outside of the main transportation corridors.

#### 9.5.4.2.2 Fugitive Dust

In order to characterize the chemical composition of the fugitive dust, it was assumed that the fugitive dust metals profile will be similar to that of the materials used to build the road. This assumption was made as it is assumed that the vast majority of dust generated during construction and operations will be due to road use. Lab analysis of 21 surface soil samples along the Access and Haul Roads indicate eight metals in exceedance of the CCME concentration criteria levels set for Agricultural Land Use. The metal species include the following:

- Arsenic (all 21 samples, maximum exceedance of 10x);
- Chromium (4 of 21 samples, maximum exceedance of 1.2x);
- Copper (14 of 21 samples, maximum exceedance of 3x);
- Molybdenum (10 of 21 samples, maximum exceedance of 7x);
- Nickel (4 of 21 samples, maximum exceedance of 1.1x);
- Selenium (17 of 21 samples, maximum exceedance 5x);
- Uranium (1 sample, maximum exceedance of slightly above 1x); and
- Zinc (1 sample, maximum exceedance of 1.2x).

Using the less-stringent CCME Industrial Land Use criteria, the list of metals of concern is reduced from eight to three, as follows:

- Arsenic (all samples, maximum exceedance of 10x), same criteria as per Agricultural Use;
- Copper (4 of 21 samples, maximum exceedance of 2.1x); and
- Selenium (7 of 21 samples, maximum exceedance 1.6x).

Elevated soil metal species appear generally similar to those noted for local geologic materials as determined for static testing as part of ML/ARD investigations (SRK Consulting, 2016). Analysis of rock samples showed elevated element concentrations of As and Cu across all 13 rock units, and elevated Se concentrations in 8 of the 13 rock units.

Fugitive dust deposition was modelled for operations, the Project phase with maximum dust potential. Dust deposition was modelled at various locations (Table 9.5-5), including all rare plant and lichen locations, soil sample locations, and at 25 m from the edge of the Project footprint (chosen as it represented the location where maximum dust deposition was assumed to occur). The AAQA guidelines of 1.7 milligrams per squared decametre per day ($mg/dm^2/day$) was used as the target benchmark at which point negative effects could be expected to occur. Background (baseline) dustfall was estimated to be 0.56 $mg/dm^2/day$. Modeled estimates for daily dust deposition during operations was estimated for both wet deposition and dry deposition.

Results of the modelling show that dustfall ranges from 0.56 to 1.24 $mg/dm^2/day$ for Operation. Dust deposition and SMU locations are presented in Figure 9.5-2. The highest levels of dust accumulation are around the Access Road (1.3 $mg/dm^2/day$). None of the modelled locations showed an exceedance of the AAQA guideline of 1.7 $mg/dm^2/day$. However, in order to account for potential accumulation of metals already elevated in soils, 150 m surrounding all Project infrastructure is considered to be altered by fugitive dust.

#### 9.5.4.2.3 Soil Acidification

Typically, acid critical loads for soils are calculated to determine soil sensitivity to alteration due to acidification. A critical load is the maximum amount of acid a soil can neutralize prior to chemical changes occurring. Neutralizing capacity is largely dependent on the base cation weathering rate, which is inherited from the mineral composition of the parent material. Soil sensitivity was determined by those factors that affect buffering capacity, including bedrock mineralogy, soils texture, drainage, soil depth, and organic matter content in the A horizon. SMUs were used as the basis to calculate soil sensitivity, as the majority of these factors are employed when deriving SMU categories (Table 9.5-6).

**Table 9.5-5: Fugitive Dust and Acidification Results**

| Receptor Description | Background Dustfall ($mg/dm^2/day$) | Final Maximum Dry Deposition ($mg/dm^2/day$) | Final Maximum Wet Deposition ($mg/dm^2/day$) | Final Maximum Total Dust Fall ($mg/dm^2/day$) | AAQO ($mg/dm^2/day$) |
|---|---|---|---|---|---|
| *Collema ceraniscum Nyl.* | 0.56 | **0.65** | **0.58** | **0.65** | 1.7 |
| *Pohlia erecta (Limpr.) H.Lindb.* | 0.56 | **0.57** | **0.56** | **0.57** | 1.7 |
| *Stereocaulon botryosum Ach.* | 0.56 | **0.59** | **0.57** | **0.59** | 1.7 |
| *Santessoniella arctophila (Th.Fr.) Henssen* | 0.56 | **0.61** | **0.57** | **0.61** | 1.7 |
| *Stereocaulon botryosum Ach.* | 0.56 | **0.59** | **0.57** | **0.59** | 1.7 |
| *Mielichhoferia elongata (Hoppe & Hornsch.) Nees & Ho* | 0.56 | **0.63** | **0.57** | **0.63** | 1.7 |
| *Mielichhoferia mielichhoferiana (Funck) Loeske* | 0.56 | **0.63** | **0.57** | **0.63** | 1.7 |
| *Bryoria nitidula (Th. Fr.) Brodo & D. Hawksw.* | 0.56 | **0.60** | **0.57** | **0.60** | 1.7 |
| *Cetraria nigricans Nyl.* | 0.56 | **0.63** | **0.58** | **0.63** | 1.7 |
| *Grimmia atrata Miel. ex Hornsch.* | 0.56 | **0.61** | **0.57** | **0.61** | 1.7 |
| *Schistidium venetum H.H.Blom* | 0.56 | **0.61** | **0.57** | **0.61** | 1.7 |
| *Niphotrichum pygmaeum (Frisvoll) Bednarek-Ochyra &* | 0.56 | **0.61** | **0.57** | **0.61** | 1.7 |
| *Imbribryum gemmiparum (De Not.) J.R. Spence? (needs* | 0.56 | **0.60** | **0.57** | **0.60** | 1.7 |
| *Cinclidium stygium Sw.* | 0.56 | **0.72** | **0.73** | **0.72** | 1.7 |
| *Niphotrichum pygmaeum (Frisvoll) Bednarek-Ochyra &* | 0.56 | **0.74** | **0.70** | **0.74** | 1.7 |
| *Stereocaulon botryosum Ach.* | 0.56 | **0.74** | **0.70** | **0.74** | 1.7 |
| *Cladonia macrophylla (Schaer.) Stenh.* | 0.56 | **0.60** | **0.60** | **0.60** | 1.7 |

| Receptor Description | Background Dustfall (mg/dm²/day) | Final Maximum Dry Deposition (mg/dm²/day) | Final Maximum Wet Deposition (mg/dm²/day) | Final Maximum Total Dust Fall (mg/dm²/day) | AAQO (mg/dm²/day) |
|---|---|---|---|---|---|
| *Cladonia coccifera (L.) Willd.* | 0.56 | **0.58** | **0.58** | **0.58** | 1.7 |
| *Botrychium crenulatum W.H.Wagner* | 0.56 | **0.58** | **0.58** | **0.58** | 1.7 |
| *Niphotrichum pygmaeum (Frisvoll) Bednarek-Ochyra &* | 0.56 | **0.57** | **0.58** | **0.57** | 1.7 |
| *Fuscopannaria ahlneri (P.M.Jørg.) P.M.Jørg.* | 0.56 | **0.58** | **0.59** | **0.58** | 1.7 |
| *Leptogidium dendriscum (Nyl.) Nyl.* | 0.56 | **0.58** | **0.59** | **0.58** | 1.7 |
| *Taraxacum sp. nov. (short)* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Botrychium spathulatum W.H.Wagner* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Umbilicaria lambii Imshaug* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Taraxacum speculorum Björk ined.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Lobaria retigera (Bory) Trevis.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Santessoniella arctophila (Th.Fr.) Henssen* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Pohlia pacifica A.J.Shaw* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Ptychostomum inclinatum (Sw. ex Brid.) J.R.Spence* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Baeomyces carneus Flörke* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Leptogium tenuissimum (Dicks.) Körb.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Placynthium asperellum (Ach.) Trevisan* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Collema crispum (Hudson) F. H. Wigg. cfr.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Heterodermia unknown sp.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Grimmia donniana Sm.* | 0.56 | **0.60** | **0.57** | **0.60** | 1.7 |

| Receptor Description | Background Dustfall ($mg/dm^2/day$) | Final Maximum Dry Deposition ($mg/dm^2/day$) | Final Maximum Wet Deposition ($mg/dm^2/day$) | Final Maximum Total Dust Fall ($mg/dm^2/day$) | AAQO ($mg/dm^2/day$) |
|---|---|---|---|---|---|
| *Micranthes separataBjörk ined.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Taraxacum sp. nov. (tall)* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Peltolepis quadrata (Saut.) K.Müller* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Sauteria alpina (Nees) Nees* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Nardia compressa (Hook.) Gray* | 0.56 | **0.64** | **0.58** | **0.64** | 1.7 |
| *Pohlia cardotii (Renauld) Broth.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Taraxacum amarum Björk ined.* | 0.56 | **0.59** | **0.59** | **0.59** | 1.7 |
| *Cladonia pseudalcicornis Asahina* | 0.56 | **0.65** | **0.58** | **0.65** | 1.7 |
| *Nephroma isidiosum (Nyl.) Gyeln.* | 0.56 | **0.58** | **0.58** | **0.58** | 1.7 |
| *Lobaria oregana (Tuck.) Müll.Arg.* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Anemone narcissiflora var. vilosissima (DC.) Hultén* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |
| *Anemone narcissiflora var. vilosissima (DC.) Hultén* | 0.56 | **0.56** | **0.56** | **0.56** | 1.7 |

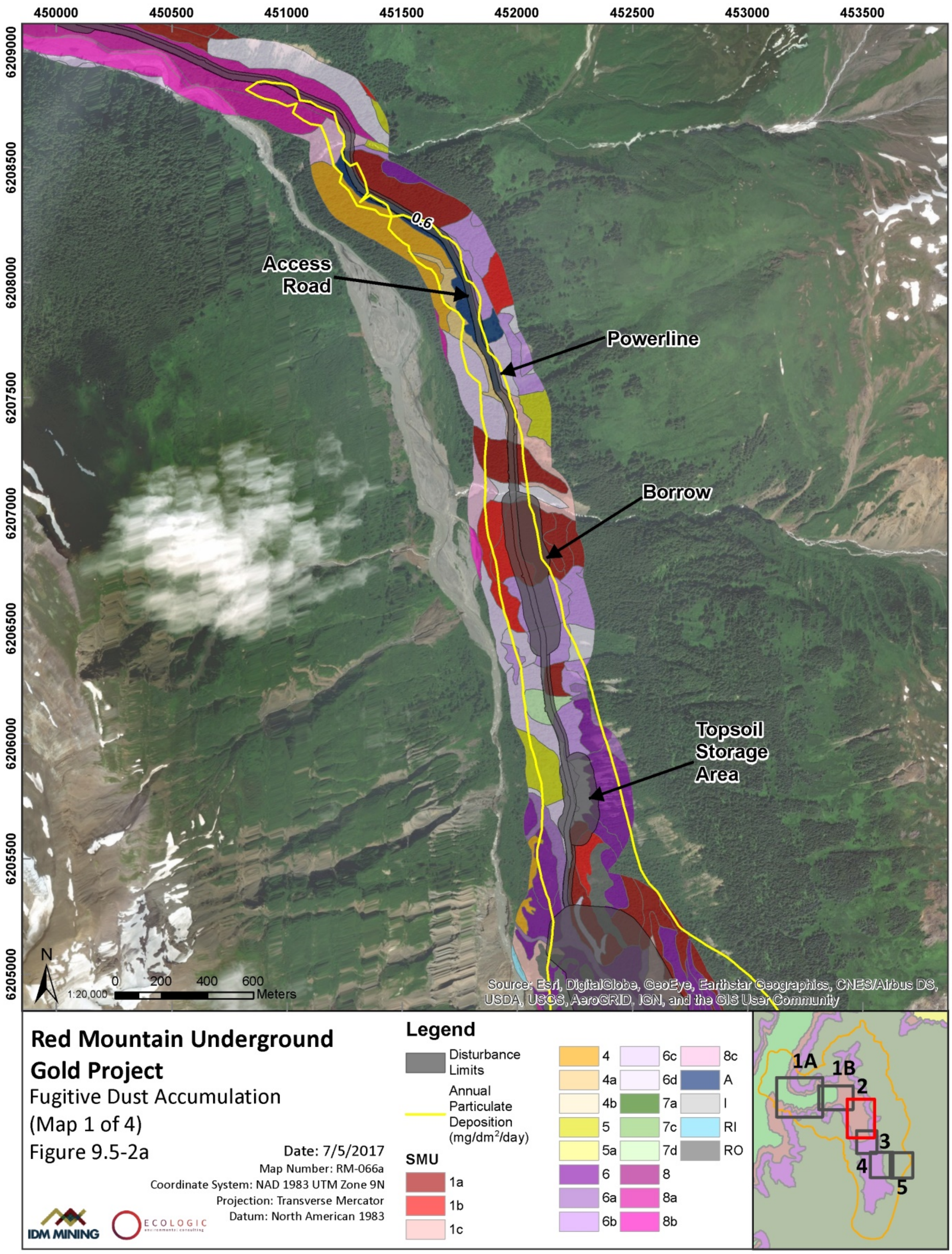
**Table 9.5-6: SMU Sensitivity to Acidification**

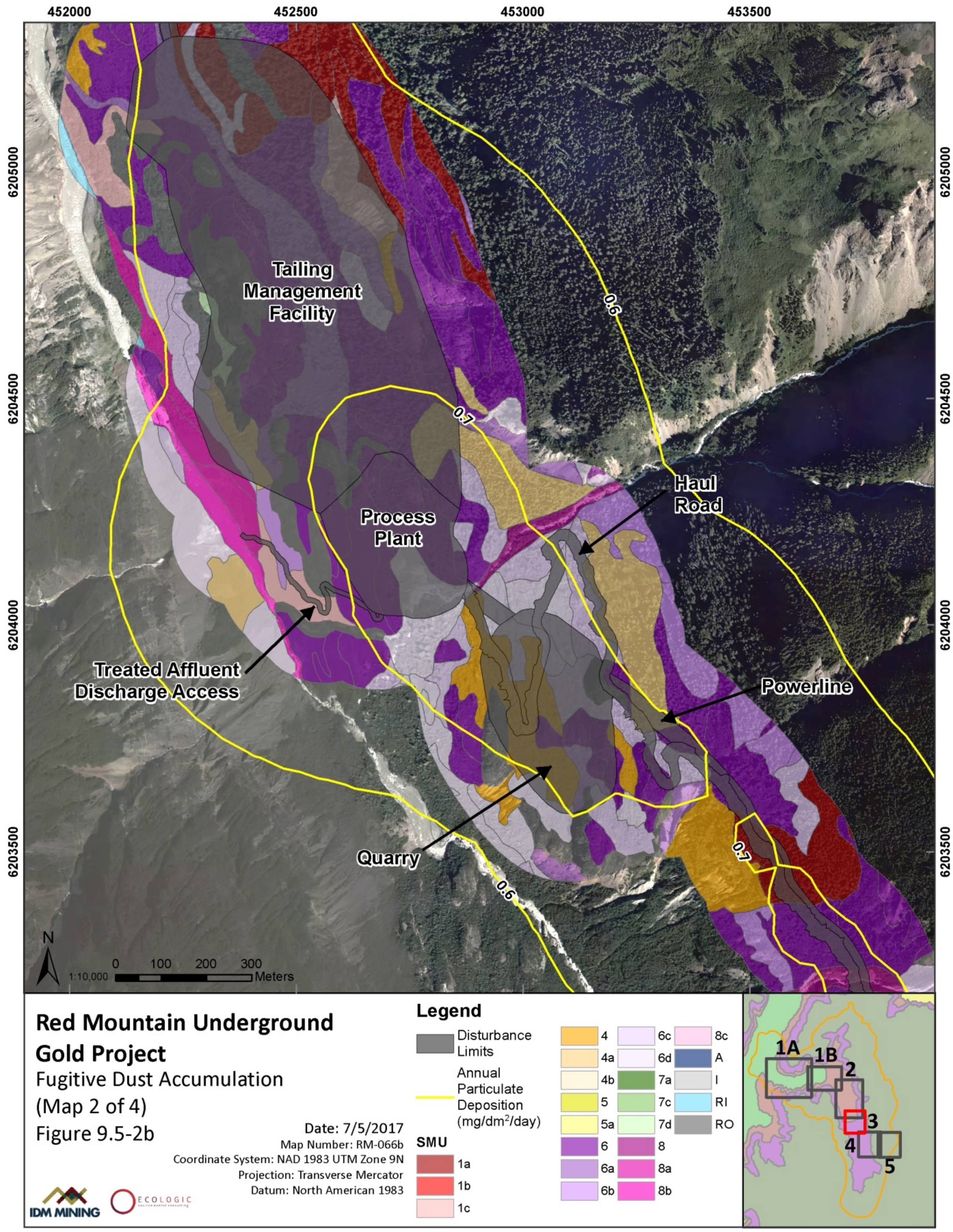
| SMU | Description | Ecologically Valuable | Acid Sensitivity |
|---|---|---|---|
| A | Anthropogenic; human-disturbed soil and landscape; includes roads and maintained clearings; O.R (little development). | No | NA |
| 1a | Well-rapidly drained; silty, sandy, (LS/SL) often gravelly, glacial till/colluvium; average to below-average nutrients and moisture; moderate to gentle slope gradient; all slope positions; O.HFP, O.DYB, and E.DYB. | Yes (Moderate) | Moderate |
| 1b | Mid-to lower/(level) slope position; mainly loamy (L)-SL tills on 5-40% slope gradient; moderate productivity forests; moderately deep (50-150 cm, and moderately well to imperfect drainage; O.EB and O.MB (thin Ah,<15cm); some weak gleying common. | Yes (moderate) | Moderate |
| 1c | Mesic, well drained Podzols and Brunisols with a veneer of silt loam at surface; surface mineral material prone to surface water erosion; slightly more productive forest types; common gullying present. | Yes (moderate) | Moderate |
| 4 | Fine-textured SiL-L glacial till and colluvium soil material; surface 30+cm contains rooting then common overlying compacted SiCL soil layers (tills) and root restricting; weak to prominent mottling; soil failures or moving slopes common, including solifluction (S). O.EB, GL.EB, O.DYB, and GL.DGL. | Yes (moderate) | Moderate |
| 4a | Organic-enriched surface soils (Ah or darker brown Bm horizons, 5-30 cm depth); productive forests and soils often form near richer ecosystems; moderately well drained soil types; seepage common; lower and toe slopes; GL.MB, O.MB, and O.SB. | Yes (high) | Moderate |
| 4b | Moist and slight receiving sites in often >80cm deep; rooting depth often >50-60 cm. | Yes (high) | Moderate |
| 4c | Deep soils (~1-2 m depth) often fine-textured deposits in lower /toe slope position; erosive silt loam to SiCL; rare type. | Yes (high) | Moderate |
| 5 | Level to gently undulating FG sand and gravel terraces; relatively loose soils with high coarse fragment content common>50%; rooting depth shallow, often <25 cm; O.HFP and E.DYB. | Yes (moderate) | High |

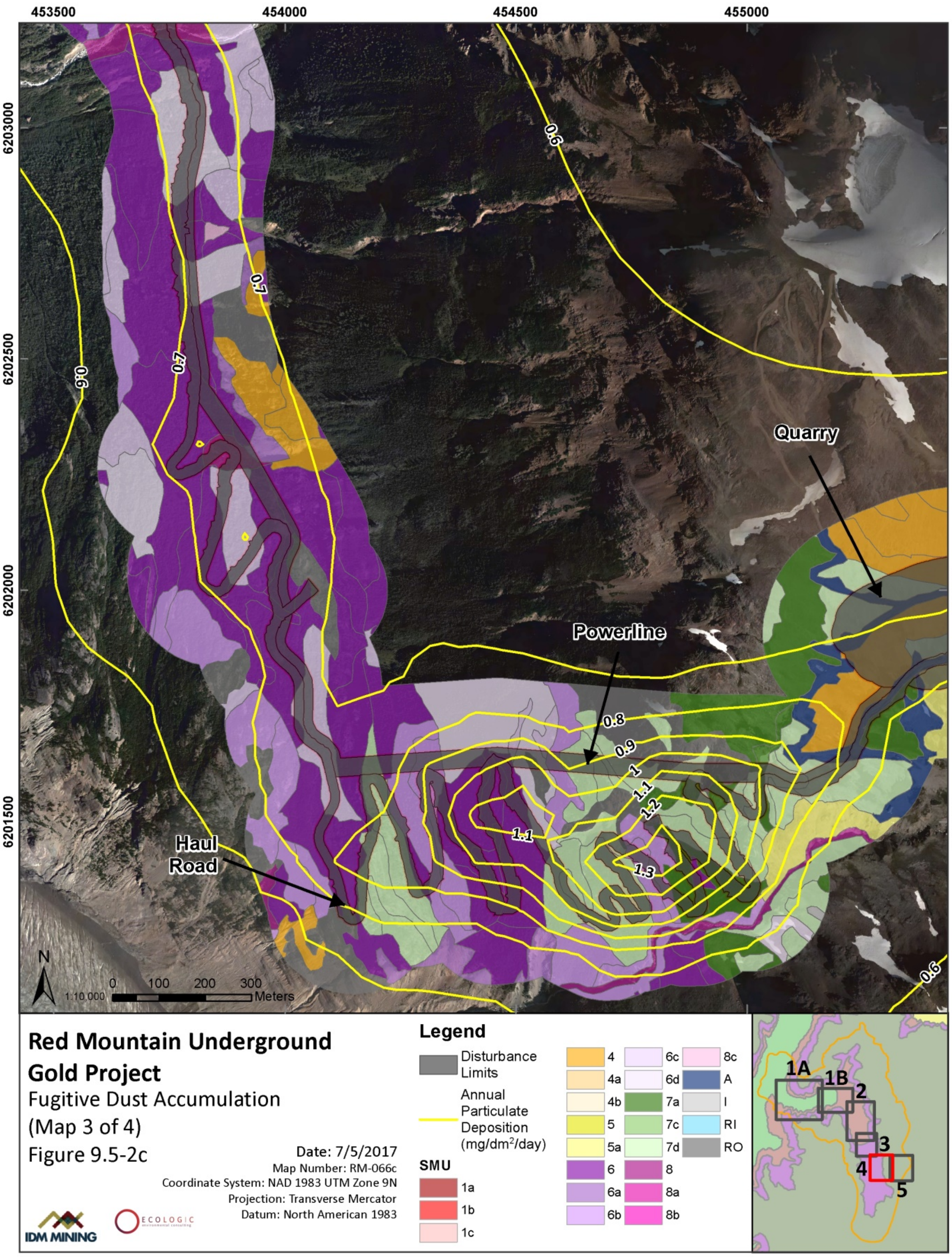
| SMU | Description | Ecologically Valuable | Acid Sensitivity |
|---|---|---|---|
| 5a | Glaciofluvial materials on steeper 30-60% gradients (e.g. rolling terrain or hummocky eskers); well-rapid drained sand and gravel soils; relatively nutrient-poor pine sites and prone to drought in very dry years; can occur on steep slopes and rapid debris failures common along slopes of steep FG terrain; rooting depth often <15-25 cm; O.HFP, E.DYB, O.DYB, and O.R. | Yes (poor) | High |
| 6 | Shallow colluvium, saprolite (rotten rock) or morainal veneers (<1 m) over bedrock; loose angular C.Frags on steep slopes; upper and crest slope position; often acidic red Podzolic soils in heath/heather vegetation or submesic forests in lower elevations; O.HFP, E.DYB, and O.R. | Yes (poor) | High |
| 6a | Rubbly bouldery talus materials, 75-90% coarse fragment volume; all bedrock types; slope gradient commonly 60-100+%; texture LS/SL/SiL, C.Frag volume variable but often >50%; O.R, O.DYB, and O.MB (in alder stands). | Yes (poor) | High |
| 6b | Moderately deep colluvium (>45-60% slope gradient) with relatively deep (zsCwks), loose soils with abundant coarse frags (>50%); common evidence of soil movement and some seepage; depth variable to bedrock, often >1 m; O.HFP and O.EB. | Yes (moderate) | High |
| 6c | Soil forming in colluvial toe and lower slope position; often very moist to wet with seepage <20 cm; common have dark mineral surface layers >10 cm and running aerated seepage common to devil's club sites; GL.MB, GL.EB, and GL.FHP. | Yes (poor) | Moderate |
| 6d | Active snow avalanche terrain (and older avalanche tracks (common slide alder, club, ferns); subject to failures and flash channel flooding. | Yes (high) | Moderate |
| 6e | Alpine, Sub-alpine shallow, silty saprolite veneer (zDvw/R) with common bedrock. O.DYB- lithic phase; rare SMU type | No | High |
| 7a | Alpine/Sub-alpine moist meadows, late snow melt areas; moist/rich herb and dwarf shrub-dominated; black soils horizons common; Seepage common <30 cm; some Ovx/Dv/R | Yes (high) | High |
| 7b | Shrubby wetlands, Ovb, mostly willow swamps; dark,wet Gleysols or rare shallow Organic soil types | Yes (high) | Moderate |
| 7c | Carex dominated wetland; very rare and small in extent | Yes (high) | Moderate |
| 7d | Alpine/subalpine SM/SZ tundra with heathers with sparse grasses/ lichens; shallow to broken rock, often <40 cm; thin Ah horizons common depth 5-15 cm; Rapid to mw drainage; thicker Ah soils in areas where "Solufluction" occurs; O.DYB, O.HFP, O.MB, and O.SB (lithic phase). | Yes (moderate) | Moderate |

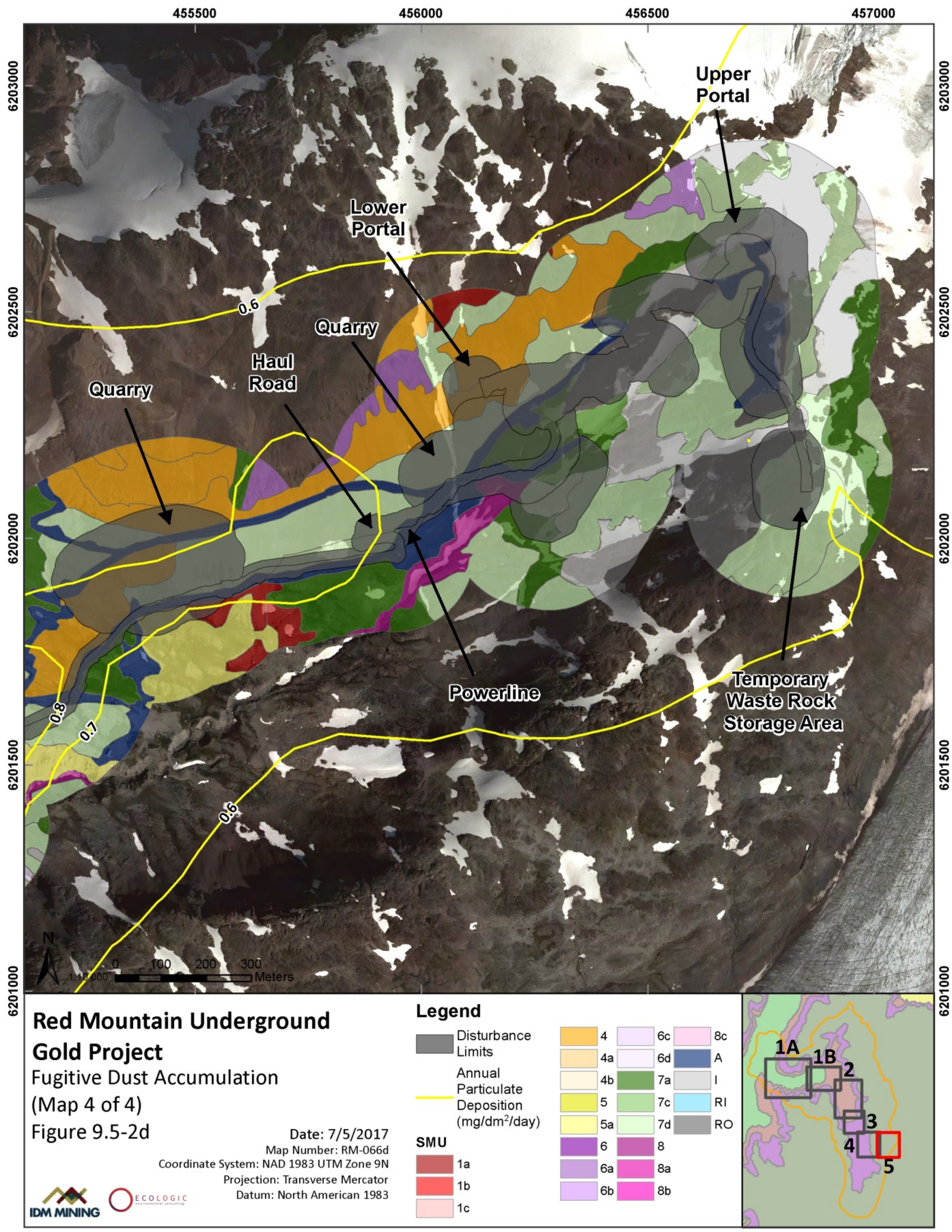
| SMU | Description | Ecologically Valuable | Acid Sensitivity |
|---|---|---|---|
| 8 | Moist to wet mountainous creek draws and side channels; subject to annual or semi-annual flash flooding; often rich, newly deposited soils; highly erosive; usually <10 m width. | No | High |
| 8a | Larger inactive older mid- and high-bench fluvial floodplains; O.EB, O.MB, GL.MB, and GLCU.R. | Yes (high) | High |
| 8b | Active (running water) fluvial deposits FAjp with extensive flooding significant part of every spring; some flash flooding during high rainfall events during main growing season (e.g., Bitter Creek); some low bench fluvial deposits; VH erosion potential; O.R, GL.R, and CU.R. | No | High |
| 8c | Fluvial fans, various textures, CFrag content; often subject to erosion; O.R and O.EB. | No | High |
| RO | Bedrock outcrops, or more common-very thin saprolite or morainal veneers <10cm or Non Soil; Rjk, /Dv, Cvx/Rak common terrain type | No | High |
| I | Ice and snow that lasts late into summer months | NA | NA |
| PO | Shallow open water <3 m depth; some completely evaporate in dry summer periods | NA | NA |

## Figure 9.5-2: Fugitive Dust Accumulation




452000
452500
453000
453500
6205000
6204500
6204000
6203500
Tailing Management Facility
Process Plant
Haul Road
Treated Affluent Discharge Access
Powerline
Quarry
0.6
0.7
N
1:10,000
0 100 200 300 Meters
Red Mountain Underground Gold Project
Fugitive Dust Accumulation
(Map 2 of 4)
Figure 9.5-2b
Date: 7/5/2017
Map Number: RM-066b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Disturbance Limits
Annual Particulate Deposition (mg/dm²/day)
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
8
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5


453500
454000
454500
455000
6203000
6202500
6202000
6201500
Quarry
Powerline
Haul Road
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
N
1:10,000
0 100 200 300 Meters
Red Mountain Underground Gold Project
Fugitive Dust Accumulation (Map 3 of 4)
Figure 9.5-2c
Date: 7/5/2017
Map Number: RM-066c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
Legend
Disturbance Limits
Annual Particulate Deposition (mg/dm²/day)
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
8
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5
IDM MINING
ECOLOGIC


455500
456000
456500
457000
6203000
6202500
6202000
6201500
6201000
Upper Portal
Lower Portal
Quarry
Haul Road
Quarry
Powerline
Temporary Waste Rock Storage Area
0.6
0.8
0.7
0.6
N
0 100 200 300 Meters
Red Mountain Underground Gold Project
Fugitive Dust Accumulation
(Map 4 of 4)
Figure 9.5-2d
Date: 7/5/2017
Map Number: RM-066d
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Disturbance Limits
Annual Particulate Deposition (mg/dm²/day)
SMU
1a
1b
1c
4
4a
4b
5
5a
6
6a
6b
6c
6d
7a
7c
7d
8
8a
8b
8c
A
I
RI
RO
1A
1B
2
3
4
5

Air quality with respect to $NO_2$ and $SO_2$ was modelled at various locations, including all rare plant and lichen locations, soil sample locations, and at 25 m from the edge of the Project Footprint (chosen as it represented the location where maximum acid deposition was assumed to occur, outside of the loss footprint). A background level of 5.0 micrograms per cubic metre per year (µg/m$^3$/year) for $NO_2$ and 2.0 µg/m$^3$/year for $SO_2$ was assumed. The annual ambient air quality objective (AAQO) threshold of 60 µg/m$^3$/year for $NO_2$ and 13 µg/m$^3$/year for $SO_2$ was selected for comparison. Modelled rates for $NO_2$ ranged from 5.04 to 17.48 µg/m$^3$ on an annual basis. This ranges from 1% of baseline to 347% percent of baseline for $NO_2$. Modelled deposition rates for $SO^2$ ranged from 2.0 to 3.7 µg/m$^3$/yr. This ranges from a 0% increase from baseline to 85% increase from baseline. Results of the modelling are presented in Table 9.5-6.

Figure 9.5-3 shows the spatial extent of the sensitive soils and the predicted levels of potential acid inputs within areas of the PFSA that have the highest likely acidification inputs. These areas include the quarry along the Access Road and the upper and lower portals. Also shown in Figure 9.5-3 are the locations of valuable soils sensitive to acidification. Valuable soils were highlighted in order to differentiate them from soils with little productive value, such as those with very high coarse fragments. In total, 14.7 ha of ecologically valuable acid-sensitive soil are subject to the highest modelled rates of more than 11 µg/m$^3$/year. These are concentrated around the quarry near the lower portal.

None of the modelled locations showed an exceedance of the AAQA guidelines. According to modelling, acid deposition associated with the Project is minimal. This is an expected result as the Project is primarily run by electricity and has no combustion sources except for tailpipe emissions from trucks and other heavy equipment.

### 9.5.5 Quantification of Potential Effects – Terrain Stability

The potential effect of decreased stability is elevated incidence and magnitude of geohazards, the effects of which include soil loss, sedimentation of streams and associated alteration of fish habitat, bank scour, damage to Project infrastructure, and health and safety risks to Project personnel. It is not necessary or feasible to assess each of these effects in isolation. Such an assessment would require data inputs regarding sediment load, volume of soil loss, and timing. Rather, the effects assessed will be limited to the potential increase in the incidence and magnitude of geohazards, as related to the potential increase in unstable terrain.

Information regarding terrain stability and geohazard type with respect to the Project infrastructure is presented in Figure 9.5-4 and Table 9.5-7, Table 9.5-8, and Table 9.5-9. The use of loss and alteration in these tables does not indicate the nature of the effect of the geohazard. Rather, loss means within the Project footprint (the lost area as per other ICs), while alteration refers to the 150 m buffer around the Project footprint (the alteration area as per other VCs). The distribution of terrain stability classes with respect to the Project infrastructure is displayed in Figure 9.5-5 and Table 9.5-9. The spatial geodatabase provides the complete information for each polygon and includes attributes for the presence of existing transport and runout zones for rapid and slow mass movement processes.

## Figure 9.5-3: Rates of $NO_2$ Deposition interaction with Acid Sensitive Soils

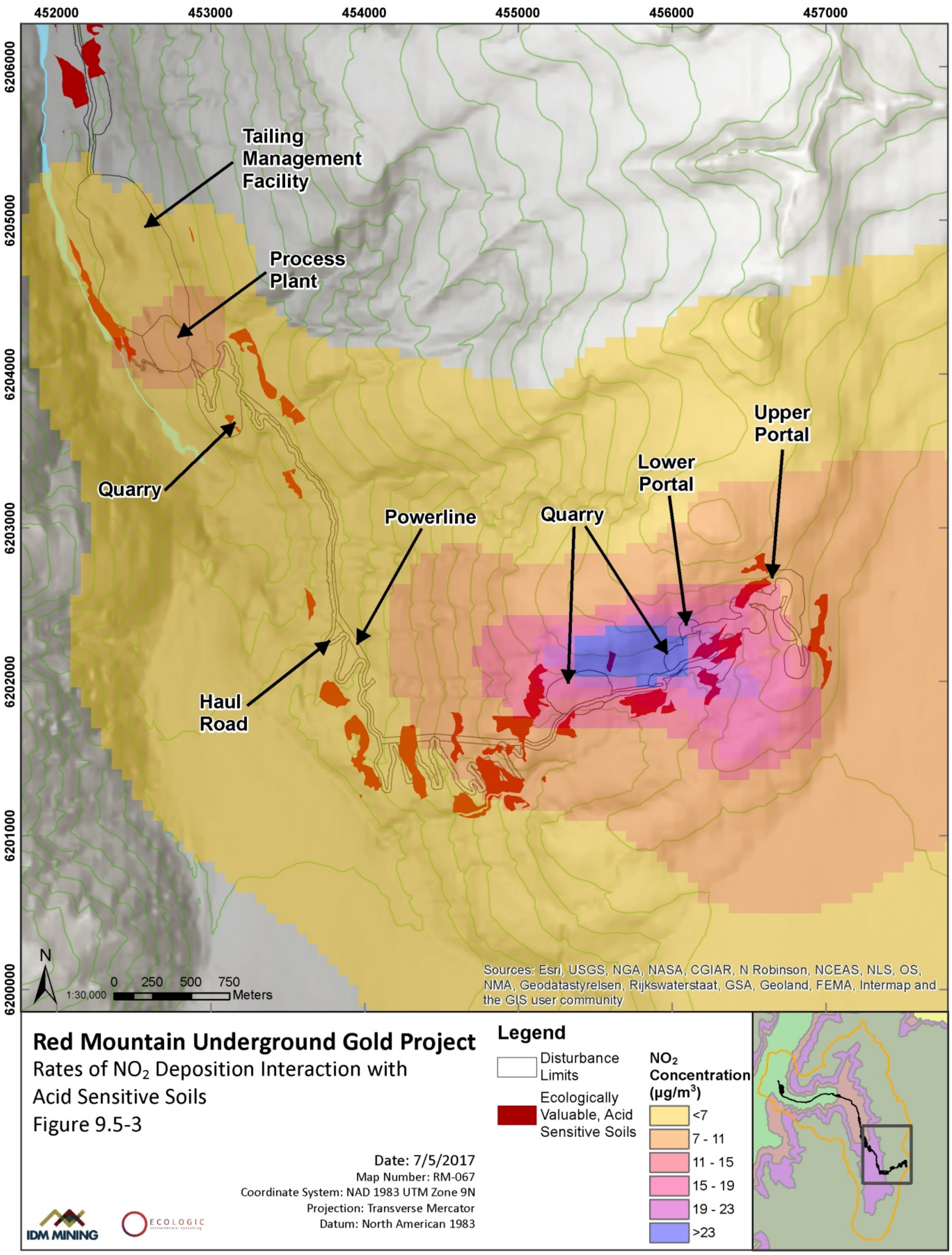
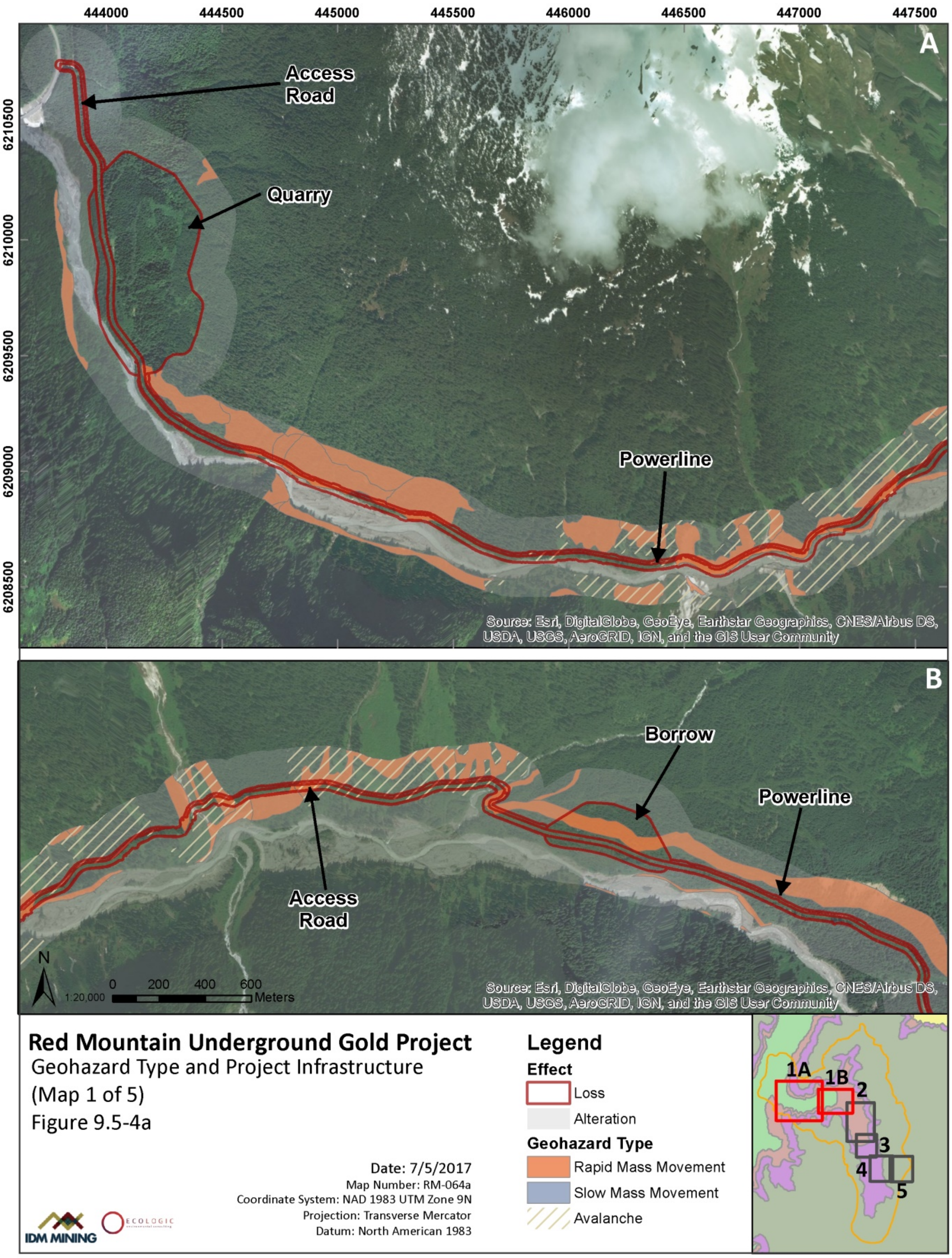
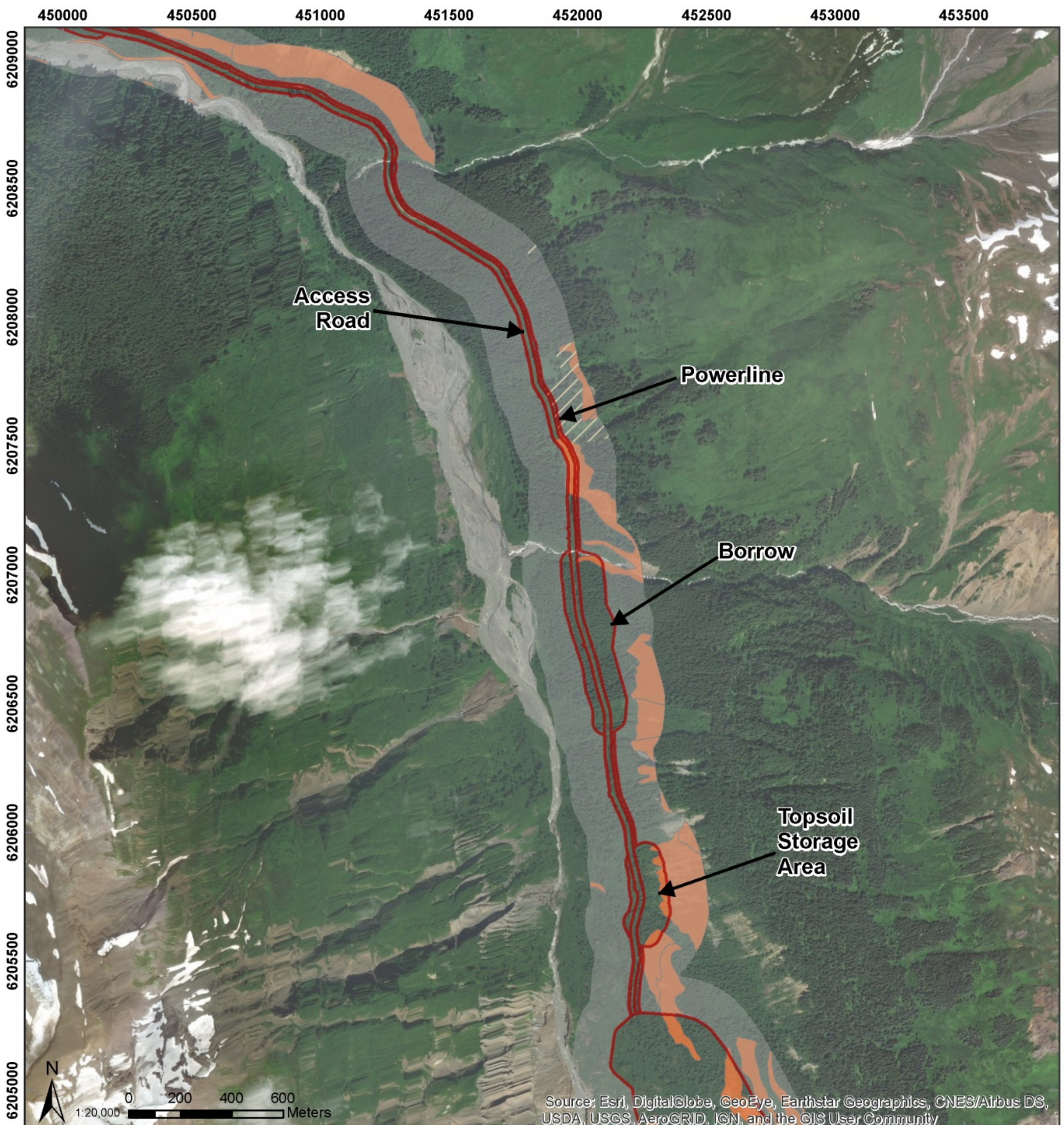


**Figure 9.5-4: Geohazard Type and Project Infrastructure**



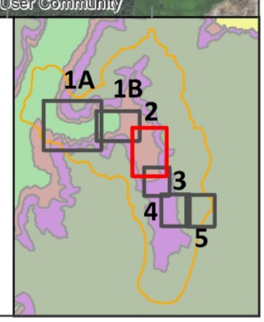


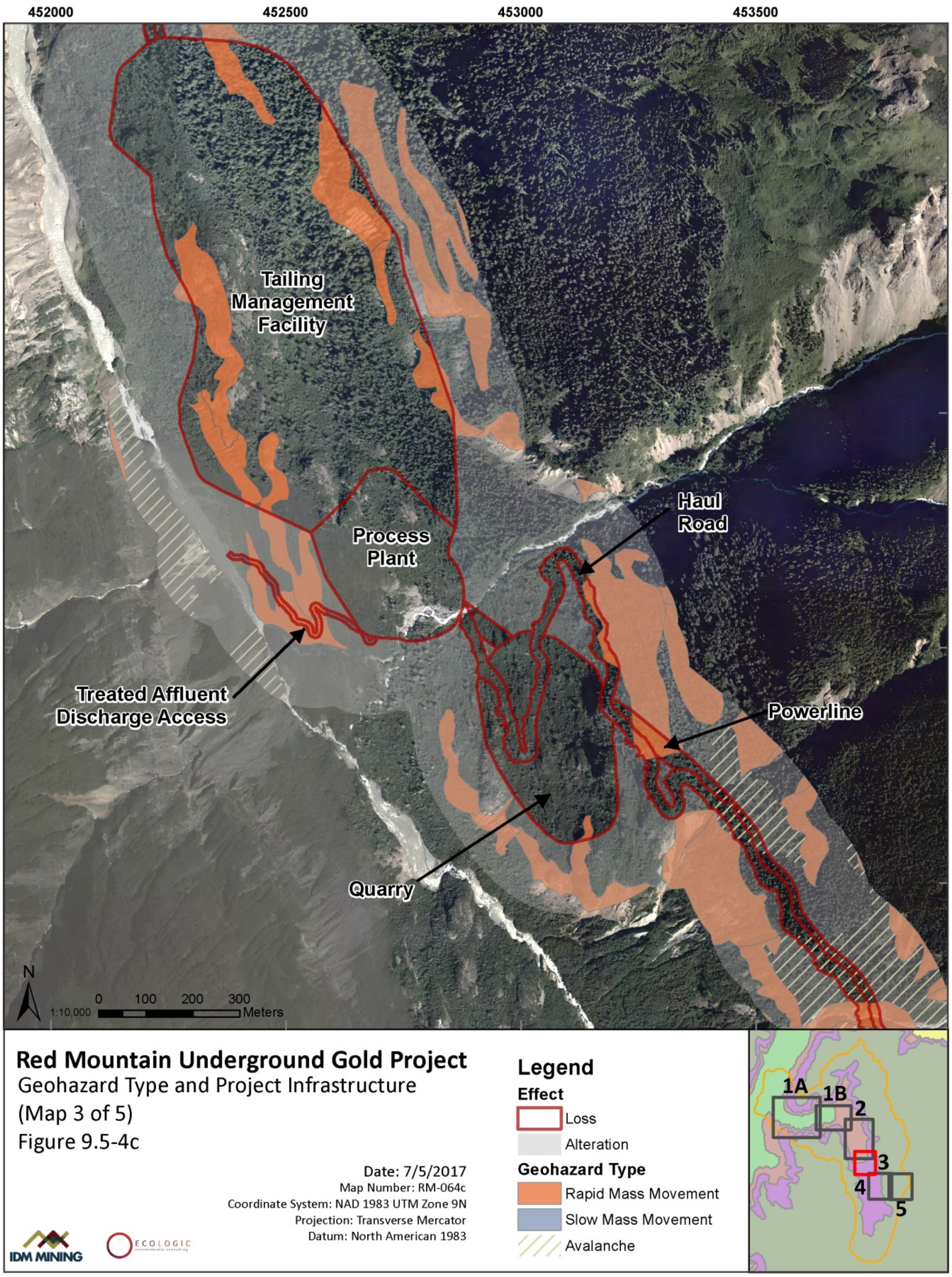

**Red Mountain Underground Gold Project**
Geohazard Type and Project Infrastructure
(Map 2 of 5)
Figure 9.5-4b

Date: 7/5/2017
Map Number: RM-064b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

IDM MINING
ECOLOGIC

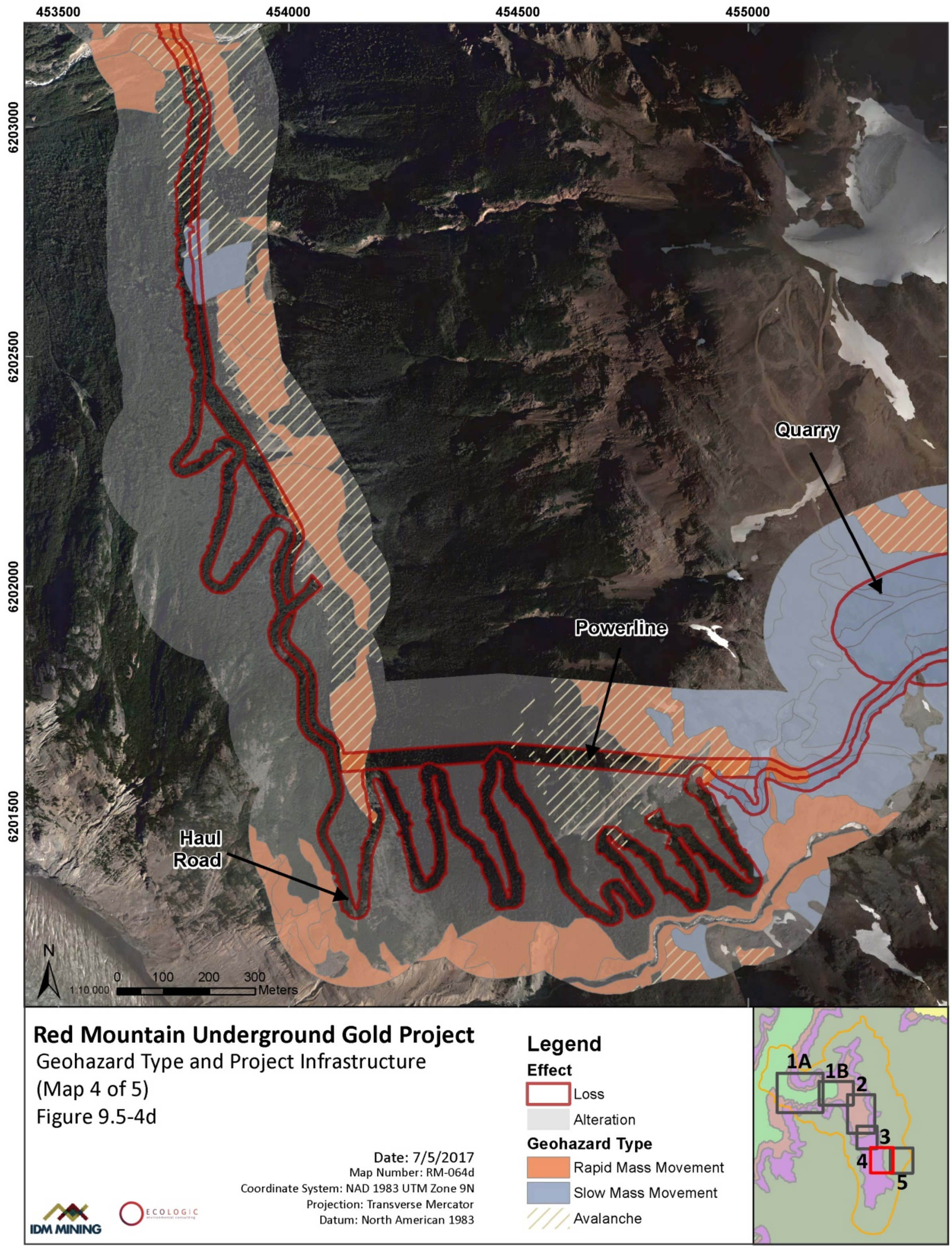
**Legend**
**Effect**
Loss
Alteration
**Geohazard Type**
Rapid Mass Movement
Slow Mass Movement
Avalanche



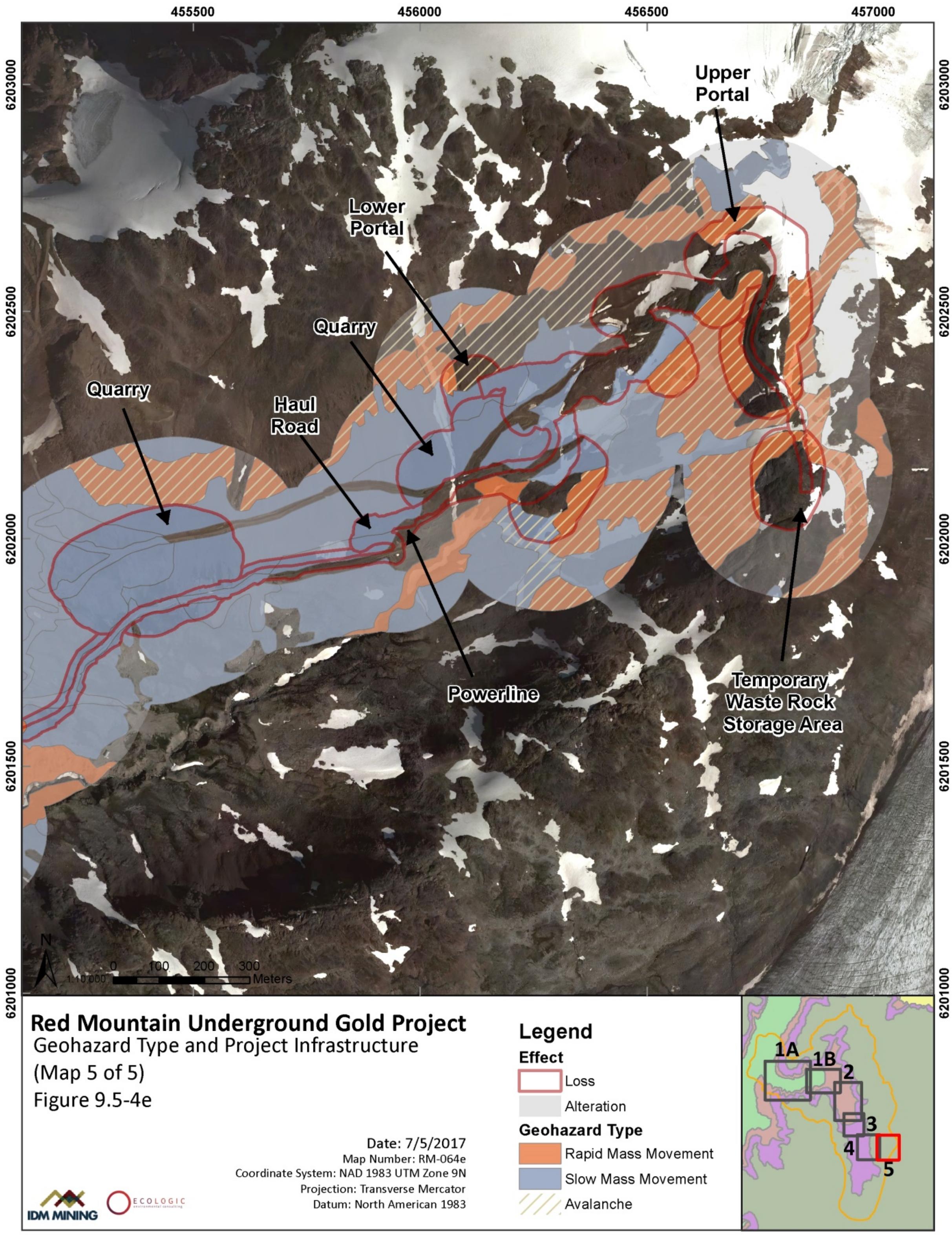



**Red Mountain Underground Gold Project**
Geohazard Type and Project Infrastructure
(Map 3 of 5)
Figure 9.5-4c

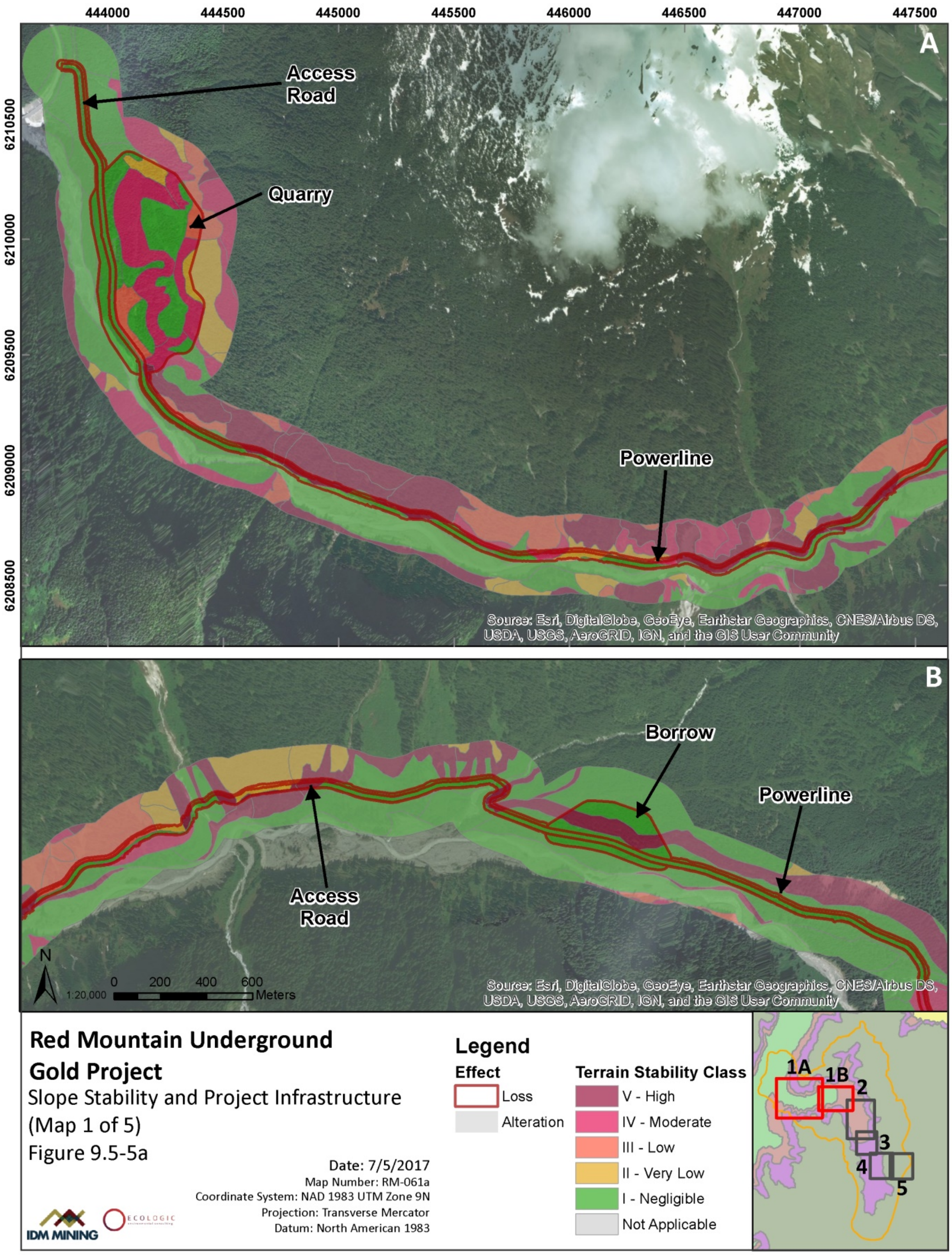
Date: 7/5/2017
Map Number: RM-064c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

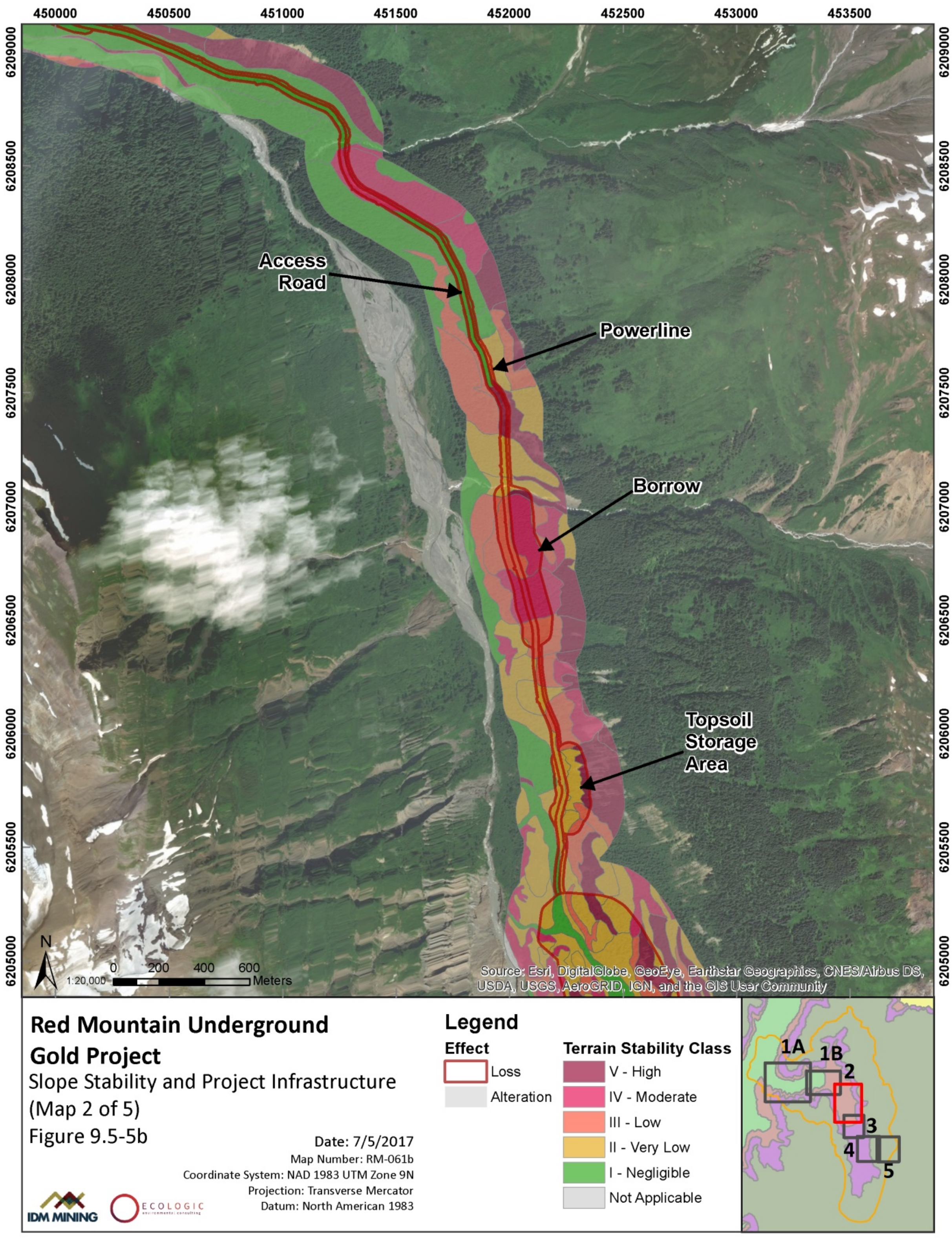


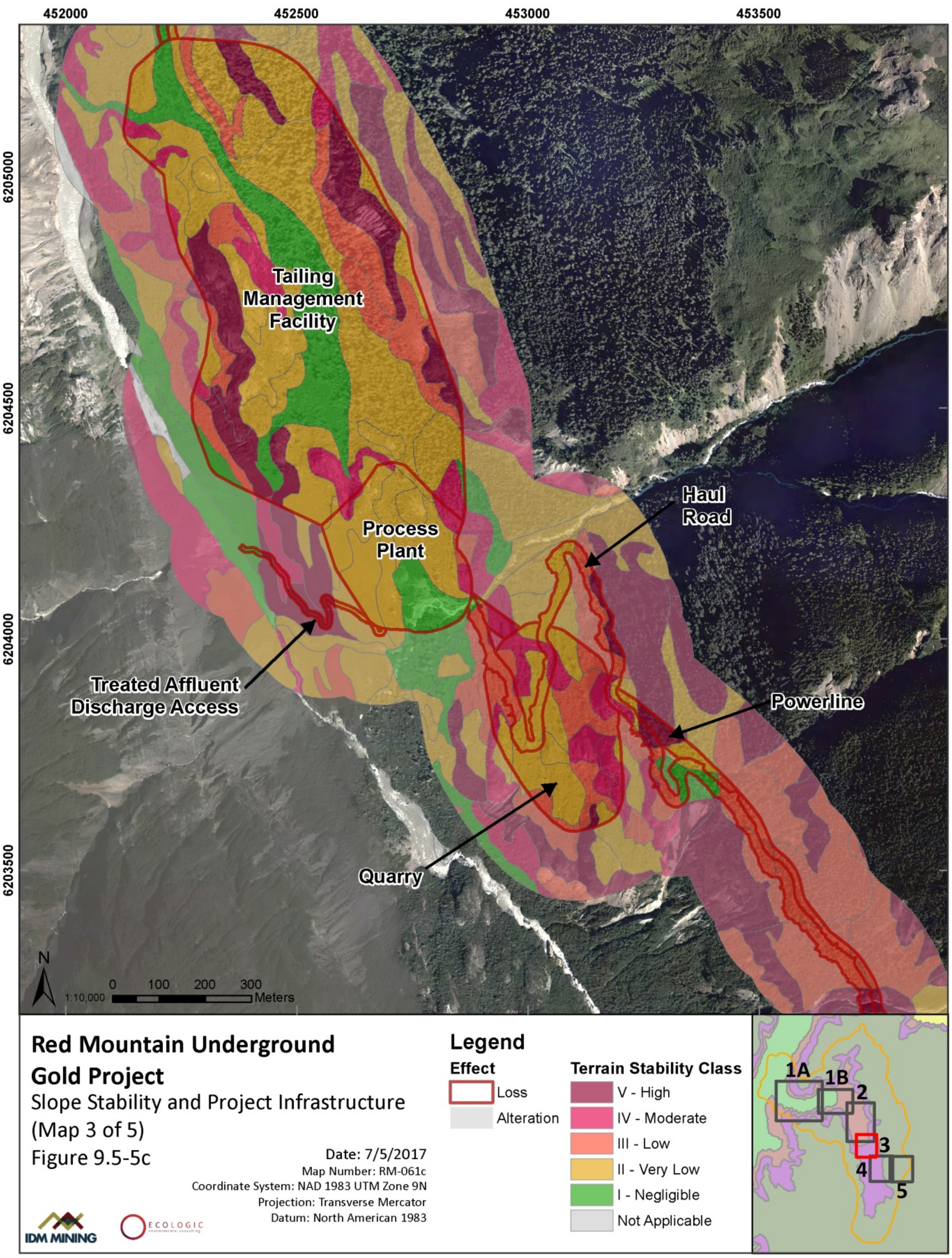

**Red Mountain Underground Gold Project**
Geohazard Type and Project Infrastructure
(Map 4 of 5)
Figure 9.5-4d

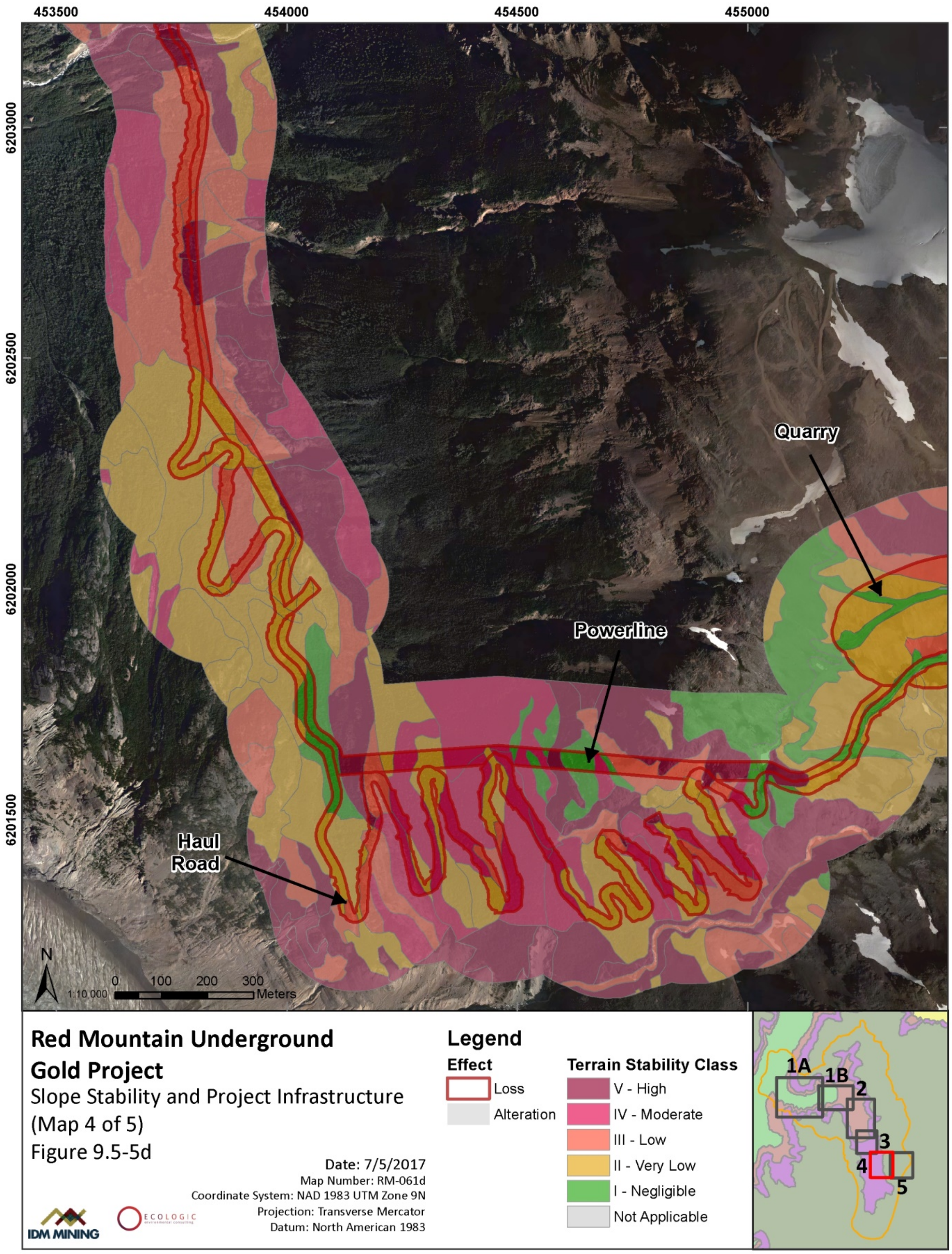

455500
456000
456500
457000
6203000
6202500
6202000
6201500
6201000
Upper Portal
Lower Portal
Quarry
Quarry
Haul Road
Powerline
Temporary Waste Rock Storage Area
N
1:10,000
0 100 200 300 Meters
Red Mountain Underground Gold Project
Geohazard Type and Project Infrastructure
(Map 5 of 5)
Figure 9.5-4e
Date: 7/5/2017
Map Number: RM-064e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
Geohazard Type
Rapid Mass Movement
Slow Mass Movement
Avalanche
1A
1B
2
3
4
5

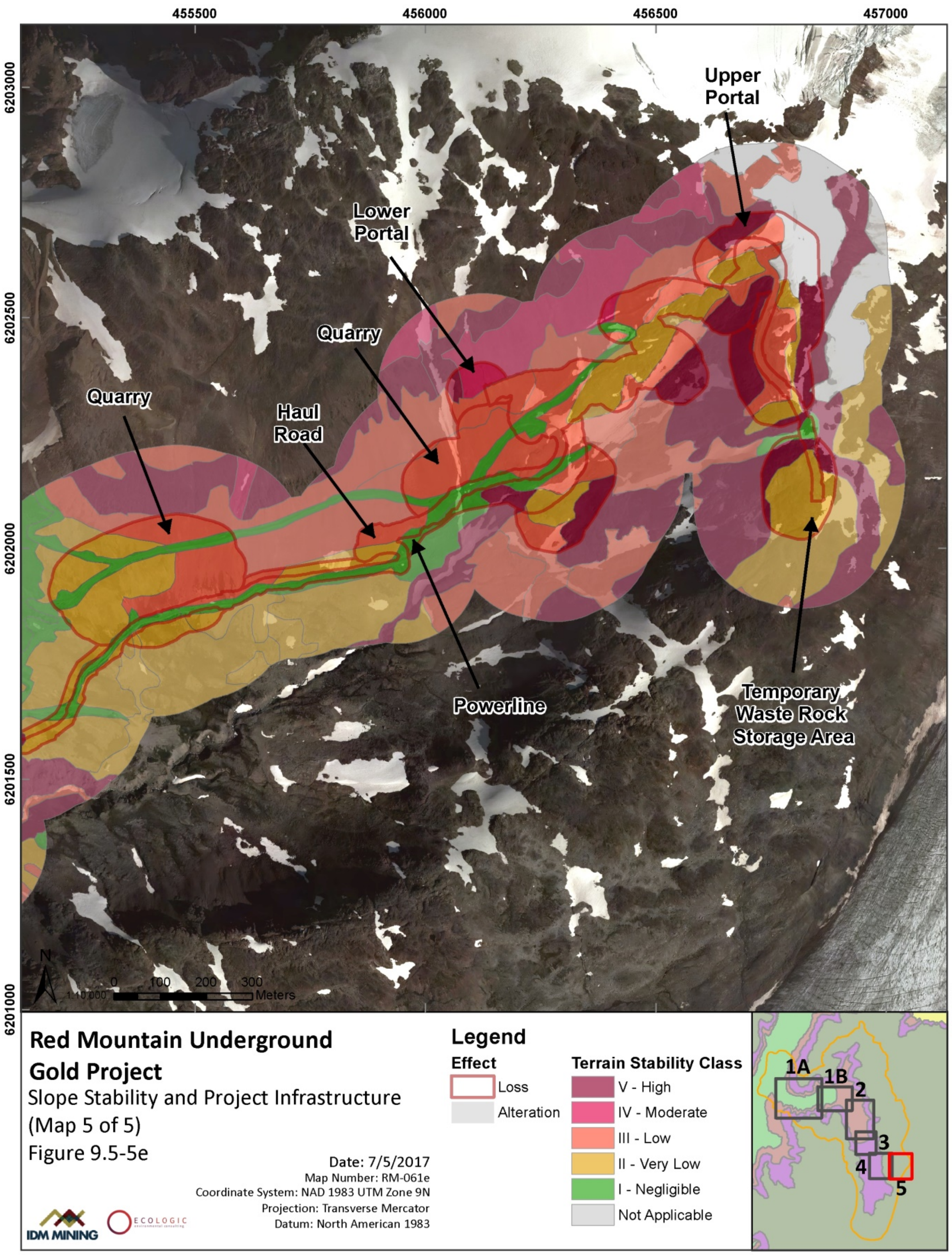
## Figure 9.5-5: Slope Stability and Project Infrastructure




450000
450500
451000
451500
452000
452500
453000
453500
6209000
6208500
6208000
6207500
6207000
6206500
6206000
6205500
6205000
Access Road
Powerline
Borrow
Topsoil Storage Area
N
1:20,000
0 200 400 600 Meters
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Red Mountain Underground Gold Project
Slope Stability and Project Infrastructure (Map 2 of 5)
Figure 9.5-5b
Date: 7/5/2017
Map Number: RM-061b
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
3
4
5


452000
452500
453000
453500
6205000
6204500
6204000
6203500
Tailing Management Facility
Process Plant
Haul Road
Treated Affluent Discharge Access
Powerline
Quarry
N
1:10,000
0 100 200 300 Meters
Red Mountain Underground Gold Project
Slope Stability and Project Infrastructure (Map 3 of 5)
Figure 9.5-5c
Date: 7/5/2017
Map Number: RM-061c
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
3
4
5


453500
454000
454500
455000
6203000
6202500
6202000
6201500
Quarry
Powerline
Haul Road
N
0 100 200 300 Meters
1:10,000
Red Mountain Underground Gold Project
Slope Stability and Project Infrastructure (Map 4 of 5)
Figure 9.5-5d
Date: 7/5/2017
Map Number: RM-061d
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983
IDM MINING
ECOLOGIC
Legend
Effect
Loss
Alteration
Terrain Stability Class
V - High
IV - Moderate
III - Low
II - Very Low
I - Negligible
Not Applicable
1A
1B
2
3
4
5




**Red Mountain Underground Gold Project**

Slope Stability and Project Infrastructure (Map 5 of 5)

Figure 9.5-5e

Date: 7/5/2017
Map Number: RM-061e
Coordinate System: NAD 1983 UTM Zone 9N
Projection: Transverse Mercator
Datum: North American 1983

IDM MINING ECOLOGIC

**Table 9.5-7: Summary of Terrain Stability Class associated with Project Footprint**

| Slope Stability Class | Area (ha) Associated with Project Footprint |
|---|---|
| I | 68.2 |
| II | 67.4 |
| III | 44 |
| IV | 37.8 |
| V | 29.2 |
| Total | 246.6 |

**Table 9.5-8: Summary of Geohazard Type with Respect to Project Infrastructure**

| Infrastructure | Effect on Soils | Rapid Mass Movement | Slow Mass Movement | Avalanche |
|---|---|---|---|---|
| Access Road | Loss | X | | X |
| | Alteration | X | | X |
| Bitter Creek Site Road | Loss | X | | |
| | Alteration | X | | X |
| Gravel Borrow | Loss | X | | |
| | Alteration | X | | |
| Haul Road | Loss | X | X | X |
| | Alteration | X | X | X |
| Lower Portal | Loss | X | X | X |
| | Alteration | X | X | X |
| Process Plant | Loss | | | |
| | Alteration | X | | |
| Rock Quarry | Loss | X | | |
| | Alteration | X | | |
| Talus Quarry | Loss | X | X | X |
| | Alteration | X | X | X |
| Temporary Waste Rock Storage Area | Loss | X | | X |
| | Alteration | X | X | X |
| TMF | Loss | X | | |
| | Alteration | X | | X |

| Infrastructure | Effect on Soils | Rapid Mass Movement | Slow Mass Movement | Avalanche |
|---|---|---|---|---|
| Topsoil Storage Area | Loss | X | | |
| | Alteration | X | | |
| Powerline | Loss | X | X | X |
| | Alteration | X | X | X |
| Upper Portal | Loss | X | | X |
| | Alteration | X | X | X |

## Table 9.5-9: Summary of Terrain Stability Classes with Respect to Project Infrastructure

| Infrastructure | Slope Stability Class | Loss (ha) | Alteration (ha) |
|---|---|---|---|
| Access Road | I | 21.1 | 163.6 |
| | II | 3.9 | 32.5 |
| | III | 2.5 | 40.1 |
| | IV | 2.4 | 31.4 |
| | V | 5.0 | 72.0 |
| Bitter Creek Site Road | I | 0.1 | 0.3 |
| | II | 0.1 | 1.7 |
| | III | | 1.5 |
| | IV | 0.1 | 1.3 |
| | V | 0.3 | 0.1 |
| Gravel Borrow | I | 5.7 | 12.5 |
| | II | 0.3 | 1.8 |
| | III | 2.8 | 0.5 |
| | IV | 5.4 | 1.6 |
| | V | 3.1 | 4.2 |
| Haul Road | I | 4.5 | 9.7 |
| | II | 12.4 | 56.1 |
| | III | 13.3 | 49.0 |
| | IV | 4.4 | 26.9 |
| | V | 3.2 | 56.7 |
| | - | 0.1 | 3.1 |

| Infrastructure | Slope Stability Class | Loss (ha) | Alteration (ha) |
|---|---|---|---|
| Lower Portal | I | 0.0 | |
| | II | 0.5 | |
| | III | 1.2 | 3.3 |
| | IV | 0.5 | 0.8 |
| | V | 0.9 | 2.4 |
| Process Plant | I | 1.6 | 2.3 |
| | II | 6.0 | 4.5 |
| | III | 0.1 | 1.0 |
| | IV | 0.6 | 1.2 |
| | V | | 1.6 |
| Rock Quarry | I | 15.4 | 2.9 |
| | II | 5.4 | 7.5 |
| | III | 5.3 | 3.5 |
| | IV | 16.0 | 11.1 |
| | V | 0.2 | 4.4 |
| Talus Quarry | I | 2.2 | 3.4 |
| | II | 4.6 | 2.0 |
| | III | 7.1 | 4.6 |
| | IV | | 0.4 |
| | V | 0.4 | 5.8 |
| Temporary Waste Rock Storage Area | I | 0.0 | |
| | II | 1.8 | 2.0 |
| | III | | 0.2 |
| | V | 0.7 | 3.5 |
| TMF | I | 7.8 | 5.4 |
| | II | 22.3 | 14.6 |
| | III | 6.5 | 5.2 |
| | IV | 3.3 | 10.2 |
| | V | 7.9 | 7.7 |
| | - | | 1.0 |

| Infrastructure | Slope Stability Class | Loss (ha) | Alteration (ha) |
|---|---|---|---|
| Topsoil Storage Area | I | 0.0 | 0.2 |
| | II | 3.0 | 0.7 |
| | III | 0.8 | 0.5 |
| | IV | | 0.4 |
| | V | 0.8 | 4.5 |
| Powerline | I | 8.8 | 4.7 |
| | II | 5.2 | 2.3 |
| | III | 4.4 | 3.4 |
| | IV | 2.5 | 3.4 |
| | V | 5.7 | 8.6 |
| Upper Portal | II | 1.0 | 1.2 |
| | III | 1.9 | 0.6 |
| | IV | | 0.4 |
| | V | 2.6 | 1.3 |
| | - | 1.0 | 2.7 |
| Total | | 246.6 | 714.1 |

As shown in Table 9.5-9, at least one geohazard type is present in each of the Project infrastructure types. The Access Road, Bitter Creek Site Road, and the TMF are exposed to two of the three geohazards types. The Haul Road, Lower Portal, Talus Quarry, Temporary Waste Rock Storage Area, Powerline, and Upper Portal are exposed to all three geohazard types.

Terrain Stability Class IV and/or V terrain is present within most of the Project infrastructure types. These are the areas of increased likelihood where rapid mass movements may occur in the future. Note that polygons with the mapped processes of solifluction and/or snow avalanche alone are not rated as terrain stability class V.

In other areas of the PFSA and LSA, terrain is currently rated as stable, but during construction terrain stability may be affected by activities that:

- Destabilize the integrity of surficial materials on slopes (e.g., vegetation clearing, soil salvage, road construction, or re-contouring);
- Alter existing groundwater movement patterns (e.g., vegetation clearing, construction of water drainage system and sedimentation ponds, damming, construction of roads or decline shaft, or underground mining); or

- Create steep terrain (e.g., construction of the TMF dam, development of a quarry, or development of storage berms for ore or salvaged soil).

Examples of such effects are mobilization of fill material used for road construction when it becomes saturated, or formation of new gullies when road runoff is diverted onto previously un-channeled slopes.

During operations, terrain stability could be affected by rock, ore, overburden, tailings, water storage and drainage, and soil storage, as well as road use and maintenance. Those activities, if not properly managed, could increase the potential for landslides and erosion and cause alteration of existing hydrological patterns, which in turn may be associated with increased risk of geohazards.

#### 9.5.5.1 Fluvial Processes and Bank Scour

Dynamic watercourses that show evidence of channel migration and exhibit a wide range of morphological features, such as pools and riffles, active gravel bars, and varied river bank types, are particularly vulnerable to disturbances such as culvert installation, stream diversion, and construction on stream banks or floodplains. Accelerated fluvial activity, such as an increase in bank erosion or bank scour, may occur in response to construction of water-crossing infrastructure or result from redirection of surficial water and tailings overflows to local creeks.

## 9.6 Mitigation Measures

Management of Project-related effects on Landforms and Natural Landscapes was determined in accordance with the key mitigation approaches outlined in the Effects Assessment Methodology (Volume 3, Chapter 6) and the Procedures for Mitigating Impacts on Environmental Values (Environmental Mitigation Procedures; BC MOE 2012).

### 9.6.1 Key Mitigation Approaches

Results from the review of best management practices (BMPs), guidance documents, and mitigation measures conducted for similar projects, as well as professional judgment for the Project-specific effects and most suitable management measures, were considered in determining the mitigation measures. The approach to the identification of mitigation measures subscribed to the mitigation hierarchy, as described in the Environmental Mitigation Policy for British Columbia (http://www.env.gov.bc.ca/emop/). The mitigation hierarchy follows the guidance that all feasible measures at one level are considered before moving to the next level. The four broad categories of mitigation and management identified for Landforms and Natural Landscapes include:

- Optimizing Alternatives;
- Design Mitigation;
- Best Management Practices (BMPs); and
- Restoration.

Technical and economic feasibility constraints dictated the highest level on the hierarchy that could be achieved for each potential effect and the identification of mitigation measures for managing these effects. The need for any proposed compensation or offset is identified where required, along with the management plan where the scope of such compensation or offset is described.

#### 9.6.1.1 Optimizing Alternatives

Optimizing alternatives includes:

- Conducting a tailings alternatives assessment (Volume 2, Chapter 4);
- Optimizing the design of the Access Road and Haul Road to minimize the distance travelled, which will reduce noise, dust, and emissions associated with construction and operations;
- Developing an underground mine, thereby minimizing surface clearing and dust emissions; and
- Using existing roads or ROWs as much as possible, thus reducing new surface disturbances to the ecosystems and plants.

#### 9.6.1.2 Design Mitigation

Design mitigation includes:

- Minimizing cut-and-fill in areas with ML/ARD potential;
- Re-routing the Access Road to avoid sensitive soils; and
- Developing objectives of closure plans for reclaimed areas to establish site conditions that allow for realistic and operationally feasible ecological trajectories that take into consideration ecosystem function and wildlife habitat objectives.

#### 9.6.1.3 Best Management Practices

Table 9.6-1 outlines applicable guideline and BMPs relevant to the management of Landforms and Natural Landscapes.

### Table 9.6-1: Best Management Practices for Landforms and Natural Landscapes

| Best Management Practice Document | Agency | Jurisdiction | Description |
|---|---|---|---|
| Develop With Care 2014: Section 3 - Site Development and Management. Environmental Guidelines for Urban and Rural Land Development in British Columbia. | Ministry of Environment | Provincial | Describes the objectives, requirements, and guidelines for good environmental development and management at the site level. Includes sections on water management, rain management, erosion and sediment control, air quality, terrain and flood hazards, contaminated sites, and spill containment and reporting. |
| Develop With Care 2014: Section 3 - Linear Developments. Environmental Guidelines for Urban and Rural Land Development in British Columbia. | Ministry of Environment | Provincial | Provides information on ways to lessen environmental impacts of linear developments such as roads. |
| Standards and Best Practices for Instream Works (2004): Section 8.3 Spill Reporting | Ministry of Water, Land, and Air Protection | Provincial | States the relevant Provincial and Federal Acts relating to the spilling of hazardous materials into streams. |
| Forest Practises Code of BC - Forest Road Engineering Guidebook (2002) | Ministry of Forests | Provincial | Provides advice on recommended road building and field practices to achieve statutory and regulatory requirements. Provides advice on earthwork activities, terrain stability, and associated components (drainage, erosion and sediment control, grubbing and stripping, backfilling, and soil management. |
| Forest and Range Practices Act - Forest & Range Evaluation Program Soil Monitoring | Ministry of Forests | Provincial | Sets objectives for soil conservation and associated 'Soil Resource Stewardship Monitoring Checklist" field forms. |
| Forest and Range Evaluation Program - Protocol for Soil Resource Stewardship Monitoring: Cutblock Level (2009) | Ministry of Forests | Provincial | Provisions set out to protect the productive and hydrologic capacity of soil and outlines indicators related to slope stability, hydrologic function, biological function, and organic matter retention. |
| Forest Practises Code of BC - Soil Conservation Guidebook (2001) | Ministry of Forests | Provincial | Provides advice on recommended soil conservation techniques. |
| Standards and Best Practices for Instream Works (2004) - General BMPs and Standard Project Considerations | Ministry of Water, Land, and Air Protection | Provincial | General operational best practices organized into 11 categories including timing of works (work windows), deleterious substance control/spill management, erosion and sediment control, and site restoration. |

| Best Management Practice Document | Agency | Jurisdiction | Description |
|---|---|---|---|
| Erosion and Sediment Control Association of Canada | Private | n/a | Canada's National Registrar for Erosion and Sediment Control Professionals (obtaining a Qualified Professional). |
| Emergency Management BC | Ministry of Forests, Lands, and Natural Resource Operations. | Provincial | Details on reporting requirements for a spill of a substance of reportable quantities that is toxic, polluting, or deleterious to aquatic life. |
| Land Development Guidelines for the Protection of Aquatic Habitat (1992) | Fisheries and Oceans Canada | Federal | Guidelines in place to protect fish populations and their habitats from the damaging effects of land development activities. Applicable sections include information on leave strips, erosion and sediment control, and stormwater management. |
| APEGBC - Guidelines for Professional Services in the Forest Sector - Forest Roads | Professional Engineers and Geoscientists of BC | n/a | Describes the professional practice associated with forest roads. |
| APEGBC - Guidelines for Management of Terrain Stability in the Forest Sector | Professional Engineers and Geoscientists of BC | n/a | Describes the professional practice associated with the management of terrain stability. |
| Best Management Handbook: Hillslope Restoration in BC (2001) | Ministry of Forests | Provincial | A compilation of successful hillslope restoration techniques. |

## 9.6.2 Project Mitigation Measures

Specific mitigation measures were identified and compiled for each category of potential effect on Landforms and Natural Landscapes and presented in this section. Management and mitigation measures will help avoid and minimize adverse effects to soil quality, soil quantity, and terrain stability. The full list of mitigation measures is presented in Table 9.6-2.

### 9.6.2.1 Management and Monitoring Plans

Effects to soil and terrain will be avoided and minimized through a Terrain and Soils Management Plan (TSMP; Volume 5, Chapter 29), following recommendations from the field-based terrain stability assessment (Volume 8, Appendix 9-C), and Project design.

The purpose of the TSMP is to provide environmentally responsible, realistic, and operationally feasible guidance for management for Landforms and Natural Landscapes during the Construction, Operations, and Closure and Reclamation Phases of the proposed Project.

The TSMP provides guidance for ICs identified in the consultation activities with NLG, regulators, and the public as identified in Section 9.3.2.

The TSMP is coordinated with the following applicable management plans to avoid and minimize effects to Ecosystems and Vegetation VCs:

- Closure and Reclamation (Volume 2, Chapter 5);
- Air Quality and Dust Management Plan (Volume 5, Chapter 29);
- Erosion and Sediment Control Plan (Volume 5, Chapter 29);
- Vegetation and Ecosystems Management Plan (Volume 5, Chapter 29); and
- Wildlife Management Plan (Volume 5, Chapter 29).

#### 9.6.2.2 Mitigation of Effects to Soil Quantity, Soil Quality, and Terrain Stability

Terrain stability and the potential for soil erosion are to be considered as a part of the planning for construction activities related to mine development. Where construction activities are planned in areas in and near polygons rated as TS Class III, IV, and V and SEP classes M, H, and VH, detailed, site-specific assessments will be conducted in order to implement construction techniques that minimize the risk of landslides and/or soil erosion. The Terrain Stability Assessment for the Project Footprint Study Area (Volume 8, Appendix 9-C) presents a detailed assessment and mitigation recommendation for the entire length of the access and haul roads as well as associated Project infrastructure.

Persons using terrain stability ratings should bear in mind that conditions are locally variable. Ratings indicate the mapper's judgment regarding the typical conditions for each terrain polygon, but locally steeper slopes, wetter slopes, emergence of water from seepage zones, and fine-grained materials give rise to areas that are potentially more unstable and/or subject to erosion than their surroundings. Consequently, persons planning, field-marking, and constructing roads and other excavations should recognize and take into account the local conditions. The run-out and deposition zone of potential slides in terrain below potentially unstable and unstable terrain should be carefully assessed. General implications for detailed terrain stability classes are shown in Table 9.6-3.

Measures to avoid, minimize, mitigate, or otherwise manage potential effects to Landscapes and Natural Landforms through effects to soil quantity, soil quality, and terrain stability are listed in Table 9.6-2.

| Table 9.6-2: Project Mitigation Measures for Landforms and Natural LandscapesVC/IC | Potential Effect | Pathway | Mitigation Measures |
|---|---|---|---|
| **Soil Quality** | Loss of Soil Quality | General | • Protection measures described in the following plans will be implemented to minimize Project effects on Natural Landscapes and Terrain (for further details see Volume 5, Chapter 29):<br>- Vegetation and Ecosystem Management Plan;<br>- Air Quality and Dust Management Plan;<br>- Aquatic Effects Management and Response Plan;<br>- Erosion and Sediment Control Plan;<br>- Terrain and Soil Management Plan;<br>- Closure and Reclamation (Volume 2, Chapter 5). |
| | | | • The need for any corrective actions to on-site management or installation of additional soil control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include:<br>- if results from the Surveillance Network Monitoring Program show non-compliance related to terrestrial discharges; or<br>- if an accident or malfunction results in degradation of soils. |
| | | | • Develop soil-handling procedures specific to alpine and parkland soils. |
| | | | • Where possible, organic soils will be salvaged and stored separately from mineral soils. |
| | | | • Revegetation will be undertaken with seeds (and/or plants) suitable for the local area and ecosystems; during the appropriate growing season and conditions to: 1) ensure maximum survival rate, 2) avoid establishment of invasive species, and 3) to facilitate the establishment of ecological functions and their associated attributes (e.g., species diversity and productivity). |

| Table 9.6-2: Project Mitigation Measures for Landforms and Natural LandscapesVC/IC | Potential Effect | Pathway | Mitigation Measures |
|---|---|---|---|
| | | | • Guidance and control of the stripping and stockpiling operations will be conducted by a qualified soil specialist. |
| | | | • Stockpile berms will be revegetated in a timely manner to control surface erosion, where required. |
| | | | • Mixing surface and subsurface soils during salvaging operations (admixing) will be avoided, where possible, as excessive mixing of surficial organic (O, LFH) and mineral horizons (A and B) with deeper soils (C) can degrade the quality of the topsoil and reduce the potential productivity of the salvaged material. |
| | | Soil Contamination | • Minimize deposition of fugitive dust in alpine ecosystems through adherence to the Air Quality and Dust Management Plan (Volume 5, Chapter 29). |
| | | | • Minimize cut-and-fill in areas with ML/ARD potential. |
| | | | • Appropriate secondary containment systems will be used for petroleum product storage to prevent spills and releases to water. This includes prevention of diesel release from pickups carrying tidy-tanks. |
| | | | • Refuelling will occur at a refuelling point with drainage capture/collection installed, in the event that refuelling occurs elsewhere, drip trays will be used under vehicles and equipment. |
| | | | • Facilities will be designed to control chemical / fuel / oil spillage. |
| | | | • Remediation of contaminated soil will be undertaken. |
| | | | • Appropriate setback and buffer distances from surface waterbodies and riparian features will be implemented and maintained. |

| Table 9.6-2: Project Mitigation Measures for Landforms and Natural LandscapesVC/IC | Potential Effect | Pathway | Mitigation Measures |
|---|---|---|---|
| | | | • Stockpiles will be constructed to avoid the promotion of changes in redox reactions that may promote the availability of metals, particularly arsenic which is naturally elevated in the area. |
| | | | • Avoid/minimize activities that may increase potential for mobilization of naturally occurring metals. |
| | | | • Sampling of salvaged soil to determine natural metal concentrations. If natural metal levels exceed the limits set in the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 2007), or exceed the Soil Criteria for Toxicity to Soil Invertebrates and Plants outlined in the Contaminated Sites Regulation (375/1966), then the contaminated soil will be stored separately and measures consistent with the ML/ARD Management Plan will be taken to inhibit metal release to the environment. |
| | | Soil Compaction | • All vehicles and machinery travel will be restricted to designated road surfaces. |
| | | | • Soil stripping and stockpiling will be carried out in conditions that minimize soil disturbance. |
| | | | • Prolonged exposure of bare soil to the elements will be avoided; whenever possible, soil salvage will immediately follow vegetation clearing. |
| | | | • Traffic in stockpile areas will be limited to stacking and shaping the stockpiles to minimize compaction. If required, stockpile areas will be lightly ripped (using a sub-soiler) to mitigate compaction, prior to seeding/planting activities. |
| | | Soil Acidification | • Minimize deposition of fugitive dust in alpine ecosystems through adherence to the Air Quality and Dust Management Plan (Volume 5, Chapter 29). |

| Table 9.6-2: Project Mitigation Measures for Landforms and Natural LandscapesVC/IC | Potential Effect | Pathway | Mitigation Measures |
|---|---|---|---|
| **Soil Quantity** | Loss of Soil Quantity | General | • Soil handling procedures will be developed specific to sensitive ecosystems (alpine and parkland, wetlands, floodplains and BC CDC-listed ecosystems). High-quality soils will be identified and stockpiled when required in accordance with the Terrain and Soil Management Plan.<br>• Where possible, soil will be:<br>- stripped and stockpiled for future reclamation<br>- preserved by minimizing the number of times soil is moved; reducing the vehicle traffic over the soil surface; and avoiding handling soils when they are too dry or too wet<br>• Revegetation will be undertaken with seeds (and/or plants) suitable for the local area and ecosystems; during the appropriate growing season and conditions to: 1) ensure maximum survival rate, 2) avoid establishment of invasive species, and 3) to facilitate the establishment of ecological functions and their associated attributes (e.g. species diversity and productivity). |
| | | | • Guidance and control of the stripping and stockpiling operations will be conducted by a qualified soil specialist. |
| | | Soil Surface Erosion | • The length and steepness of bare, exposed slopes will be limited to minimize runoff energy.<br>• Prolonged exposure of bare soil to the elements will be avoided; whenever possible, soil salvage will immediately follow vegetation clearing<br>• Regular inspections will be conducted to ensure drainage, erosion, and sediment control measures are effective and functioning properly; all necessary repairs and adjustments will be conducted in a timely manner.<br>• Appropriate setback and buffer distances from surface waterbodies and riparian features will be implemented and maintained. |
| | | Soil Mass Wasting | • Through design, avoid the placement of infrastructure in areas with known terrain stability issues; |

| Table 9.6-2: Project Mitigation Measures for Landforms and Natural LandscapesVC/IC | Potential Effect | Pathway | Mitigation Measures |
|---|---|---|---|
| | | | • Follow mitigation measures and best practices as outlined in the Erosion and Sediment Control Plan; and<br>• If a situation arises where the risk of geotechnical failure becomes apparent, undertake proactive preventive measures to address the problem and ensure geotechnical stability is reinstated.<br>• Stockpiles will be designed to be geotechnically stable |
| **Terrain Stability and Geohazards** | **Decreases in Terrain Stability** | Increase in Landslide Frequency and Intensity | • Through design, avoid the placement of infrastructure in areas with known terrain stability issues;<br>• Between 4 and 5 km of the Access Road, avoid destabilizing the sensitive slop by minimizing cuts and constructing the road as a fill, as well as extending the fill slope onto the Bitter Creek floodplain.<br>• Follow mitigation measures and best practices as outlined in the Erosion and Sediment Control Plan; and<br>• If a situation arises where the risk of geotechnical failure becomes apparent, undertake proactive preventative measures to address the problem and ensure geotechnical stability is reinstated. |

### Table 9.6-3: Management Implications of Terrain Stability Classes

| Class | Rating | Implication |
|---|---|---|
| I | Negligible | No significant stability problems exist. |
| II | Very Low | There is a very low likelihood of landslides following development related construction. Minor slumping is expected along cut slopes, especially for one or two years following construction. |
| III | Low | Minor stability problems can develop. Minor slumping is expected along cutslopes, especially for one or two years following construction. There is a low likelihood of landslide initiation following development-related construction. |
| IV | Moderate | Expected to contain areas with a moderate likelihood of landslide initiation following development-related construction. |
| V | High | Expected to contain areas with a high likelihood of landslide initiation following development-related construction. |

Source: B.C. Ministry of Forests (1999).

Potential effects on terrain stability can be mitigated by identifying areas where there is a moderate to high likelihood of slope failure following Project development, conducting terrain stability field assessments of those areas by a qualified terrain specialist, and adapting designs to address stability issues. Detailed geotechnical plans will be required in order to avoid adverse effects on terrain. Follow-up monitoring is required in these areas in order to determine the effectiveness of mitigation (Table 9.6-4). Mitigation will be used to reduce the risk of associated Project development in areas of terrain that is unstable and potentially unstable to an acceptable level. These strategies will reduce the risk in the following ways:

- Reduce the probability of the geohazard occurring;
- Reduce the geohazard magnitude (e.g., volume, peak discharge);
- Reduce the geohazard intensity (e.g., run-out distance, velocity, impact forces);
- Reduce the spatial probability of effect (e.g., likelihood that the geohazard will reach or effect the element at risk);
- Reduce the temporal probability of effect (e.g., likelihood of workers being present in the zone subject to the hazard); and
- Reduce the vulnerability (e.g., the degree of loss to a given element at risk within the area affected by the snow avalanche or landslide hazard).

Slope stabilization techniques, including terracing and bioengineering structures such as wattle fences and brush layers, will be used in areas with highly erodible soils and those areas with long and/or steep slopes. Erosion-control measures will include seeding of exposed soils with an erosion-control seed mix or hydro-seeding with a mix of seed, mulch, and a tackifier as soon as possible after soil surface disturbance. Where required, such as along water-diversion channels, soil-erosion control measures to be adopted may include construction of channel-bank protection and the installation of erosion-control blankets. Silt fences will be used to contain sediments eroding off-site and to prevent them from entering waterways. To protect erodible channel banks, rock material, willow bundles, or gabions will be used, as required. Details are provided in the Erosion and Sediment Control Plan (Volume 5, Chapter 29).

Sections of the access and haul roads will be exposed to avalanche hazards. The exposed areas will be inspected by the Occupational Health and Safety and the Emergency Response planning committees to determine the associated risks. A road maintenance and avalanche management plan will be developed to reduce and manage the associated risks (see Volume 5, Chapter 29, Emergency Response Plan and Volume 5, Chapter 29, Health and Social Services Plan).

#### 9.6.2.3 Mitigation for Access and Haul Road Effects on Terrain Stability

Engineers and geoscientists were retained by IDM to design and assess an Access Road from Highway 37A to the TMF and a Haul Road from the TMF to the mine portals. During the assessment, areas of potentially unstable terrain were identified along the route and the design was adjusted to avoid such areas wherever feasible (Appendix 9-C). In areas where avoidance was not feasible, the road was located in areas where the alignment could be adjusted or special construction techniques could be used to minimize risk. Examples of such areas include steep terrain, watercourse crossings prone to high debris potential, and where the road encroaches on Bitter Creek.

The majority of the Access Road follows an existing grade that parallels Bitter Creek. Much of this alignment is over gentle terrain where normal construction techniques and drainage structures are adequate to ensure a stable road prism and minimal disturbance to the surrounding area. An exception to this occurs between approximately 4 and 5 km where the historic road has been washed out; there is a sensitive slope above and Bitter Creek is immediately below. To avoid destabilizing the sensitive slope above, cuts will be minimized and the road will be constructed as a fill. Here the road's fill slope will extend onto the Bitter Creek floodplain and, in places, within the Bitter Creek high-water mark. The road surface elevation will be set to remain above expected high-water elevations and the fill slope will be armoured with appropriately sized riprap to protect against erosion.

Steep slopes are encountered in multiple locations along the proposed alignment. In these sections, a variety of techniques are proposed to minimize terrain stability concerns. Where side slopes are too steep to build a stable road prism with standard fill materials, stacked rock fills may be prescribed to achieve a stable fill slope. In these sections, the toe of the fill slope will be founded on an excavated bench of competent mineral soil or bedrock, and large riprap will be selectively placed to create an interlocking rock slope. Road subgrade is then filled and compacted in lifts against the upper edge of the rock fill. In sections where side slopes are too steep to build a stable road prism using stacked rock fill, full bench end-haul construction was prescribed. In these sections, the entire road prism will be built on a full bench cut and generated material will be end-hauled to a designated spoil site or to another portion of the road to be used in its construction. In full bench end-haul sections, no excavated material will be placed on the slope below the road. An example of where full bench end-haul is prescribed is at station 1+400 on the Haul Road and an example of where stacked rock fill is prescribed is at station 6+300 on the Haul Road.

For all sections of road, the ground will be stripped of the organic layer before constructing the prism, and cut-and-fill slopes will be constructed at stable angles. Where stable cut slope angles are not feasible or an upslope hazard exists, several methods are proposed to mitigate risk. Examples of proposed mitigation measures include:

- At station 4+050 on the Access Road, a wide ditch is proposed to catch ravelling debris;
- At station 4+700 on the Access Road, a barrier is proposed to catch ravelling debris; and
- At station 2+880 on the Access Road, the cut slope will be buttressed with riprap to stabilize the sensitive slope above the road.

Several watercourse crossings along the proposed route are prone to debris movement and avalanches. Proposed crossing structures include culverts, clear-span bridges, and modified fords. Modified ford crossings are used in locations where flows are expected to be high velocity, low volume, and with high debris potential. They are often used to cross watercourses that have constrained gully flows, avalanches, large debris potential, or unstable stream bank conditions. The ford crossings will be constructed from large, keyed-in riprap. Large riprap will be placed to train rainfall shutdown event flows through the heavy gauge steel pipe culverts and 100-year flows over the structure. Modified fords are proposed on Rio Blanco, Otter Creek, and Radio Creek. Culverts and clear-span bridges will be designed to pass expected debris and Q100 flows under/through the structure. Clear-span bridges are proposed on Roosevelt Creek, Cambria Creek, and Hartley Gulch. All other watercourse crossings will be culverts.

### 9.6.3 Effectiveness of Mitigation Measures

The anticipated effectiveness of mitigation measures to minimize adverse effects is evaluated and classified as follows:

- Low effectiveness: Proposed measure is experimental or has not been applied in similar circumstances.
- Moderate effectiveness: Proposed measure has been successfully implemented but perhaps not in a directly comparable situation.
- High effectiveness: Proposed measure has been successfully applied in similar situations.
- Unknown effectiveness: Proposed measure has unknown effectiveness because it has not been implemented elsewhere in a comparable project or environment.

The key measures for mitigation of potential effects on the Landforms and Natural Landscape IC, along with mitigation effectiveness and uncertainty, are summarized in Table 9.6-4. This table also identifies the residual effects that will be carried forward for residual effects characterization and significance determination.

The timing of effectiveness of the mitigation measures varies depending on the type of mitigation. Mitigation measures that are part of the Project design or that rely on avoidance or prevention of effect through BMPs or regulatory requirements are effective immediately. Mitigation measures that are based on monitoring are dependent on the monitoring schedule. The implementation of all the mitigation measures as a whole will generally provide close to immediate effectiveness.

The proposed mitigation measures include standard measures that are known to be effective, based on relevant and applicable experience with other mining projects, and therefore the uncertainty associated with their use is primarily low. Any further uncertainty associated with the effectiveness of the proposed mitigation trends will be addressed through the TSMP (Volume 5, Chapter 29) and Closure and Reclamation (Volume 2, Chapter 5). If monitoring indicates that effectiveness of mitigation measures is lower than predicted, further mitigation may be required as per adaptive management strategies outlined in the TSMP and Closure and Reclamation.

**Table 9.6-4: Proposed Mitigation Measures and Their Effectiveness**

| VC/IC | Potential Effects | Mitigation Measures | Rationale | Applicable Phase(s) | Effectiveness[1] | Uncertainty[2] | Residual Effect |
|---|---|---|---|---|---|---|---|
| **Soil Quality** | **Loss of Soil Quality** | • Protection measures described in the following plans will be implemented to minimize Project effects on Natural Landscapes and Terrain (for further details, see Volume 5, Chapter 29):<br>- Vegetation and Ecosystem Management Plan;<br>- Air Quality and Dust Management Plan;<br>- Aquatic Effects Management and Response Plan;<br>- Erosion and Sediment Control Plan;<br>- Terrain and Soil Management;<br>- Closure and Reclamation (Volume 2, Chapter 5). | Integrating management plans and best practices allows for the integration of environmental management, leading to more effective mitigation | Construction, Operation, Closure and Reclamation, Post Closure | Moderate | Low | Yes |
| | | • The need for any corrective actions to on-site management or installation of additional soil control measures will be determined on a case-by-case basis. Indications of the need for corrective actions and additional control measures may include:<br>- if results from the Surveillance Network Monitoring Program show non-compliance related to terrestrial discharges; or<br>- if an accident or malfunction results in degradation of soils. | Corrective actions result in reduced negative effects to the soil resource | Construction, Operation, Closure and Reclamation, Post Closure | Moderate | Low | |
| | | • Develop soil-handling procedures specific to alpine and parkland soils. | Alpine and parkland soils can be particularly sensitive to disturbance due to certain characteristics such as low buffering capacity | Construction, Operation, Closure and Reclamation, | Moderate | Low | |
| | | • Where possible, organic soils will be salvaged and stored separately from mineral soils. | The usefulness of organic material is reduced if subject to ad mixing | Construction | High | Low | |
| | | • Revegetation will be undertaken with seeds (and/or plants) suitable for the local area and ecosystems; during the appropriate growing season and conditions. | 1) ensure maximum survival rate, 2) avoid establishment of invasive species, and 3) to facilitate the establishment of ecological functions and their associated attributes (e.g., species diversity and productivity). | Construction, Operation, Closure and Reclamation | High | Low | |
| | | • Guidance and control of the stripping and stockpiling operations will be conducted by a qualified soil specialist. | Qualified persons are able to best manage soil stripping and storage | Construction | Moderate | Low | |

| VC/IC | Potential Effects | Mitigation Measures | Rationale | Applicable Phase(s) | Effectiveness[1] | Uncertainty[2] | Residual Effect |
|---|---|---|---|---|---|---|---|
| | **Loss of Soil Quality through Soil Contamination** | • Stockpile berms will be revegetated in a timely manner to control surface erosion, where required. | Controlling surface erosion reduces soil loss and sedimentation of other areas including waterbodies | Construction | High | Low | |
| | | • Mixing surface and subsurface soils during salvaging operations (admixing) will be avoided, where possible, as excessive mixing of surficial organic (O, LFH) and mineral horizons (A and B) with deeper soils (C) can degrade the quality of the topsoil and reduce the potential productivity of the salvaged material. | Proactive treatment and handling is more effective than post-hoc reclamation | Construction | Moderate | Low | |
| | | • Minimize deposition of fugitive dust in alpine ecosystems through adherence to the Air Quality and Dust Management Plan (Volume 5, Chapter 29). | Due to low buffering capacity, alpine soils can be particularly sensitive to dust effects which can lead to acidification | Construction, Operation, Closure and Reclamation, Post Closure | Moderate | Low | Yes |
| | | • Minimize cut-and-fill in areas with ML/ARD potential. | Reducing the source of the potential effect minimizes the potential effect. | Construction | Moderate | Low | |
| | | • Appropriate secondary containment systems will be used for petroleum product storage to prevent spills and releases to water. This includes prevention of diesel release from pickups carrying tidy-tanks. | Secondary containment reduces soil contamination in the event of a spill | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | |
| | | • Refuelling will occur at a refuelling point with drainage capture/collection installed, in the event that refuelling occurs elsewhere, drip trays will be used under vehicles and equipment. | Capturing potential fuel spills avoids soil contamination | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | |
| | | • Facilities will be designed to control chemical / fuel / oil spillage. | Controlling fluid spills avoids soil contamination | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | |
| | | • Remediation of contaminated soil will be undertaken. | Remediation of soil reduces potential of soils to cross contaminate | Construction, Operation, Closure and Reclamation, Post Closure | Moderate | Low | |
| | | • Appropriate setback and buffer distances from surface waterbodies and riparian features will be implemented and maintained. | Reduces potential for spill material to enter water bodies | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | |
| | | • Stockpiles will be constructed to avoid the promotion of changes in redox reactions that may promote the availability of metals, particularly arsenic which is naturally elevated in the area. | Reduces potential for metal mobilization | Construction | Moderate | Moderate | |

| VC/IC | Potential Effects | Mitigation Measures | Rationale | Applicable Phase(s) | Effectiveness[1] | Uncertainty[2] | Residual Effect |
|---|---|---|---|---|---|---|---|
| | | • Avoid/minimize activities that may increase potential for mobilization of naturally occurring metals. | Reduces potential for metal mobilization | Construction, Operation, Closure and Reclamation, Post Closure | High | Moderate | |
| | | • Sampling of salvaged soil to determine natural metal concentrations. If natural metal levels exceed the limits set in the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME 2007), or exceed the Soil Criteria for Toxicity to Soil Invertebrates and Plants outlined in the Contaminated Sites Regulation (375/1966), then the contaminated soil will be stored separately and measures consistent with the ML/ARD Management Plan will be taken to inhibit metal release to the environment. | Avoids the cross contamination of soil material | Construction, Operation, Closure and Reclamation | Moderate | Low | |
| | **Loss of Soil Quality through Soil Compaction** | • All vehicles and machinery travel will be restricted to designated road surfaces. | Machinery can cause soil compaction | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | Yes |
| | | • Soil stripping and stockpiling will be carried out in conditions that minimize soil disturbance. | Reducing soil disturbance maintains soil structure which is important for fertility | Construction | Moderate | Low | |
| | | • Prolonged exposure of bare soil to the elements will be avoided; whenever possible, soil salvage will immediately follow vegetation clearing. | Bare exposed soil can be degraded by wind, rain, and invasive plants | Construction | Moderate | Low | |
| | | • Traffic in stockpile areas will be limited to stacking and shaping the stockpiles to minimize compaction. If required, stockpile areas will be lightly ripped (using a sub-soiler) to mitigate compaction, prior to seeding/planting activities. | Machinery can cause soil compaction | Construction, Operation, Closure and Reclamation | Moderate | Low | |
| | **Loss of Soil Quality through Soil Acidification** | • Minimize deposition of fugitive dust in alpine ecosystems through adherence to the Air Quality and Dust Management Plan (Volume 5, Chapter 29). | Due to low buffering capacity, alpine soils can be particularly sensitive to dust effects which can lead to acidification | Construction, Operation, Closure and Reclamation, Post Closure | Moderate | Low | No |
| **Soil Quantity** | **Loss of Soil Quantity** | • Soil handling procedures will be developed specific to sensitive ecosystems (alpine and parkland, wetlands, floodplains and BC CDC-listed ecosystems). High-quality soils will be identified and stockpiled when required in accordance with the Terrain and Soil Management Plan.<br>• Where possible, soil will be:<br>- stripped and stockpiled for future reclamation<br>- preserved by minimizing the number of times soil is moved; reducing the vehicle traffic over the soil surface; and avoiding handling soils when they are too dry or too wet<br>• Revegetation will be undertaken with seeds (and/or plants) suitable for the local area and ecosystems; during the appropriate growing season and conditions to: 1) ensure maximum survival rate, 2) avoid establishment of invasive species, and 3) to facilitate the establishment of ecological functions and their associated attributes (e.g. species diversity and productivity).<br>• Guidance and control of the stripping and stockpiling operations will be conducted by a qualified soil specialist. | Soils forming in these environments can have specific sensitivities | Construction, Operation, Closure and Reclamation | Moderate | Low | Yes |

| VC/IC | Potential Effects | Mitigation Measures | Rationale | Applicable Phase(s) | Effectiveness[1] | Uncertainty[2] | Residual Effect |
|---|---|---|---|---|---|---|---|
| | **Loss of Soil Quantity through Soil Surface Erosion** | • The length and steepness of bare, exposed slopes will be limited to minimize runoff energy.<br>• Prolonged exposure of bare soil to the elements will be avoided; whenever possible, soil salvage will immediately follow vegetation clearing<br>• Regular inspections will be conducted to ensure drainage, erosion, and sediment control measures are effective and functioning properly; all necessary repairs and adjustments will be conducted in a timely manner.<br>• Appropriate setback and buffer distances from surface waterbodies and riparian features will be implemented and maintained. | These measures will reduce soil erosion and thus reducing soil loss | Construction, Operation, Closure and Reclamation | High | Low | Yes |
| | **Loss of Soil Quantity through Soil Mass Wasting** | • Through design, avoid the placement of infrastructure in areas with known terrain stability issues;<br>• Follow mitigation measures and best practices as outlined in the Erosion and Sediment Control Plan; and<br>• If a situation arises where the risk of geotechnical failure becomes apparent, undertake proactive preventive measures to address the problem and ensure geotechnical stability is reinstated.<br>• Stockpiles will be designed to be geotechnically stable | Design is the most effective mitigation measure to avoid soil mass wasting | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | No |
| **Terrain Stability and Geohazards** | **Decreases in Terrain Stability due to Increase in Landslide Frequency and Intensity** | • Through design, avoid the placement of infrastructure in areas with known terrain stability issues;<br>• Between 4 and 5 km of the Access Road, avoid destabilizing the sensitive slop by minimizing cuts and constructing the road as a fill, as well as extending the fill slope onto the Bitter Creek floodplain;<br>• Follow mitigation measures and best practices as outlined in the Erosion and Sediment Control Plan; and<br>• If a situation arises where the risk of geotechnical failure becomes apparent, undertake proactive preventative measures to address the problem and ensure geotechnical stability is reinstated. | Design is the most effective mitigation measure to avoid landslides | Construction, Operation, Closure and Reclamation, Post Closure | High | Low | No |

[1]Effectiveness: Low = measure unlikely to result in effect reduction; Moderate = measure has a proven track record of partially reducing effects; High = measure has documented success (e.g., industry standard; use in similar projects) in substantial effect reduction

[2]Uncertainty: Low = proposed measure has been successfully applied in similar situations; Moderate = proposed measure has been successfully implemented, but perhaps not in a directly comparable situation; High = proposed measure is experimental, or has not been applied in similar circumstances.

# 9.7 Residual Effects Characterization

Management and mitigation measures will help avoid and minimize adverse effects to Landforms and Natural Landscapes; however, direct and indirect effects cannot be fully mitigated and thus loss and/or alteration soil quality and soil quantity are expected. Some residual effects on terrain stability may occur, but Project design and mitigation will alleviate most potential residual effects.

## 9.7.1 Summary of Residual Effects

### 9.7.1.1 Methods

The residual adverse effects on Landforms and Natural Landscapes were evaluated in relation to their effects on the measurement indicators of changes to soil quality, changes to soil quantity, changes to background rates of soil erosion, changes to bank scour, changes to sedimentation rates of waterbodies, and changes to terrain stability (Section 9.5.3).

### 9.7.1.2 Residual Effects Criteria

The residual effects on Landforms and Natural Landscapes were characterized in terms of direction, magnitude, geographic extent, duration, frequency, reversibility, and resiliency according to the definitions in Table 9.7-1

**Table 9.7-1: Characterization of Residual Effect on Landforms and Natural Landscapes ICs**

| Criteria | Characterization for ICs |
|---|---|
| Direction | • **Adverse** – the residual effect on the IC is negative<br>• **Positive** – not assessed for significance<br>• **Neutral** – not assessed for significance |
| Magnitude | • **Negligible**: no detectable change from baseline conditions.<br>• **Low)**: differs from the average value for baseline conditions but remains within the range of natural variation and below a guideline or threshold value.<br>• **Moderate**: differs substantially from the average value for baseline conditions and approaches the limits of natural variation but equal to or slightly above a guideline or threshold value.<br>• **High**: differs substantially from baseline conditions and is significantly beyond a guideline or threshold value, resulting in a detectable change beyond the range of natural variation. |
| Geographical Extent (Biophysical) | • **Discrete):** effect is limited to the Project area.<br>• **Local:** effect is limited to the LSA.<br>• **Regional:** effect extends beyond the LSA but within the RSA.<br>• **Beyond regional:** effect extends beyond the RSA. |

| Criteria | Characterization for ICs |
|---|---|
| Duration | • **Short term:** effect lasts less than 18 months (during the Construction Phase of the Project).<br>• **Long-term:** effect lasts greater than 18 months and less than 22 years (encompassing Operation, Closure and Reclamation, and Post-Closure Phases).<br>• **Permanent:** effect lasts more than 22 years. |
| Frequency | • **One time**: effect is confined to one discrete event.<br>• **Sporadic**: effect occurs rarely and at sporadic intervals.<br>• **Regular**: effect occurs on a regular basis.<br>• **Continuous:** effect occurs constantly. |
| Reversibility | • **Reversible**: effect can be reversed.<br>• **Partially reversible)**: effect can be partially reversed.<br>• **Irreversible**: effect cannot be reversed, is of permanent duration. |
| Context | • **High**: the receiving environment or population has a high natural resilience to imposed stresses and can respond and adapt to the effect.<br>• **Neutral**: the receiving environment or population has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.<br>• **Low:** the receiving environment or population has a low resilience to imposed stresses and will not easily adapt to the effect. |

### 9.7.1.3 Assessment of Likelihood

Likelihood refers to the probability of the predicted residual effect occurring (Table 9.7-2), where possible to predict.

**Table 9.7-2: Attributes of Likelihood**

| Likelihood Rating | Quantitative Threshold |
|---|---|
| High | > P80 (effect has > 80% chance of effect occurring) |
| Moderate | P40 - P80 (effect has 40-80% chance of effect occurring) |
| Low | < P40 (effect has < 40% chance of effect occurring) |

### 9.7.1.4 Confidence

Confidence is the level of certainty associated with the evaluation and characterization of residual effects. Confidence is a measure of the reliability of data inputs, the analytical methods used to predict residual effects, the confidence regarding the effectiveness of mitigation measures, and the certainty of the predicted outcomes. Confidence ratings are based on the definitions provided in Table 9.7-3.

### Table 9.7-3: Confidence Ratings and Definitions

| Confidence Rating | Quantitative Threshold |
|---|---|
| High | There is a good understanding of the cause-effect relationship between the Project and a VC, and all necessary data are available to support the assessment. The effectiveness of the selected mitigation measures is moderate to high. There is a low degree of uncertainty associated with data inputs and/or modelling techniques, and variation from the predicted effect is expected to be low. Given the above, there is high confidence in the conclusions of the assessment. |
| Moderate | The cause-effect relationships between the Project and a VC are not fully understood (e.g., there are several unknown external variables or data for the Project area are incomplete). The effectiveness of mitigation measures may be moderate or high. Modelling predictions are relatively confident. Based on the above, there is a moderate confidence in the assessment conclusions |
| Low | Cause-effect relationships between the Project and a VC are poorly understood. There may be several unknown external variables and/or data for the Project area is incomplete. The effectiveness of the mitigation measures may not yet be proven. Modelling results may vary considerably given the data inputs. There is a high degree of uncertainty in the conclusions of the assessment. |

## 9.7.2 Potential Residual Effects Assessment

### 9.7.2.1 Residual Effects on Soil Quantity

This section discusses the effects of soil disturbance associated with the development of the Project footprint on the quantity of available soil within the PFSA. The assessment is focused on the spatial aspect of soil quantity. The bulk losses of soil associated with potential mass movement events and erosion are considered in the assessment of the Project effects on terrain stability and soil quality.

#### 9.7.2.1.1 Residual Effect Analysis

The maximum area of soil lost under the Project footprint before reclamation and other forms of mitigation will be equal to 219.5 ha (Table 9.5-3 and Figure 9.5-1). This amount includes a buffer of 50 m around proposed infrastructure to account for potential changes in the Project footprint. It is estimated that 73 ha (one third of the lost soil) of this will be reclaimed, given that reclamation is considered to be moderately successful at mitigating effects to soils that result in lost material. This material is expected to recover a significant portion of its original ecological function and fertility, as much of this material is in the early staged of pedogenesis and will not have developed mature soil functions at the time of disturbance. The recovery period is expected to take several decades before the soils return to baseline biological functions. Given mitigation measures, it is expected that the Project will result in the loss of 146.5 ha of soil.

This loss of soil includes that expected from erosion, both associated with site clearing, road construction, and potential minor slumping associated with road construction into steep slopes.

##### 9.7.2.1.2 Characterization of Residual Effects on Soil Quantity

The permanent loss of soil on 146.5 ha is a detectable change beyond the baseline conditions, but is within the range of natural variation, thus the loss is characterized as a moderate magnitude (Table 9.7-4). This characterization is due to the environment within which the Project is situated, which is highly active with respect to soil loss due to recent deglaciation. While the geographic extent of this effect is discrete (limited to the immediate area of the Project surface facilities) it is expected that the duration of the land loss will be permanent (effects last more than 22 years). The loss will occur sporadically, mostly occurring during Construction but also during the Closure and Reclamation Phase. The effect is considered irreversible as the soils under the footprint of roads and infrastructure remaining after Closure and Reclamation will be permanently lost. The context is neutral as the environment has the ability to adapt to the effect, as many ecosystems within the PFSA and LSA are developing in areas with little to no soil.

##### 9.7.2.1.3 Likelihood

The likelihood of soil loss is high (greater than 80%). The size of the Project footprint was enlarged in order to allow for design changes, so the loss estimate is highly conservative, as the Project will not fully expand into the buffer.

**Table 9.7-4: Characterization of Residual Effects on Soil Quantity**

| Criteria | Characterization for Soil Quantity |
|---|---|
| Magnitude | Moderate |
| Geographical Extent | Discrete |
| Duration | Permanent |
| Frequency | Sporadic |
| Reversibility | Irreversible |
| Context | Neutral |

##### 9.7.2.1.4 Confidence and Risk

There is a good understanding of the relationship between the Project activities and the soil loss, and all necessary data are available to support the assessment. The effectiveness of the selected mitigation measures ranges from moderate to low. It is well understood how Project activities can result in changes to soil quantity through direct loss, through changes in rates of soil erosion (and potential associated changes in background rates of sedimentation), and terrain stability. There is a low degree of uncertainty associated with collected data and modelling. Thus, there is high confidence in the conclusions of the assessment.

#### 9.7.2.2 Residual Effects on Soil Quality

##### 9.7.2.2.1 Residual Effect Analysis

It is likely that, after mitigation measures are incorporated, residual effects to soil quality will occur. These effects could include the following:

- Fugitive dust;
- Declining soil quality in stockpiles;
- Compaction;
- Erosion;
- Alteration of structure due to soil handling; and
- Changes in soil moisture and nutrient regimes within reclaimed soils.

In total, there are 625.7 ha of soil that may be subject to some level of alteration. The vast majority of this alteration is due to fugitive dust, as the fugitive dust zone of influence was set at 150 m. This is highly conservative, as dustfall did not exceed AAQA standards at any location. The highest levels of dustfall were confined to sections of the Access Road.

##### 9.7.2.2.2 Characterization of Residual Effect

The alteration of soil on 625.7 ha is a detectable change beyond the baseline conditions, but the amount of alteration is very close to natural background levels (given that dust levels are approaching background levels during operations) thus the alteration is characterized as a low magnitude. This characterization is due to the environment within which the Project is situated, which is highly active with respect to soil alteration due to recent deglaciation. While the geographic extent of this effect is discrete (limited to the immediate area adjacent to Project surface facilities) it is expected that the duration of the soil alteration will be permanent (effects last more than 22 years). The alteration is continuous, as it is mostly due to vehicle traffic dust which will occur throughout the life of the Project. The effect is considered reversible as, due to natural process, soils will recover over time from alteration. The context is high as the environment has the ability to adapt to the effect (Table 9.7-5).

**Table 9.7-5: Characterization of Residual Effect on Soil Quality**

| Criteria | Characterization for Soil Quality |
|---|---|
| Magnitude | Low |
| Geographical Extent | Discrete |
| Duration | Permanent |
| Frequency | Continuous |
| Reversibility | Reversible |
| Context | High |

#### 9.7.2.2.3 Likelihood

The likelihood of loss of soil quality is high (greater than 80%). The size of the Project footprint was enlarged in order to allow for design changes, so the alteration estimate is highly conservative, as the Project will not fully expand into the buffer.

#### 9.7.2.2.4 Confidence and Risk

There is a good understanding of the relationship between the Project activities and the soil alteration, and all necessary data are available to support the assessment. It is well understood how changes to soil fertility (from compaction, dust effects, acidification, and other forms of alteration) reduce soil quality. The effectiveness of the selected mitigation measures ranges from moderate to low. There is a low degree of uncertainty associated with collected data and modelling. Thus, there is high confidence in the conclusions of the assessment.

### 9.7.2.3 Residual Effects on Terrain Stability and Geohazards

This section discusses the effects of Project activities on terrain stability. The assessment is focused on bulk losses of soil associated with potential mass movement events and erosion.

#### 9.7.2.3.1 Residual Effect Analysis

Past studies have indicated that roads constructed in unstable terrain can increase the likelihood of a landslide by approximately two orders of magnitude compared to undisturbed forest land (Morrison 1975; O'Loughlin and Pearce 1976; Amaranthus et al. 1985). A road's potential effect on terrain stability is largely determined by the road's position on the slope (e.g., roads traversing the upper portions of unstable terrain generally have less of a destabilizing effect than those that traverse lower sections) (Madej 2001)). Other determinants include construction methods, maintenance of drainage structures, the type of parent material in the area, the slope gradient, the proportion of the footprint located within the unstable area, and the presence of existing geohazards near the road.

Although the Access Road and Haul Road are being constructed in areas that do have unstable and potentially unstable terrain, road design and stability mitigation measures are expected to result in no residual effects for terrain stability. Extensive mitigation has been incorporated into the Project design phase of the Project. This includes locating infrastructure to avoid geohazards, construction techniques, and timing of activity.

### 9.7.3 Summary of Residual Effects Assessment

Residual effects and the selected mitigation measures, characterization criteria, likelihood, and confidence evaluations are summarized in Table 9.7-6.

**Table 9.7-6: Summary of the Residual Effects Assessment**

| Residual Effect (Measurement Indicators) | Intermediate Component | Project Phase(s) | Mitigation Measures | Summary of Residual Effects Characterization *(context, magnitude, geographic extent, duration, frequency, reversibility)* | Likelihood *(High, Moderate, Low)* | Confidence |
|---|---|---|---|---|---|---|
| Loss of Soil Quantity | Soil Quantity | Construction Operation Closure and Reclamation | See Table 9.6-4 | Magnitude: Moderate<br>Geographic Extent: Discrete<br>Duration: Permanent<br>Frequency: Sporadic<br>Reversibility: Irreversible<br>Context: Neutral | High | High |
| Alteration of Soil Quality | Soil Quality | Construction Operation<br>Closure and Reclamation | See Table 9.6-4 | Magnitude: Low<br>Geographic Extent: Discrete<br>Duration: Permanent<br>Frequency: Continuous<br>Reversibility: Reversible<br>Context: Low | High | High |

## 9.8 Cumulative Effects Assessment

Cumulative effects are the result of a Project-related residual effect interacting with the effects of other projects or activities to produce a combined effect. Cumulative effects are assessed as required by EAO (2013).

The method for conducting a cumulative effects assessment (CEA) generally follows the same steps as the Project-specific effects assessment; however, there is a greater reliance on qualitative methods due broader scale nature of the assessment. The approach to assessing cumulative effects comprises the following steps:

1. Review the residual effects for each IC;
2. Identify potential cumulative effects;
3. Identify any additional mitigation measures, beyond those identified for each IC;
4. Prepare a Project activity/residual effect interaction matrix;
5. Determine if the interaction will result in a cumulative effect in addition to the residual, Project-specific effect; and
6. If a cumulative effect is determined:
    a. The effect is characterized by magnitude, geographic extent, duration, frequency, reversibility, and context;
    b. The significance of the cumulative effect is determined; and
    c. The likelihood, confidence, and risk of the cumulative effect are identified.

### 9.8.1 Review Residual Effects

Residual effects for soil quality and soil quantity were carried forward from the Project-specific assessment to be considered in combination with the residual effects of past and future human actions, where some spatial and temporal overlap occurs.

Spatial and/or temporal overlap of residual effects of the Project coupled with the residual effects of past, present, and future infrastructure and human actions are termed cumulative effects and can occur in the following ways:

- Physical-chemical transport – A physical or chemical constituent is transported away from the action under review where it then interacts with another action.
- Nibbling loss – The gradual disturbance and loss of land and habitat.

- Spatial and temporal crowding – Cumulative effects can occur when too much is happening within too small an area and in too brief a period. A threshold may be exceeded and the environment may not be able to recover to pre-disturbance conditions.
- Synergistic – Combined effects along a pathway that collectively result in an increased effect that may not have existed if the effect occurred in isolation.
- Additive – Combined effects along a pathway that equal the sum of the individual effects.
- Growth-inducing – Each new action can induce further actions to occur.

## 9.8.2 Cumulative Effects Assessment Boundaries

### 9.8.2.1 Spatial Boundaries

The cumulative effects assessment boundary is the RSA delineated for the Landforms and Natural Landscapes baseline studies. The RSA boundary provides context for the type, abundance, distribution, and extent of Landforms and Natural Landscapes within the region. This boundary represents the area beyond which effects of the Project are expected to cumulatively interact with effects of other projects.

### 9.8.2.2 Temporal Boundaries

The temporal boundaries for the assessment of cumulative effects on Landforms and Natural Landscapes encompass the periods during which the proposed Project-related residual effects are expected to interact with residual effects of other past, present, or reasonably foreseeable future projects and activities. The following temporal boundaries are evaluated as part of each CEA:

- Past: 1988 to 2014 (includes projects that are active and ones that are inactive);
- Present: 2014 to 2017, from the start of the Project's detailed baseline studies to the completion of the effects assessment; and
- Foreseeable Future: The cut-off date for incorporating any new future developments in the CEA is 2029. This represents the final anticipated year of the mine life after the Reclamation and Closure Phase is complete.

## 9.8.3 Identifying Past, Present, and Reasonably Foreseeable Projects and/or Activities

The list of past, present, and reasonably foreseeable projects and/or activities for consideration in the CEA was compiled from a variety of information sources, including municipal, regional, provincial and federal government agencies, and company websites (see Volume 3, Chapter 6).

The following development categories were considered in the Application:

- Certain (past and present): Projects or activities that have already been built or conducted for which the environmental effects overlap with those of the proposed Project (i.e., certain); and

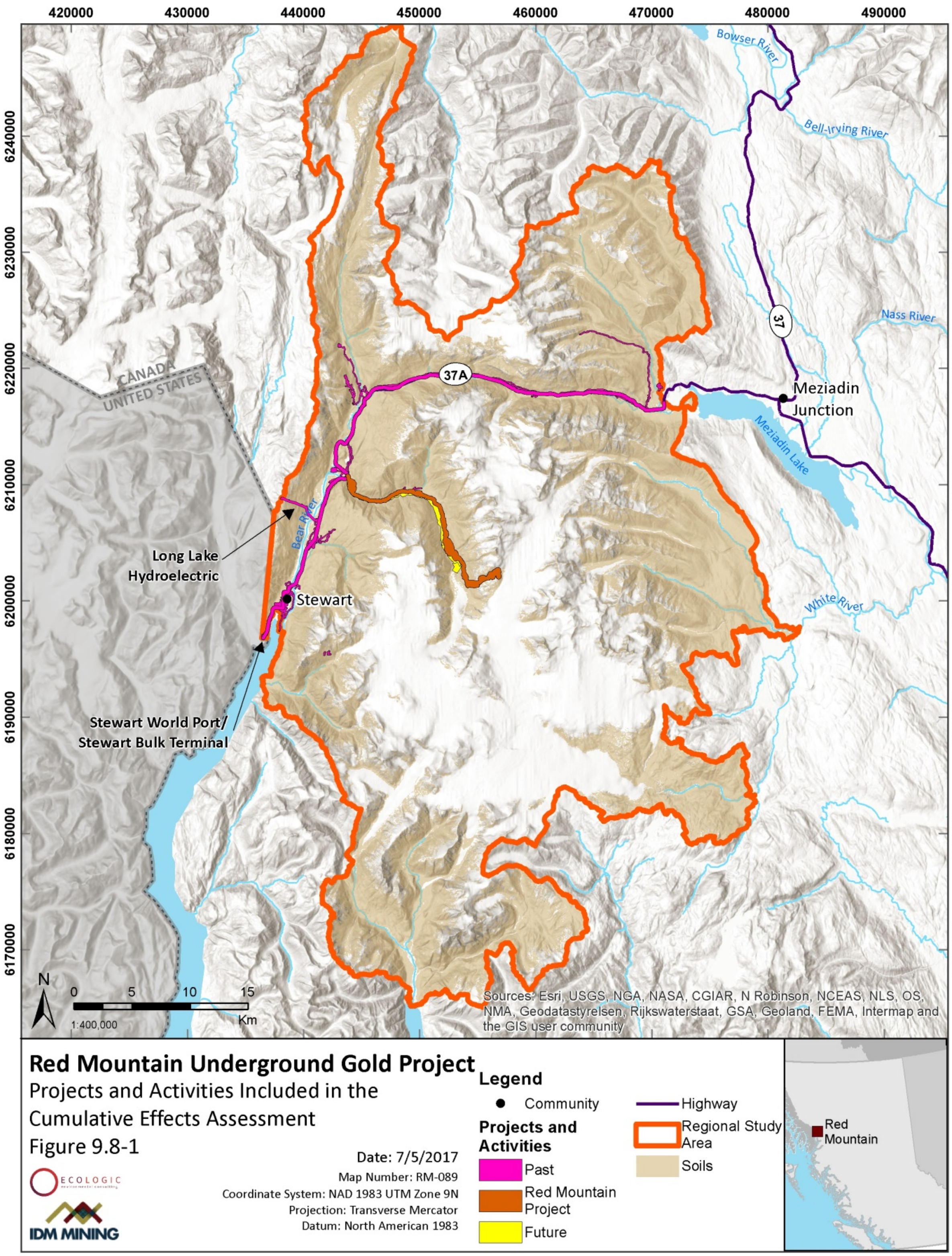
- Reasonably foreseeable: Projects that are either proposed (public disclosure) or have been approved to be built but are not yet built, for which the environmental effects overlap the proposed Project.

Table 9.8-1 presents a summary of the Projects and activities identified within the RSA for the cumulative effects analysis, while Figure 9.8-1 presents a map of the RSA illustrating the distribution and abundance of Landforms and Natural Landscapes relative to the Project and cumulative projects and activities. The complete disturbance footprint was not available for all identified projects and activities, particularly forestry.

### Table 9.8-1: Past, Present, and Reasonably Foreseeable Projects and Activities

| Project/Activity | Project Life | Location | Proponent | Potential Cumulative Effect (Y/N) |
|---|---|---|---|---|
| Stewart Bulk Terminals | Currently Operating | Stewart | Stewart Bulk Terminals Ltd. | N |
| Stewart World Port | Currently Operating | Stewart | Stewart World Port | Y |
| Highway 37A | Ongoing | Stewart | MOTI | Y |
| Long Lake Hydroelectric Project | Currently Operating | 25km east of Stewart | Long Lake Hydro Inc. | Y |
| Bitter Creek Hydroelectric Project | Proposed | 15 km northeast of Stewart | Bridge Power | Y |
| Forestry | Ongoing | Regional | Various | Y |
| Mineral Exploration | Historic | Regional | Various | N |
| Public Transmission Lines | Ongoing | Regional | BC Hydro | Y |
| Urban Development | Ongoing | Stewart | Various | Y |
| Transportation (excluding Highway 37A) | Ongoing | Regional | Various | Y |

**Figure 9.8-1: Projects and Activities Included in the Landforms and Natural Landscapes Cumulative Effects Assessment**



## 9.8.4 Cumulative Project Interactions and Effects

Two cumulative effects were identified: 1) Nibbling loss, attributable to the incremental loss and alteration of soils due to development infrastructure; and 2) Growth-inducing, attributable to infrastructure development, primarily roads.

## 9.8.5 Cumulative Effects Interaction Matrix

A cumulative effects interaction matrix, summarizing potential cumulative interactions between the residual effect of the Project on Landforms and Natural Landscapes and each past, current, and foreseeable future project, is presented in Table 9.8-2.

### 9.8.5.1 Residual Cumulative Effects Assessment

Past projects include Stewart Bulk Terminals, Stewart World Port, Long Lake Hydroelectric Project, Highway 37A, BC Hydro transmission line, and various old roads, cut blocks, transportation quarries, and urban areas (mainly Stewart). The Bitter Creek Hydroelectric Project is the only known future project in the RSA. All historic mines present in the RSA finished operations before 1988 and were not included in the assessment. Highway 37A included a 150 m buffer to include potential effects (consistent with the approach used for the Project components). All other past and future projects were buffered by 50 m to account for past or present alterations. Where buffers overlapped, the Highway 37A buffer was given precedence, then equal weights were given to the other buffered features to eliminate any overlaps. The buffered area was then overlain on the PEM, which was then associated with likely soil management units to generate a list of soil units that have been or may be disturbed. From that, the area of each Landforms and Natural Landscapes IC was calculated (Table 9.8-3) and used for the CEA.

**Table 9.8-2: Interaction with Effects of other Past, Present, or Reasonably Foreseeable Future Projects and Activities**

| Residual Effects of the Project on ICs | Past Projects and Activities | | | | | | | | Future Projects and Activities |
|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Transportation (excluding Hwy 37A) | Urban | Public Transmission Lines | Highway 37A | Long Lake Hydroelectric Project | Stewart Bulk Terminals | Stewart World Port | Bitter Creek Hydroelectric Project |
| Soil Quantity | Y | Y | N | N | N | Y | N | N | Y |
| Soil Quality | Y | N | N | N | N | Y | N | N | Y |

Notes:
Y = Yes, interaction exists between the residual effect of the Project and the other past, current, or future project/activity
N = No, interaction does not exist between the residual effect of the Project and the other past, current, or future project/activity

**Table 9.8-3: Summary of Cumulative Effects for Landforms and Natural Landscapes Intermediate Components in relation to Past, Present and Future Activities**

| VC | Past (ha) | Project Loss and Alteration (ha) | Future (ha) | Total Loss and Alteration/Alteration (ha) | RSA Total (ha)[1] | Cumulative RSA Change (%) |
|---|---|---|---|---|---|---|
| Soil Quality and Quantity | 2,414 | 772.2 | 0 | 3186.2 | 115,352 | 2.8 |

The future effects for Bitter Creek Hydroelectric and historic roads that fell within the PFSA were included in the Project effects and not for future or historic effects. For all ICs, the total hectares of cumulative effects were based on an analysis of the PEM mapping, in conjunction with vegetation resource information (VRI) data, to determine potential soil distribution in the RSA. Potential total soil in the RSA was estimated by subtracting from the total RSA area features that are non-soil, including ice, rock, water features, and anthropogenic features. The cumulative effects footprint (excluding the Project) was created using all available information regarding past, current, and future projects, as well as provincial TRIM data (e.g., roads). Additional known features were digitized in ArcGIS using a variety of orthomosaic and satellite imagery.

### 9.8.5.2 Cumulative Effects Characterization- Soil Quantity and Soil Quality

Loss of soil quantity and alteration of soil quality are expected to be a residual cumulative effect because reclamation activities associated with the various projects within the RSA were either limited or unlikely to restore soils to baseline conditions. Soil quality and quantity are assessed together, as it is not feasible to separate effects to soil quantity and soil quantity given the resolution of information available for the CEA.

#### 9.8.5.2.1 Characterization of Cumulative Residual Effects on Soil Quantity and Soil Quality

The total cumulative effect of past, present, and future projects on soil quantity and soil quality is 3,186.2 ha. Regionally, this constitutes loss or alteration of 2.76% of soils within the RSA. For the purposes of this assessment, all areas within the RSA were considered to have functional soils, with the exception of bedrock, ice, and water features.

The Project will represent an alteration of 772.2 ha of soils which represents 32.0% of the total contribution to the 2.8% cumulative change.

The magnitude of the cumulative residual effects on soil function is low. Cumulative residual effects are not expected to have a notable change on soil distribution or abundance. Effects to soils are expected to occur at the site level within the relevant project footprints and adjacent areas and are expected to subside over time.

The changes to soils are considered long-term to permanent, depending on the soil type and the level of effort invested in reclamation activities and follow-up. Loss is considered a regional effect because each project contributes to the incremental loss of the resource at a regional scale, which may also influence the way in which these ecosystems are used. Frequency of effects is difficult to quantify, as this will vary between projects and is based on the proposed or historic activities and on the effect itself. Most effects are expected to occur continuously until a new steady state is reached at which time they may occur sporadically. The majority of soils have low resiliency to disturbance, as they develop over the long term. As a result, they have limited ability to adapt to changes that extend beyond their natural range of variation.

#### 9.8.5.2.2 Likelihood of Cumulative Residual Effects on Soil Quantity and Quality

There is a high likelihood of loss and alteration to soils within the region based on the spatial footprints and likely activities associated with historic, present, and proposed developments.

## 9.8.6 Summary of Cumulative Effects Assessment

Residual cumulative effects, characterization criteria, likelihood, and confidence evaluations are summarized in Table 9.8-4.

## Table 9.8-4: Summary of Residual Cumulative Effects Assessment

| Residual Effect (Measurement Indicators) | Intermediate Components | Project Phase(s) | Mitigation Measures | Summary of Residual Effects Characterization *(context, magnitude, geographic extent, duration, frequency, reversibility)* | Likelihood *(High, Moderate, Low)* | Confidence *(High, Moderate, Low)* |
|---|---|---|---|---|---|---|
| Loss and alteration to Soil Quantity and Quality | Soil Quality<br>Soil Quantity | Construction<br>Operation<br>Closure and Reclamation | See Table 9.6-4 | Magnitude: Low<br>Geographic Extent: Regional<br>Duration: Long-term to Permanent<br>Frequency: Continuous<br>Reversibility: Partially Reversible<br>Context: Low | High | High |

## 9.9 Follow-up Program

A follow-up program will be implemented to evaluate the effectiveness of mitigation measures on soil quantity and quality, and to verify the accuracy of the predictions made in this effects assessment. Field surveys will be conducted prior to Construction to identify areas of high quality soil for salvage and borrow. Monitoring will be established during all Project phases to ensure soil alteration and soil loss is minimized. This information will be used to identify, evaluate, and track Project-related changes to soil quality and quantity over time.

Mitigation and monitoring strategies for Landforms and Natural Landscapes will be updated to maintain consistency with best management practices, improved scientific methods, and regulatory changes that may become available during the life of the Project. Key stakeholders, Aboriginal Groups, and government agencies will be involved in developing strategies and additional mitigation as applicable.

## 9.10 Conclusion

In summary, the Project-related residual effects on Landforms and Natural Landscapes will result in residual effects on soil quantity and soil quality, but will not result in residual effects on terrain stability. As identified in the previous section, a follow-up program will be implemented to evaluate the effectiveness of mitigation measures and to verify the accuracy of the predictions made during the environmental assessment/ application.

This chapter is linked to the potential effects of the Project on other related ICs and VCs, including those identified and evaluated in the following chapters:

- Vegetation and Ecosystems Effects Assessment (Volume 3, Chapter 15);
- Wildlife and Wildlife Habitat Effects Assessment (Volume 3, Chapter 16);
- Fish and Fish Habitat (Volume 3, Chapter 18); and
- Air Quality Effects Assessment (Volume 3, Chapter 7).

# 9.11 References

Agency, Region 6, Multimedia Planning and Permitting Division, Center for Combustion

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A Field Guide to Site Identification and Interpretation for the Prince Rupert Forest Region. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 26.

BC Min. of Forests and Range and BC Min. of Env. 2010. Field Manual for Describing Terrestrial Ecosystems; 2nd Edition. Victoria, B.C. Land Manage. Handb. No. 25.

BC MOE. 2017. Conservation Status Ranks. Available at http://www2.gov.bc.ca/gov/content/environment/plants-animalsecosystems/conservation-data-centre/explore-cdc-data/status-ranks (accessed March 15, 2017)

Beyers, J. L. (2004), Postfire Seeding for Erosion Control: Effectiveness and Impacts on Native Plant Communities. Conservation Biology, 18: 947–956.

Chapter 5: Estimating Media Concentrations. EPA530-R-05-006. U.S. Environmental Protection

Chen, J., J.F. Franklin, and T.A. Spies. 1995. Growing-season microgradients from clearcut edges into old-growth Douglas-fir forests. Ecological Applications. 5(1) pp. 74-86.

Esseen, P.-A. and Renhorn, K.-E. (1998), Edge Effects on an Epiphytic Lichen in Fragmented Forests. Conservation Biology, 12: 1307–1317

Gomez, A., R. F. Powers, M. J. Singer, and W. R. Horwath. 2002. Soil Compaction Effects on Growth of Young Ponderosa Pine Following Litter Removal in California's Sierra Nevada. Soil Sci. Soc. Am. J. 66:1334-1343

Greenberg, C. H., S. H. Crownover, D. R. Gordon. 1997. Roadside soil: a corridor for invasion of xeric scrub by nonindigenous plants. Natural Areas Journal 17:99 109.

GWRTAC, “Remediation of metals-contaminated soils and groundwater,” Tech. Rep. TE-97-01,, GWRTAC, Pittsburgh, Pa, USA, 1997, GWRTAC-E Series. View at Google Scholar

Hejda, M., Pyšek, P. and Jarošík, V. (2009), Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology, 97: 393–403

Ickes, B. S., J. Vallazza, J. Kalas, and B. Knights. 2005. River floodplain connectivity and lateral fish passage: A literature review. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, June 2005. 25 pp.

Junk, W. J., P. B. Bayley, and R. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Resources 106:110–127.

Kolb, A. and Diekmann, M. (2005), Effects of Life-History Traits on Responses of Plant Species to Forest Fragmentation. Conservation Biology, 19: 929–938.

Kozlowski, T.T. 1999. Soil Compaction and Growth of Woody Plants. Scandinavian Journal Of Forest Research, Vol. 14 , Iss. 6,1999

Luce, C. H., and T. A. Black (1999), Sediment production from forest roads in western Oregon, Water Resour. Res., 35(8), 2561–2570.

MacKenzie and Moran 2004. Wetlands of BC. – full ref should be in section 9.4

MacKenzie, W.H. 2012. Biogeoclimatic ecosystem classification of non-forested ecosystems in British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 068.

MacKenzie, W.H. and J.R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handb. No. 52.

Matlack, Glenn R. 1993 Microenvironment variation within and among forest edge sites in the eastern United States. Biological conservation 66.3 (1993): 185-194.

Montgomery, D. R. (1994), Road surface drainage, channel initiation, and slope instability, Water Resour. Res., 30(6), 1925–1932.

Murphy, H. T. and J. Lovett-Doust. 2004. Context and connectivity in plant metapopulations and landscape mosaics: Does the matrix matter? Oikos, 105: 3-14

Nisga'a Lisims Government Available at http://www.nisgaanation.ca (accessed March 15, 2017)

Raphael K. Didham, R.K., J. M. Tylianakis, M. A. Hutchison, R.M. Ewers, and N. J. Gemmell. 2005. Are invasive species the drivers of ecological change? Trends in Ecology & Evolution, 20(9):470-4

Science and Engineering, Office of Solid Waste and Emergency Response.

Stevens, Carly J., et al. “Contribution of Acidification and Eutrophication to Declines in Species Richness of Calcifuge Grasslands along a Gradient of Atmospheric Nitrogen Deposition.” Functional Ecology, vol. 24, no. 2, 2010, pp. 478–484., www.jstor.org/stable/40603066.

Trombulak, S. C. and Frissell, C. A. (2000), Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology, 14: 18–30.

US-EPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities,

Wemple, B. C., J. A. Jones, G. E. Grant. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon. Water Resources Bulletin 32:1195 1207.