# RED MOUNTAIN UNDERGROUND GOLD PROJECT
# VOLUME 3 | CHAPTER 12
# HYDROLOGY EFFECTS ASSESSMENT

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# 12 HYDROLOGY EFFECTS ASSESSMENT

## 12.1 Introduction

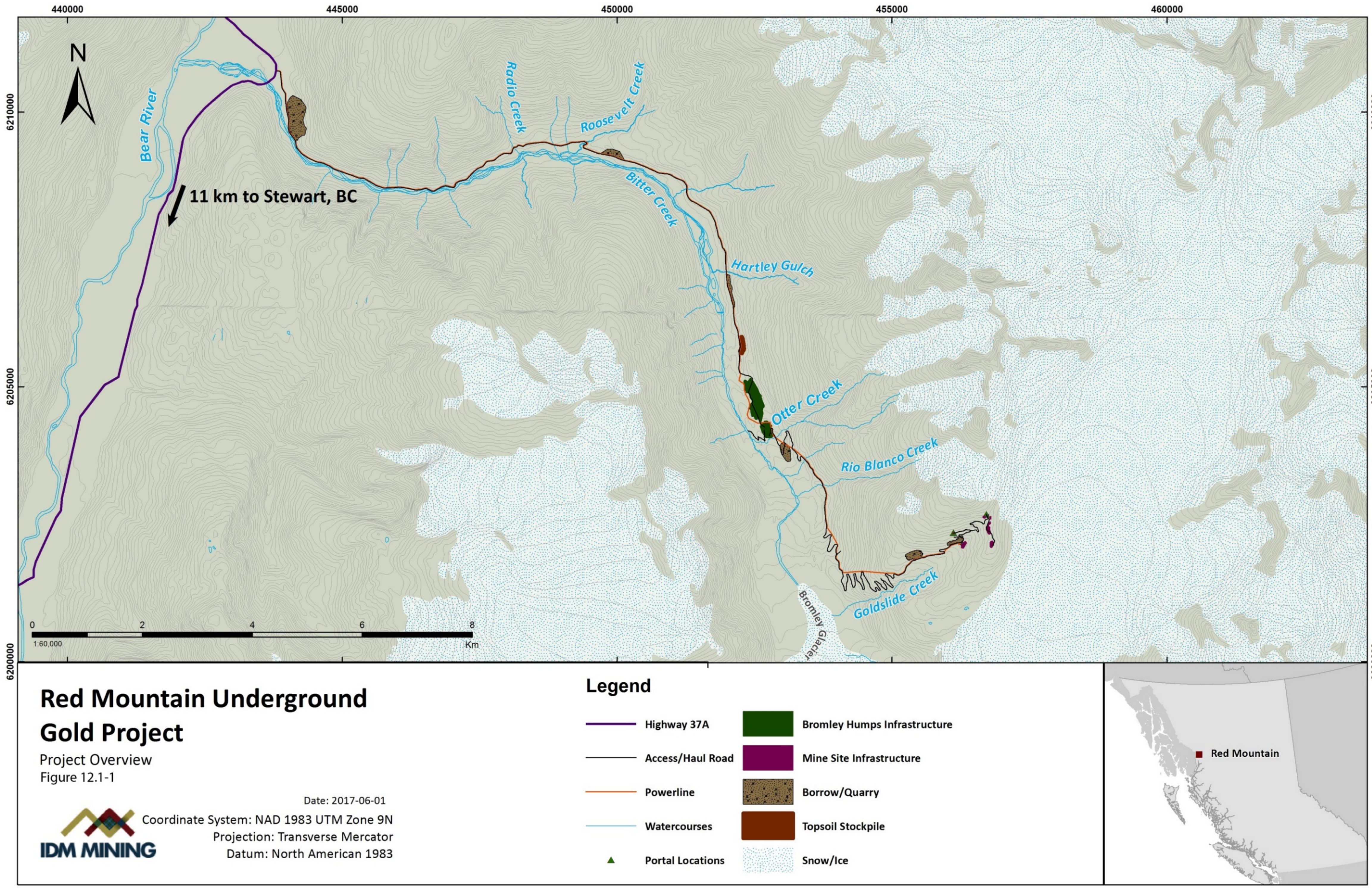
Hydrology is an aspect of the environment that may be altered by the proposed Red Mountain Underground Gold Project (the Project), as proposed by IDM Mining Ltd. (IDM). Figure 12.1-1 to Figure 12.1-3 below illustrate the established disturbance limits for the entire footprint, for the Mine Site (portal locations and ancillary infrastructure), and for Bromley Humps (location of Process Plant and Tailings Management Facility (TMF)).

Hydrology is a valued component (VC) for the Project. This chapter evaluates the potential interactions between hydrology and the Project components through the Project lifespan. Specific components of hydrology include the mine inflows, surface water flow pathways, contributions of surface water flow to creek flows, and proportions of mine contact surface water discharging to surface water receptors. Linkages to other components of the aquatic environment include the intermediate components (ICs) Hydrogeology (Volume 3, Chapter 10) and Groundwater Quality (Volume 3, Chapter 11), and the VCs, Surface Water Quality (Volume 3, Chapter 13), Aquatic Resources (Volume 3, Chapter 17), Fish, and Fish Habitat (Volume 3, Chapter 18).

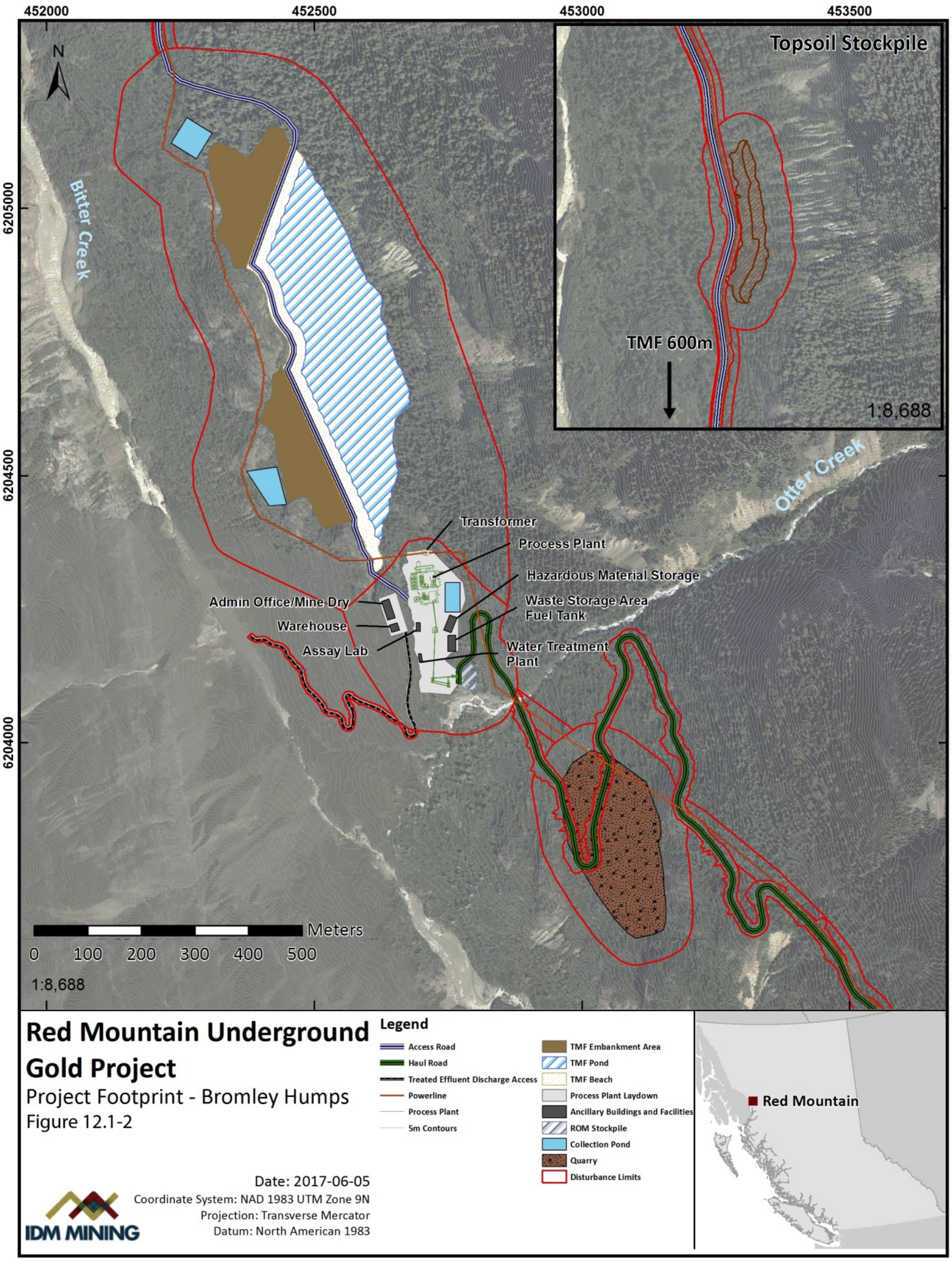
This chapter follows the effects assessment methodology described in the Application/EIS, Volume 8, Chapter 3.

Further details on baseline studies and numerical modelling completed in support of the environment assessment are provided in Appendix 12-A, the *Baseline Climate and Hydrology Report*, and Appendix 14-C, the *Water and Load Balance Model Report*.

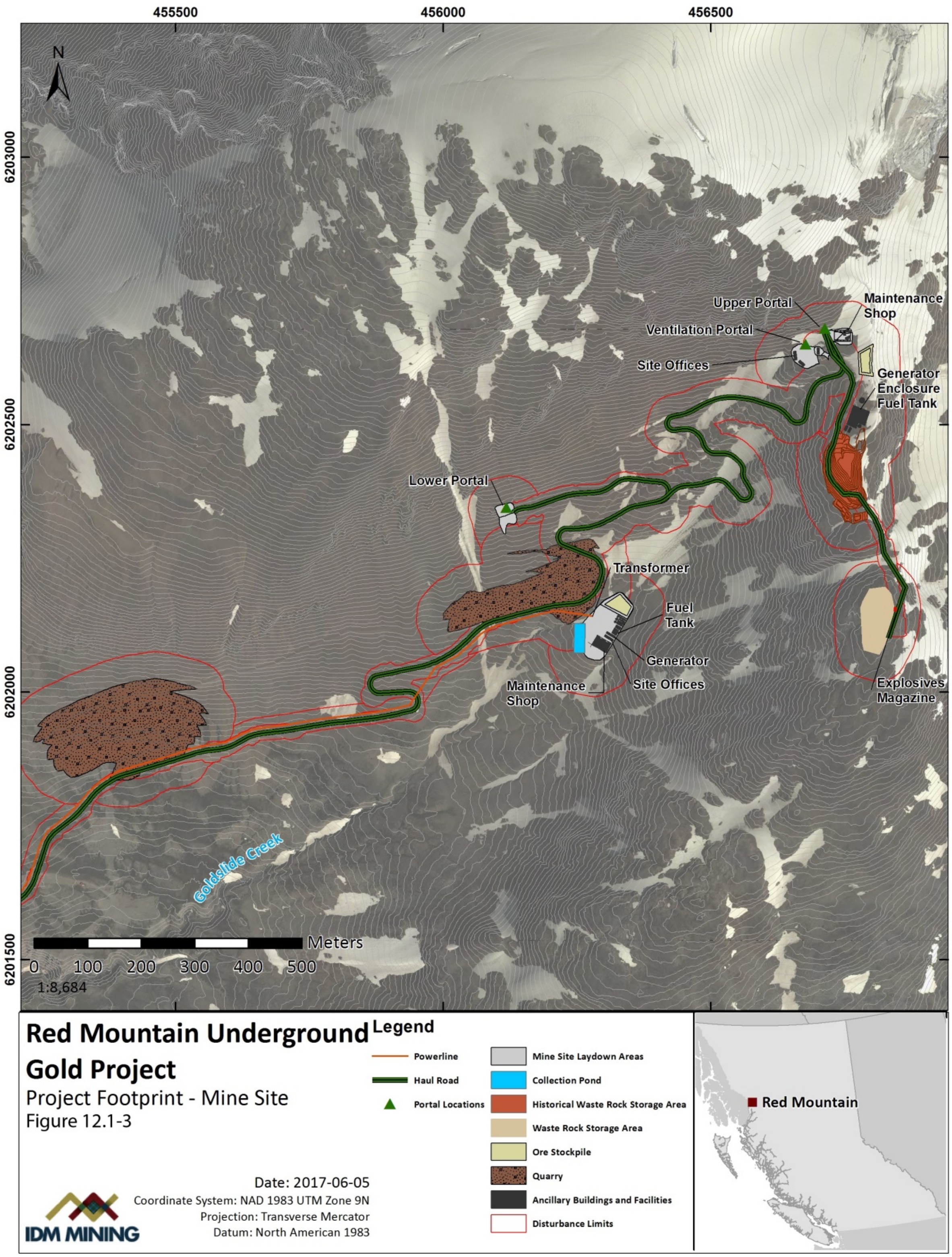
**Figure 12.1-1: Project Overview**



## Figure 12.1-2: Project Footprint – Bromley Humps



## Figure 12.1-3: Project Footprint – Mine Site



## 12.2 Regulatory and Policy Setting

The Application Information Requirements (AIR) for the Project, approved by the British Columbia Environmental Assessment Office (BC EAO 2017), and the final Environmental Impact Statement (EIS) Guidelines (Canadian Environmental Assessment Agency 2017), outline the requirements of the Hydrology effects assessment to meet both the provincial and federal environmental assessment requirements under the *BC Environmental Assessment Act* (2002) and *Canadian Environmental Assessment Act 2012* (2012), respectively.

Additional environmental regulations and guidelines are listed below and were consulted to help with the characterization of hydrological baseline conditions and the assessment of potential Project influences on the surface water system:

- "Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators" Version 2. BC Ministry of Environment.

The Project is 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 Nisga'a Lisims Government (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.

## 12.3 Scope of the Assessment

### 12.3.1 Information Sources

The following information was reviewed as part of a desktop study:

- *Environmental Baseline Data Report* prepared by Hallam Knight Piésold for Lac Minerals Ltd. (HKP 1992).
- Synopsis of Environmental Programs Undertaken and Draft Project Application prepared by Rescan for Lac North America (Rescan 1994, 1995).
- Hydrometric data from the Water Service of Canada (WSC) (WSC 2014)
- Regional station climatic data from Environment Canada (EC) (EC 2015)

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 Canadian Environmental Assessment 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 publicly available. As no TEK relevant to this effects assessment was publicly available at the time of writing, no TEK has been incorporated.

### 12.3.2 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. 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.

The input from consultations incorporated in the assessment are summarized in Table 12.3-1.

**Table 12.3-1: Summary of Consultation Feedback on Hydrology**

| Topic | Feedback by* | | | | Consultation Feedback | Response |
|---|---|---|---|---|---|---|
| | NLG | G | P/S | O | | |
| Hydrology | | X | | | British Columbia Ministry of Environment (BC MOE) requested that the water load and balance model:<br>• Be calibrated and or validated to the baseline hydrology data;<br>• Incorporate hydrologic variability; and<br>• Consider climate change or existing climate and hydrologic trends. | BC MOE suggestions have been incorporated into the water load balance model. A climate change analysis is included in Appendix 12-A, but was not included into the water and load balance model (Appendix 14-C). |
| Hydrology | X | | | | NLG requested that Hydrology be included in the assessment as a VC, rather than an IC. | IDM has included Hydrology as a VC in the effects assessment. |

| Topic | Feedback by* | | | | Consultation Feedback | Response |
|---|---|---|---|---|---|---|
| | NLG | G | P/S | O | | |
| Hydrology | X | | | | NLG requested that baseline discharge, water level, and climate data should be collected for a minimum of three years. NLG recommended the data be used to facilitate estimation of long term monthly and annual streamflow statistics. | IDM has accumulated two years of current data that will be supplemented with a historical dataset containing approximately six years of data for most parameters. IDM continues to collect hydrology data over 2017. |
| Hydrology | X | | | | NLG suggested that historical streamflow data for the Bear River should be considered in the Application. | IDM has included the Bear River hydrology information in the Application/EIS. |

*NLG = Nisga'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

## 12.3.3 Valued/Intermediate Components, Assessment Endpoints, and Measurement Indicators

The Hydrology effects assessment follows the structure indicated in the Project AIR (BC EAO 2017) using the measurement indicators listed in Table 12.3-2.

**Table 12.3-2: Assessment Endpoints and Measurement Indicators for Hydrology**

| Pathways | Primary Measurement Indicators | Rationale for Selection | Assessment Endpoints |
|---|---|---|---|
| The following pathways will inform the assessment of potential Project effects to Hydrology:<br>• Hydrogeology<br>• Landforms and Natural Landscapes | Bitter Creek, Otter Creek, Goldslide Creek Hydrology:<br>• Average annual flows<br>• Average monthly flows<br>• Peak flows<br>• Baseflow and low flows | Hydrology was selected as a VC as it will provide an understanding of the change in flow regime from the Project footprint. Change in flow regime will also be required to evaluate other VCs such as Vegetation and Ecosystems, Fish Habitat, and Water Quality.<br>Changes in the water level regime can affect the sustainability of existing habitat. An understanding of the water level regime will allow to estimate these effects. | • Maintenance of the quantity of stream flows in the receiving environment.<br>• Maintenance of other VCs that are influenced by Hydrology. |

## 12.3.4 Assessment Boundaries

### 12.3.4.1 Spatial Boundaries

The spatial boundaries define the limit within which changes to VCs will be evaluated. Two spatial boundaries were considered for the Hydrology assessment: the Regional Study Area (RSA) and the Local Study Area (LSA). The LSA encompasses the Project footprint and extends beyond it to include the surrounding area where there is a reasonable potential for adverse Project-specific effects to occur. The RSA is a larger area that is used to provide context for the assessment of potential Project effects, and represents the cumulative effects assessment study area.

A description of the spatial boundaries is provided in Table 12.3-3. The hydrological analyses included data from regional meteorological and hydrometric gauge stations located as far away as 200 to 300 kilometres (km) from the proposed Project. The general extent of the regional stations used were Dease Lake to the north, Bella Bella to the south, Graham Island to the west, and 200 km to the east. Figure 12.3-1 illustrates the LSA, RSA, and the meteorology and hydrology baseline study region.

## Figure 12.3-1 Spatial Boundaries for Hydrology

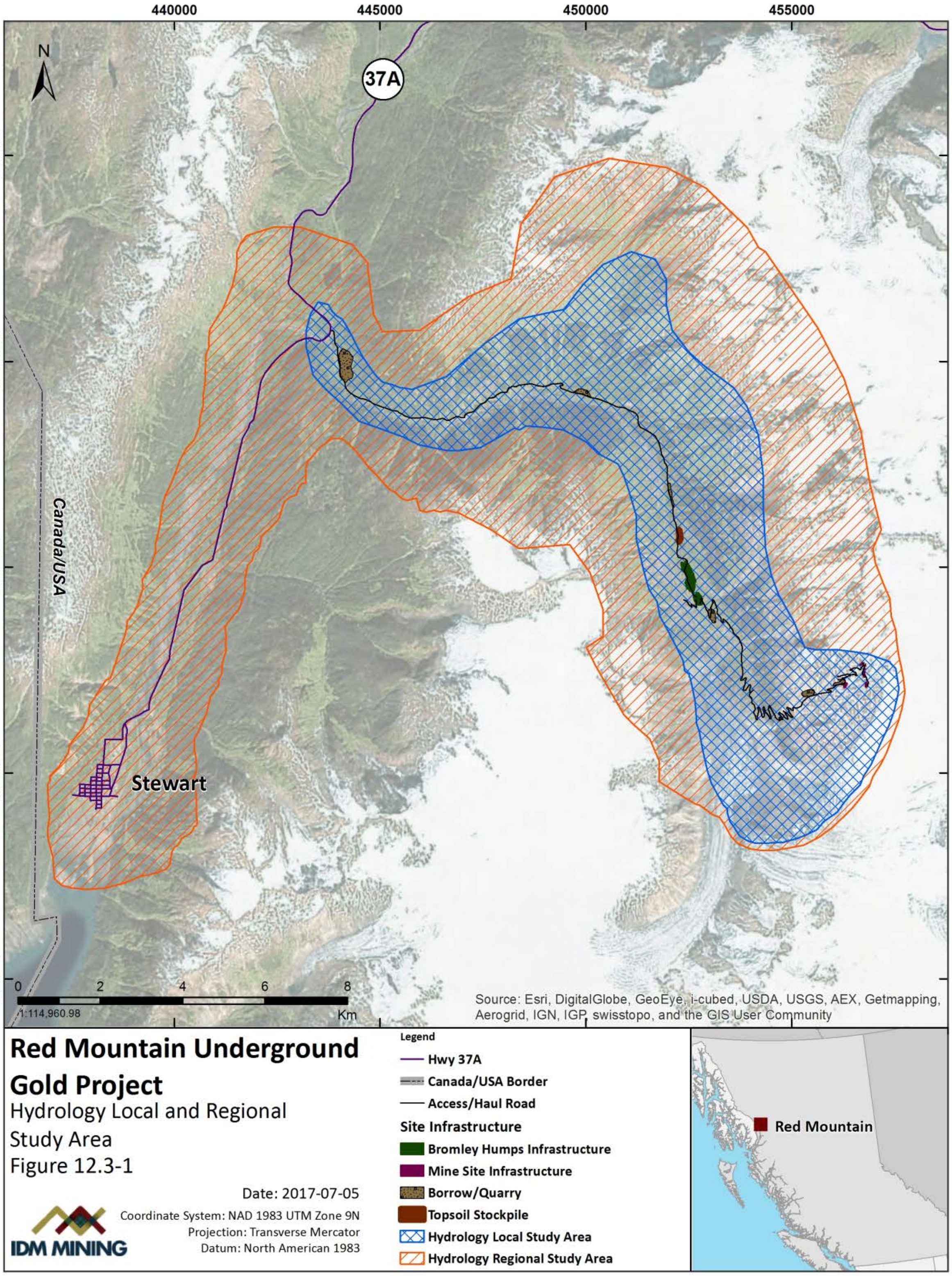


**Table 12.3-3: Spatial Boundaries for the Hydrology Assessment**

| Name | Spatial Boundary Description |
|---|---|
| LSA | The LSA corresponds to the Bitter Creek watershed up to the glacial extent. It includes Goldslide and Otter Creeks. |
| RSA | The RSA corresponds to the Bitter Creek watershed including the glacial extent, the Bear River watershed, from American Creek to Stewart, and the northern end of the Portland Canal. |

#### 12.3.4.2 Temporal Boundaries

The temporal boundaries encompass the periods during which the Project is expected to have potential effects on Hydrology. The relevant time-steps used for the Hydrology effect assessment are provided in Table 12.3-4.

**Table 12.3-4: Temporal Boundaries of the Hydrology 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 6 | 6 years | Ramp up to commercial ore production and maintain a steady state of production, underground dewatering, tailings storage, water treatment, gold ore shipping, environmental monitoring, and progressive reclamation. |
| Closure and Reclamation, and Post-Closure | Year 7 to Year 21 | 15 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; and receiving environment monitoring. |

* Post-closure changes to groundwater will continue until water levels in the mine reach steady state in about 30 years, and monitoring of this component will continue until steady state conditions have been established.

#### 12.3.4.3 Administrative and Technical Boundaries

No administrative or technical boundaries are relevant to hydrology.

## 12.4 Existing Conditions

Section 3.3 of the Application Information Requirements (AIR) requests the following information for existing conditions. Specific references are provided for each request in the following list.

- A description of the existing (or baseline) conditions within the study area in sufficient detail to enable potential Project-VC or -IC interactions to be identified, understood, and assessed: please see Sections 12.4.1 and 12.4.3 in this Chapter and Sections 4 and 5 in Appendix 12-A.
- A description of the quality and reliability of the existing (or baseline) data and its applicability for the purpose used, including any gaps, insufficiencies, and uncertainties, particularly for the purpose of monitoring activities: please see the "Limitations" discussion in Section 12.4.3.2.1.
- Reference to natural and/or human-caused trends that may alter the environmental, economic, social, heritage, and health setting, irrespective of the changes that may occur as a result of the proposed Project or other project and/or activities in the area: please see Section 6 in Appendix 12-A on climate change.
- An explanation of if and how other past and present projects and activities in the study area have affected or are affecting each VC or IC: please see Section 12.4.2 in this Chapter.
- Documentation of the methods and data sources used to compile information on existing (or baseline) conditions, including any standards or guidelines followed: please see Sections 12.2, 12.4.3, and 12.4.4 in this Chapter and Sections 4 and 5 in Appendix 12-A.
- Where additional Project and VC- or IC-specific field studies are conducted, the scope and methods to be used will follow published documents pertaining to data collection and analysis methods, where these are available. Where methods used for the assessment deviate from applicable published guidance, the rationale for the variance will be provided in the Application: please see Sections 12.2, 12.4.3, and 12.4.4 in this Chapter and Sections 4 and 5 in Appendix 12-A.
- Description of what Traditional Ecological Knowledge (TEK), including Aboriginal Traditional Knowledge, was used in the VC or IC assessment: please see Section 12.3.1 in this Chapter.

### 12.4.1 Overview of Existing Conditions

Baseline surface water quantities in the Project area have been characterized from historical data, local meteorological and hydrometric stations that were established as monitoring locations in the summer of 2014, and are supported by regional climatic and hydrometric data analysis.

The Mine Site is in the Red Mountain cirque, a hanging valley above the Bitter Creek valley. The cirque is drained by Goldslide Creek, a small headwater creek that flows southwest into the east side of Bromley Glacier, but is not glacially influenced. Flows in Goldslide Creek peak during freshet (typically in June). Goldslide, Rio Blanco, Otter and Roosevelt Creeks are the main headwater creeks to the Bear River, which flows into the Portland Canal near Stewart, BC. Bitter Creek and Otter Creek are glacially influenced therefore peak flows generally occur during the summer (typically in July) because of glacial melt.

The hydrologic regime is dominated by rapid runoff (from rainfall or snowmelt). Due to the proximity to the Pacific Ocean, large scale atmospheric circulation, occurring over the Pacific Ocean and the Gulf of Alaska, is the main driver of seasonal variations in precipitation and weather patterns in the region. The Mine Site is fully exposed to regional winds and precipitation and approximately two-thirds of precipitation occurs during half of the year (October to March) from the Pacific storm track and much of this precipitation falls locally within the Cambria range. In addition to large scale atmospheric circulation effects, the climate and hydrology of the area are seasonally influenced by three factors: distance from the coast, site elevation, and glacial cover. (Appendix 12-A).

The region is heavily glaciated and glacial ice persists year-round in the Bitter Creek valley at elevations greater than 600 masl. The Bromley, Bear River, Kitsault and Sutton Glaciers, and the Cambria Icefield cover a total of about 58% of the RSA (Appendix 12-A).

## 12.4.2 Past and Current Projects and Activities

Mineral exploration of the Project started in 1989 and has included exploration drilling, construction of an exploration decline, and a bulk sample program. These activities have not affected hydrological conditions.

## 12.4.3 Project-Specific Baseline Studies

### 12.4.3.1 Data Sources

Historical hydrological baseline studies were completed at the site between 1990 to 1992 by Hallam Knight Piésold (HKP 1992) for Bond Gold and then Lac Minerals. In the mid-1990s, further baseline studies were completed between 1993 to 1996 by Rescan (1994, 1995) for Lac Minerals, and finally in 1996 by Golder (Golder 1996a, 1996b) for Royal Oak Mines. Baseline information related to hydrology included meteorological data and hydrometric measurements. The historical studies included collection of climate data (1993 to 1996), stream gauge data (1993 to 1994), and snow course surveys. In addition to past baseline studies, Avison Management Services Ltd. initiated additional monitoring programs started in June 2014.

A summary of the activities included in Project-specific baseline studies is provided Table 12.4-1; Appendix 12-A provides a detailed review and results of these programs.

**Table 12.4-1: Baseline Hydrological Studies**

| Studies | Activities |
|---|---|
| HKP<br>Early 1990s | Meteorological station installed October 11, 1990 at 1524 m elevation. Data from October 11, 1990 to June 30, 1992 is available.<br>H1 hydrometric station installed October 11, 1990. |
| Rescan<br>1994 | Climate section includes summary of monthly air temperature, regional and local snow course data for 1994, historical regional snow course data, and monthly regional and onsite precipitation. |
| Rescan<br>1995 | Includes daily climatic data for the Upper Tram Weather Station, the Lower Tram Weather Station, and the Mount Dickie Weather Station.<br>Hand measured samples were collected from July 20, 1993 to Marcy 17, 1994 for Bitter Creek flows. From July 3, 1993 to July 8, 1994 hand measured sample data is available for Goldslide Creek flows. Both hand measured samples and daily flow readings are reported for the Kitsault River between January 1994 and September 1994.<br>Daily flow measurements at Bitter Creek and Goldslide Creek between 1991 and 1994.<br>Two snow survey stations operational between 1993 and 1994 at Red Mountain Camp and Roosevelt Creek comprising ten sampling points each provide snow depth, snowpack density and water equivalent measurements. |
| Golder<br>1996 | Climatic data retrieved from weather stations between 1993 and 1996 for Lower Tram Weather Station, Upper Tram Weather Station, and the Mt. Dickie Weather Station. |
| Avison<br>2014 - Present | Installation of three hydrometric monitoring stations, installation of the Redmount climate station instrumentation on the existing tower located within the Goldslide Creek watershed, and installation of a precipitation gauge. Monitoring at the three hydrometric stations occurs monthly. |

### 12.4.3.2 Primary Data Collection and Analysis Methods

#### 12.4.3.2.1 Data Collection

The methods used to characterize the hydrological conditions have included the following activities:

- Meteorological data collection from the Redmount station; and
- Hydrometric data collection from site hydrometric stations.

The parameters measured at the Redmount station included barometric pressure (mbar), net radiation (W/m$^2$), wind speed and direction (m/s and degrees, respectively), total solar radiation (W/m$^2$), total solar density (J/m$^2$), relative humidity (%), air temperature (degrees Celsius), snow depth (mm), and precipitation (mm). Table 12.4-2 provides a summary of the parameters and their respective measurement frequency for the Redmount meteorological station and the 2MW snow course.

### Table 12.4-2: Summary of Site Climate Monitoring Stations

| Site Name | Established | Location and Description | Methodology Implemented | Sampling Frequency | Measurements Taken |
|---|---|---|---|---|---|
| Redmount | July 30, 2014 | Ridge above Goldslide Creek Elevation 1,498 m above sea level | Station design, installation and ongoing monitoring methodology follow standards outlined in BC MOE (1996) | Hourly | Air temperature, relative humidity, solar radiation, atmospheric pressure, precipitation |
| 2MW Snow Course | January 20, 2016 | Adjacent to Goldslide Creek, across the creek from the exploration camp located in Red Mountain cirque | Manual snow measurements taken using a Federal Snow Sampler (Mt. Rose Sampler) in accordance with BC government standards (BC MOE, 2003) | Monthly when course is snow-covered | Average snow depth and snow-water equivalent |

In addition to the site-specific data collected for meteorology, regional meteorological information used in the baseline analysis was obtained from the following sources/programs:

1. Environment and Climate Change Canada (ECCC): the ECCC databases (ECCC 2016) provide meteorological records with daily information for the following parameters: precipitation, maximum temperature, minimum temperature, relative humidity, wind speed, wind direction and solar radiation.

2. Reanalysis (ERA-Interim & MERRA): reanalysis combines satellite information, land records and numerical models that simulate the earth's climatic conditions. ERA-Interim is produced by the European Center for Medium-Range Weather Forecast (ECMWF) (ECMWF 2016). ERA-Interim includes sub-daily data at 12-hour intervals from 1979 to present (2016) for the entire world, based on a 0.75-degree latitude by 0.75-degree longitude grid. MERRA from the National Aeronautics and Space Administration (NASA) presents daily information from 1981 to present (2016) for the entire world, based on 0.5-degree latitude and 0.5-degree longitude grid.

Climatic conditions at the site share important similarities with the closest ECCC meteorological station, Stewart A (located 17 km west of the site), therefore the results from this regional station and other regional stations were considered in the hydrologic baseline analysis (Appendix 12-A).

The site-specific data used in the baseline hydrological analysis includes both historical and more recent monitoring data from the baseline program. In general, data from recent monitoring (i.e., July 2014 to December 2016) were used as the basis for establishing relationships with regional information, and then the historical data were used to validate these estimates. The quality and quantity of data collected by ECCC is appropriate to characterize the region's climatic conditions due to the strict quality assurance system used by ECCC.

The 2MW snow course is located on the south side of Goldslide Creek (Figure 12.3-1). Snow sampling was conducted here historically and the course was found to be in good condition with the baseline monitoring reinitiated in 2014. The snow course consists of ten sampling posts. Manual snow measurements were taken using a Federal Snow Sampler in accordance with BC government standards (BC MOE 2013).

During monthly site visits, all monitoring instruments were visually inspected. Both climate and snow observations have been reviewed as a quality control and assurance measure to confirm that the recorded values are reasonable and without anomalies, outliers, gaps or inconsistencies.

Hydrometric station design, installation and ongoing monitoring methodology follows standards outlined in the Manual of British Columbia Hydrometric Standards, March 12, 2009 (BC MOE 2009). The Red Mountain hydrometric monitoring network consists of monitoring in three catchments: GSC05 (Goldslide Creek), OC04 and OC07 (Otter Creek) are located close to proposed Project infrastructure, and BC02 (Bitter Creek) is located further downstream (Figure 12.3-1).

These stations have been monitored during the open water season in 2014, 2015, and 2016. Monitoring in 2016 commenced in the winter, with field programs conducted throughout the year to capture low flows and freshet. Monitoring has continued through 2017 to add to the site-specific dataset. The program includes continuous monitoring of water level and monthly flow measurements at each of the stream gauging stations, with weekly to daily flow measurements during spring freshet to establish a rating curve.

Discharge measurements were taken monthly over three time periods: June 2014 to October 2014, July 2015 to October 2015, and January 2016 to December 2016. Weekly sampling was conducted during freshet between May 29, 2016 and June 29, 2016. Focused efforts were made to capture spring freshet and winter low-flows.

In addition, the data collected from the site hydrometric stations, regional hydrometric data was used in the baseline analysis and obtained from the following sources/programs:

1. Water Survey of Canada (WSC): provides daily, monthly, annual and peak-flows records for regional gauge stations.

2. United States Geological Survey (USGS): data retrieved from the USGS flow database was combined with information from the WSC to create one database to be analyzed into the regional hydrological analysis.

Relevant results from historical baseline monitoring were compared to results from the more recent baseline monitoring program and regional analysis, and used to validate these results, and provide a far more robust base for the analyses.

The RISC hydrometric standards and methods outlined in the *Manual of British Columbia Hydrometric Standards* (BC MOE 2009) were used throughout the hydrology monitoring program. Site discharge data was used to develop site-specific rating curves and all subsequent data points served as a review for anomalies, further refining the curve. Site results were then compared to other adjacent stations to further verify that there were no anomalies.

*Limitations*

- The location and height of the Redmount meteorological station is ideal for monitoring wind speed and direction; however, the location is not ideal for collecting precipitation data, especially snow depth, as the site has been observed to be completely wind-scoured during the winter.

- Precipitation gauge collection efficacy can become affected by strong winds despite a wind shield. Precipitation data presented in this assessment has not been adjusted for potential under-catch, so actual precipitation is likely higher than what was measured.

- Snow courses are subject to severe wind scour and resultant snow drifting.

- Conditions for hydrometric monitoring in the Project area are challenging due to steep gradients, unstable and mobile beds, snow and ice accumulation, high sediment loads, and difficult/limited access.

- Due to the dynamic nature and high variability in stage and discharge of the streams in the area, no reference gauges were installed at the hydrometric stations. Full benchmark surveys were conducted during each field visit to determine an instantaneous direct water level.

- During winter low-flows, stations at higher elevations (i.e., GSC05 and OC04) would become buried in snow pack and therefore access to these sites difficult. An alternate snow-free site (i.e., GSC99) was established 300 m upstream of GSC05.

- Sediment yield is often considered in the context of hydro-electric projects or sites where sediment laden flows are impounded by dams or rock drains that could act as traps for sediment. It may also be important for projects with high rates of sediment release. Sediment yield was not estimated as part of the baseline characterization for this project because it was determined that it would not be affected by the proposed project activities. However, this Project does not have any structures or rock drains that would trap natural sediments, and best practices for controlling release of suspended sediments will be followed to limit mining-related sediment release.

- The short- and long-term functionality of rock drains is considered when those features are part of the water management strategy. The short- and long-term functionality of rock drains was not considered for this Project because rock drains are not planned for the Project.

#### 12.4.3.2.2 Data Analysis

The typical methods used for the baseline analyses are as follows: correlation matrices, regional analysis, cluster analysis, frequency analysis and meteorological patching. These tools are standard methods often utilized within the field of hydrology. Due to the nature of the available site-specific data for the Project, it was preferable to use the more recent (i.e. 2014 to 2016) monitoring data to establish relationships between the site and regional data. However, historical data and previous data interpretations were used to validate the interpreted data record.

## 12.4.4 Baseline Characterization

The full baseline climate and hydrology dataset is provided in the baseline report (Appendix 12-A). Specifically, peak flow information is located in Appendix 12-A, Section 5.4.5 (Peak Flow Analysis), Table 5-8 (Unit Peak-Flows for Goldslide and Bitter – Otter Creek Runoff Models), Table 5-10 (Maximum Instantaneous Peak-Flow – Comparison of Rescan (1994) and SRK (2016)), and Table 7-1 (Summary of Unit Peak-Flow and Low-Flow Conditions - 7Q10 for Red Mountain).

Information about water management assumptions is provided in Appendix 1-H (Tailings and Water Management Design Report), Section 2.3, Section 7, Appendix F, and Appendix G, and in Appendix 14-C (Water and Load Balance Model Report), Section 3.6.

Selected summary statistics for the Project area climate and hydrology are provided in the following subsections.

### 12.4.4.1 Climate

The mean annual air temperature (MAAT) at an elevation of 1514 metres is -0.8°C, with monthly variability ranging between -6.4°C in December and January and 6.9°C in August. MAAT is strongly correlated with elevation. The regional meteorological station Stewart A has the most representative daily precipitation of the site, with a mean annual precipitation (MAP) of 1847 mm/yr. Based on frequency analysis, the estimated Project area annual precipitation for extreme conditions ranges from 1,140 mm for the 200-year dry return period (1,140 mm) to 2,550 mm for the 200-year wet return period (2,550 mm).

The probable maximum precipitation (PMP) was calculated using the Hershfield methodology (Hershfield 1965; WMO 2009) and the historical precipitation records from the Stewart A meteorological station (EC 2015). Based on this methodology, the 24-hour PMP was estimated to be 481 mm. This value is supported by a regional analysis of the relationship between MAP and PMP (see Appendix 12-A).

### 12.4.4.2 Hydrology

The hydrological analysis presented in Appendix 12-A suggests that the hydrology for the LSA hydrology can be represented by two runoff models: (1) Bitter-Otter for watersheds with more than 10% glacial cover (i.e., all creeks except for Goldslide) and (2) Goldslide for watersheds with less than 10% glacial cover (i.e., Goldslide Creek only). The mean annual runoff (MAR) for Bitter and Otter Creeks is 2,828 mm/yr and the MAR for Goldslide Creek is 1,555 mm/yr.

For glacially-influenced watersheds like Bitter and Otter Creeks, the peak flow is during July due to glacial melt (Table 12.4-3). For watersheds that are not glacially-influenced like Goldslide Creek, the peak flow is in June due to freshet (Table 12.4-4).

### Table 12.4-3: Monthly Flow Statistics for Bitter and Otter Creeks in L/s/km$^2$

| Percentiles | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 1.4 | 3.4 | 4.3 | 6 | 32 | 121 | 233 | 182 | 70 | 20 | 7.1 | 1.5 |
| 25% | 2.1 | 4.8 | 5.9 | 12 | 47 | 178 | 279 | 214 | 100 | 48 | 10 | 2.7 |
| 50% | 2.8 | 5.9 | 7.2 | 14 | 59 | 211 | 319 | 232 | 113 | 59 | 14 | 3.4 |
| 75% | 3.4 | 7.7 | 9.3 | 19 | 75 | 233 | 357 | 248 | 141 | 78 | 20 | 5.3 |
| 100% | 6.7 | 17 | 19 | 39 | 118 | 306 | 495 | 289 | 282 | 195 | 43 | 9.7 |
| **Mean** | **3** | **6.6** | **8.1** | **16** | **62** | **208** | **323** | **231** | **122** | **68** | **16** | **4** |
| Standard Deviation | 1.3 | 2.6 | 3 | 6.5 | 19 | 41 | 50 | 28 | 37 | 32 | 7.3 | 1.9 |

### Table 12.4-4: Monthly Flow Statistics for Goldslide Creek in L/s/km$^2$

| Percentiles | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 1.4 | 3.4 | 4.3 | 6.1 | 33 | 98 | 104 | 51 | 29 | 14 | 6.8 | 1.6 |
| 25% | 2.1 | 4.8 | 5.9 | 12 | 48 | 143 | 126 | 61 | 41 | 34 | 9.7 | 2.8 |
| 50% | 2.8 | 5.9 | 7.2 | 14 | 60 | 169 | 144 | 66 | 46 | 41 | 14 | 3.5 |
| 75% | 3.4 | 7.7 | 9.3 | 19 | 77 | 186 | 158 | 69 | 58 | 54 | 19 | 5.6 |
| 100% | 6.6 | 17 | 19 | 39 | 120 | 249 | 222 | 82 | 109 | 135 | 40 | 10 |
| **Mean** | **3** | **6.6** | **8.1** | **16** | **63** | **166** | **144** | **65** | **50** | **47** | **15** | **4.2** |
| Standard Deviation | 1.3 | 2.7 | 3 | 6.5 | 19 | 33 | 23 | 7.9 | 15 | 22 | 6.8 | 1.9 |

During the winter, when precipitation is stored as snow, the primary contribution to stream flow is baseflow. The lowest flow conditions for baseflow occur in January, when Bitter and Otter Creeks have a baseflow of 1.6 l/s/km$^2$ and Goldslide Creek has a baseflow of 1.9 l/s/km$^2$ (Table 12.4-5).

The 7Q10 for Bitter and Otter Creeks is 2.7 $l/s/km^2$ and 2.9 $l/s/km^2$ for Goldslide Creek. Bitter and Otter Creeks' 7Q10 results tend to have the lowest values in January, whereas Goldslide Creek has slightly lower values in March.

**Table 12.4-5 Monthly Baseflow Summary for Bitter, Otter and Goldslides Creeks**

| Location | Baseflow ($L/s/km^2$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Bitter and Otter Creeks | 1.6 | 3 | 5.3 | 7.7 | 18 | 69 | 165 | 135 | 62 | 28 | 7.2 | 2.2 |
| Goldslide Creek | 1.9 | 3.2 | 5.3 | 7.7 | 19 | 64 | 82 | 41 | 28 | 21 | 7.2 | 2.6 |

### 12.4.4.3 Climate Change

Climate change modelling for the Project was conducted through a compilation of Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and by completing a probability analysis on the multiple climatic models using a purpose-built script developed by SRK using R Software (CRAN 2016). The results of the analysis provide an estimate of the expected change of different climatic parameters for a specific longitude and latitude with respect to baseline conditions.

Climate change effects at the Project area will develop over a long timescale. The potential climate trends may manifest as small but continuous increase in temperature and total precipitation. The MAAT is predicted to increase to 2.11°C by the year 2100, representing a change of +2.99°C over the baseline conditions. As climate change progresses, the change in MAAT with respect to baseline conditions follows a near-linear trend. The total Project area precipitation is forecasted to increase +185 mm (+10%) by the year 2100. As climate change progresses, the change in annual precipitation with respect to baseline conditions follows a near-linear trend.

It is not possible to quantify the effects of changing precipitation and temperature on the hydrology due to the uncertainties associated with quantifying melt rate, the inventory of glacial ice over time, and the available hydrological data. However, some qualitative trends can be anticipated. The increase in precipitation of 10% could be expected to translate to an approximately 10% increase in MAR for unglaciated catchments. The increase in precipitation would have the same effect on glaciated catchments, but over the short to medium term, there would also be an unquantifiable increase in flows associated with glacial meltwater due to rising temperatures and increased melting rates. Over the much longer term, as the inventory of ice is depleted, there would be an unquantifiable decrease in the glacial meltwater. If the glacial ice is fully depleted, the MAR would eventually reach values equivalent to that of an unglaciated catchment.

# 12.5 Potential Effects

## 12.5.1 Methods

A scoping exercise was undertaken to identify the Project components and activities that could be expected to interact with the hydrology and cause a potential effect to the surface water flow system. The potential interactions were identified based on professional experience with other mining Projects in British Columbia and through multi-disciplinary consultation with external consultants working on behalf of IDM.

Potential effects from mining activities associated with the Project were quantified by comparing baseline hydrology to the water quantity (flow) predictions from the water and load balance model (Appendix 14-C).

## 12.5.2 Project Interactions

Table 12.5-1 presents the Project components and activities and the expected interaction with Hydrology.

**Table 12.5-1: Potential Project Interactions, Hydrology**

| Project Component or Activity | Potential Effect / Pathway of Interaction with Hydrology |
|---|---|
| Construct Access Road and Haul Road Hwy 37A to the Upper Portal. | Changes to watercourses due to temporary diversions and culvert installations |
| Excavate and secure Lower Portal entrance and access tunnel. | Changes to site drainage patterns due to construction works |
| **Construction** | |
| **Construct Mine Site water management infrastructure including talus quarry and portal collection ponds, dewatering systems, and water diversion, collection and discharge ditches and swales.** | **Changes to site drainage patterns due to construction works and diversions** |
| Install and fill Fuel Tanks at Mine Site | Changes to site drainage patterns due to construction works and diversions |
| Construct Explosives Magazine | Changes to site drainage patterns due to construction works and diversions |
| Construct other Mine Site ancillary buildings and facilities | Changes to site drainage patterns due to construction works |
| **Discharge of water from underground workings at the Mine Site** | **Changes to stream flows from water discharge** |
| **Initiate underground lateral development and cave gallery excavation** | **Change in groundwater flow and quantity reporting to nearby creeks** |

| Project Component or Activity | Potential Effect / Pathway of Interaction with Hydrology |
|---|---|
| Temporarily stockpile ore at the Mine Site | Changes to site drainage patterns due to construction works and diversions |
| Install construction and permanent ventilation systems and underground water pumps | Changes to site drainage patterns due to construction works and diversions |
| Water withdrawal for the purposes of dust suppression and construction use (primarily contact water management ponds; secondarily Bitter Creek, Goldslide Creek, and Otter Creek) and to meet freshwater needs (Otter Creek, Goldslide Creek) | Changes to stream flows from water withdrawal because of changes in hydrology |
| Clear and prepare the TMF basin and plant site pad | Changes to site drainage patterns due to construction works and temporary diversions |
| Excavate rock and till from the TMF basin and local borrows / quarries for construction activities (e.g. dam construction for the TMF) | Changes to site drainage patterns due to construction works |
| **Establish water management facilities including diversion ditches for the TMF and Process Plant** | **Changes to watercourses and site drainage patterns due to construction works and diversions** |
| Construct the Process Plant and Run of Mine Stockpile | Changes to watercourses and site drainage patterns due to construction works and diversions |
| Construct water treatment facilities and test facilities at Bromley Humps | Changes to site drainage patterns due to construction works and diversions |
| Construct Bromley Humps ancillary buildings and facilities | Changes to site drainage patterns due to construction works and diversions |
| **Operation** | |
| **Commence milling to ramp up to full production** | **Changes to stream flows from temporary water withdrawal** |
| Maintain Access Road and Haul Road, including grading and plowing as necessary | Changes to the natural runoff coefficient due to changes in drainage patterns (relates to snow plowing) |
| **Continue underground lateral development, including dewatering** | **Changes to site drainage patterns due to dewatering; changes to stream flows from dewatering** |
| **Discharge of water from underground facilities** | **Changes to stream flows from water discharge** |
| Pump process water from the TMF (reclaim water) to supply the Process Plant | Changes to site surface water and groundwater flow through changes to local scale flow or drainage pathways |
| **Excess process water for the mill will be obtained through water withdrawal from contact water management ponds, treated effluent water, and/or Otter Creek** | **Changes to stream flows from water withdrawal because of changes in hydrology** |
| Water withdrawal for the purposes of dust suppression along Project roads and to meet freshwater needs (Otter Creek, Goldslide Creek) | Changes to stream flows from water withdrawal because of changes in hydrology |

| Project Component or Activity | Potential Effect / Pathway of Interaction with Hydrology |
|---|---|
| Pump tailings and waste water to the TMF for disposal | Changes to site surface water and groundwater flow through changes to local scale flow or drainage pathways |
| **Treat and discharge, as necessary, excess water from the TMF** | **Changes to stream flows due to discharges** |
| Progressively reclaim disturbed areas no longer required for the Project | Changes to site drainage patterns due to reclamation activities |
| **Closure and Reclamation** | |
| Flood underground | Changes to watershed characteristics and local scale flow or drainage paths |
| Decommission and reclaim Lower Portal Area and Powerline | Changes to site drainage patterns due to decommissioning activities |
| Decommission and reclaim Haul Road | Changes to site drainage patterns due to decommissioning activities |
| Decommission and reclaim all remaining mine infrastructure (Mine Site and Bromley Humps, except TMF) in accordance with Closure Plan | Changes to site drainage patterns due to decommissioning activities |
| Construct the closure spillway | Changes to sit drainage patterns due to construction of closure spillway |
| **Treat and discharge water from the TMF** | **Changes to stream flows due to discharge** |
| Conduct maintenance of mine drainage, seepage, and discharge | Changes to stream flows due to routing, storage and discharge of mine impacted waters |
| Remove discharge water line and water treatment plant | Changes to stream flows and site drainage patterns due to removal of discharge water line |
| Decommission and reclaim Access Road | Changes to site drainage patterns due to decommissioning activities |

Note: Key interactions are highlighted in bold.

### 12.5.3 Discussion of Potential Effects

Potential activities that are likely to influence surface water flows include the dewatering of the underground mine, construction of surface water management facilities, and the use of water for mine-related activities such as dust suppression and providing fresh water for the Process Plant. The specific activities that fall within this group are:

- Construction of Mine Site water management infrastructure including talus quarry and portal collection ponds, dewatering systems, and water diversion, collection and discharge ditches and swales;
- Discharge of water from underground workings at the Mine Site;

- Initiate underground lateral development and cave gallery excavation;
- Continue underground lateral development, including dewatering;
- Discharge of water from underground facilities;
- Establishment of water management facilities including diversion ditches for the TMF and Process Plant;
- Commencement of milling to ramp up to full production;
- Excess process water for the Process Plant will be obtained through water withdrawal from contact water management ponds, treated effluent water, and/or Bitter Creek; and
- Treatment and discharge, as necessary, of excess water from the TMF.

All other activities listed in Table 12.5-1 are anticipated based on professional judgment to have limited localized effects to the hydrology and no adverse effect. Therefore, further assessment is not warranted.

#### 12.5.3.1 Changes to Surface Characteristics and Surface Water Flow

During construction and operations, the surface water flow system will be dominated by the construction and operation of various surface water management facilities, including diversion ditches and collection ponds. Construction and the installation of surface water management facilities will result in minor changes to site drainage patterns by changing the natural topography of the landscape. None of these changes are in headwater areas that would result in changes to flows any of the main stream tributaries. After reclamation, when these facilities are decommissioned, the surface water system is expected to return to close to baseline conditions.

#### 12.5.3.2 Changes to Stream Flows from Water Withdrawal

Surface water may be used for various fresh water requirements, including dust suppression and fresh water for the Process Plant. Water withdrawal will be limited to less than 10% of stream flows and will only last for the duration of operations. The source of the water may be contact water management ponds, treated effluent water, and/or creeks in the LSA.

#### 12.5.3.3 Changes to Stream Flows due to Discharge

During operations and the beginning of closure, excess water from the TMF will be treated and discharged into Bitter Creek. In addition, underground facility dewatering/drainage will increase stream flows in Goldslide Creek and Bitter Creek during construction and operations.

## 12.6 Mitigation Measures

### 12.6.1 Key Mitigation Approaches

Results from the review of best management practices, 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 BC (http://www.env.gov.bc.ca/emop/).

Potential Project-related changes to Hydrology will be reduced through mitigation measures, management plans, and adaptive management. If mitigation measures were considered entirely effective, potential Project-related effects to the Hydrology VC were not identified as residual effects.

Specific mitigation measures were identified and compiled for each category of potential effect on Hydrology and presented in this section. For the purposes of this assessment, mitigation measures included any action or Project design feature that will reduce or eliminate effects to the Hydrology VC. Key approaches include:

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

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.

During the construction and operations, the key mitigation measures for Hydrology are the construction of site water management infrastructure, limiting withdrawal to no more than 10% of stream flows, and matching the discharge from the TMF to the hydrograph. Monitoring of stream flow during operations will determine whether additional measures are needed as mining continues.

### 12.6.2 Environmental Management and Monitoring Plans

The management of water on site will be guided by several environmental management plans, which will define the standard operating procedures, the best management practices, the adherence to existing environmental regulations, and the use of appropriate design criteria. The list below compiles the EMPs with a potential linkage to the site hydrology:

- Aquatic Effects Management and Response Plan;
- Site Water Management Plan;
- Materials Handling and ML/ARD Management Plan; and
- Mine Closure and Reclamation.

### 12.6.3 Effectiveness of Mitigation Measures

The anticipated effectiveness of mitigation measures to minimize the potential for significant adverse effects is evaluated and classified as follows within this section:

- 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 proposed for mitigating potential effects on the Hydrology VC from changes to surface water characteristics and stream flow, along with mitigation effectiveness and uncertainty, are outlined in Table 12.6-1. These mitigation measures are described in Volume 7, Appendix 1-H.

The effectiveness of the proposed mitigation measures was qualitatively assessed by evaluating the water quantity (flow) predictions (Volume 8, Appendix 14-C). The predictions indicated that the Project activities that had a demonstrable effect on surface water flows were:

- Discharge of water from the TMF during Operation; and
- Discharge of water from the underground mine during Operation.

The mitigation measures associated with these two activities, which fall under the potential effect of changes to stream flow from discharge, were consequently given a “moderate” effectiveness ranking because there is still an effect from discharge. All of the other mitigation measures were given a “high” effectiveness ranking because the related Project activities did not have a demonstrable effect on surface water flows. The timing for the mitigation measures to become effective is expected to be immediate upon implementation.

**Table 12.6-1: Proposed Mitigation Measures and Their Effectiveness**

| VC/IC | Potential Effects | Mitigation Measures | Rationale | Applicable Phase(s) | Effectiveness[1] | Uncertainty[2] | Residual Effects |
|---|---|---|---|---|---|---|---|
| Hydrology | Changes to surface characteristics and surface water flow | Clean, non-contact catchment water will be diverted away from the TMF and other Project infrastructure to maintain water quality and natural drainage networks as much as possible. | Maintains natural drainages and reduces changes to surface flow | Construction<br>Operation<br>Closure and Reclamation | High | Low | No |
| | | TMF is fully lined and will be covered with a liner/soil cover at closure to reduce infiltration through the tailings thus restoring flows to the environment | | Closure and Reclamation<br>Post-Closure | High | Low | No |
| | Changes to stream flows from water withdrawal | The Process Plant has been designed to use reclaim water from the TMF, thereby reducing the amount of water required from local natural surface waters. | Reduces amount of surface water drawdown | Operation | High | Low | No |
| | | Water withdrawal will follow provincial regulatory requirements and standard best practices to avoid adverse impacts to stream flows, fish and fish habitat. | | | High | Low | No |
| | Changes to stream flows from discharge | Discharge from the TMF will match the receiving environment hydrograph, to the extent possible.<br>There are no practical measures available for controlling the rate of discharge from the underground mine during operations. | Reduces changes to surface flow | Construction<br>Operation | Moderate | Low | Yes |
| | | Bulkhead on the mine will limit discharges post-closure. | | Closure and Reclamation<br>Post-Closure | High | Low | Yes |

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

# 12.7 Residual Effects Characterization

This section summarizes the analyses and results used to quantify the residual effects identified in Table 12.6-1. Residual effects resulting from changes in groundwater flow, which is an effect pathway to the surface water system, are presented in Chapter 10 of Volume 3.

## 12.7.1 Summary of Residual Effects

Through consideration of potential effects and mitigation measures, the only residual effect associated with the Hydrology VC relates to changes to stream flows from discharge, which includes discharges from both the underground mine and from the TMF during Construction and Operation Phases; and increased flow of mine contact groundwater during Closure and Reclamation and Post-Closure, as identified in Table 12.6-1.

## 12.7.2 Methods

The residual environmental effects are characterized using the criteria and general definitions presented in Volume 3, Chapter 6. Further details specific to the hydrological effects are summarized in Table 12.7-1.

### 12.7.2.1 Residual Effects Criteria

The magnitude ratings were developed based on site-specific hydrology related to the natural variability between wet and dry years (to characterize flow decreases) and comparability to summer high flows (to characterize flow increases). The specific delineations between magnitude ratings were determined by professional judgment. There are no applicable policies or guidelines for this type of rating. Potential effects of changes in flow were also considered in the Aquatic Resources Effects Assessment (Volume 3, Chapter 17) and the Fish and Fish Habitat Effects Assessment (Volume 3, Chapter 18).

## Table 12.7-1: Characterization of Residual Effects on Hydrology

| Criteria | Characterization for Hydrology |
|---|---|
| Magnitude | Magnitude ratings were developed for both decreases and increases in flow. Changes from baseline flow are evaluated at GSC2 on Goldslide Creek; RBC02 on Rio Blanco Creek; BC08, BC06 and BC02 on Bitter Creek; and BR06 on Bear River.<br>***Flow Decreases***<br>Decreases in flow were evaluated using the percent difference between predicted flow versus baseline flow for each month (e.g., April flow predictions were compared to baseline flows in April). The magnitude of ratings for decreases were based roughly on a seasonal frequency analysis for winter low flow conditions, which shows that a 10% decrease in winter low flows corresponds to a return period of about 1:3 to 1:4 years, a 20% decrease corresponds to a return period of about 1:5 years, and a 40% decrease corresponds to a return period of about 1:20 years. The ratings for flow decrease are as follows:<br>**Negligible (flow decrease):** less than 10% decrease<br>**Low (flow decrease):** 10 to 20% decrease<br>**Moderate (flow decrease):** 20 to 40% decrease<br>**High (flow decrease):** greater than 40% decrease |
| | ***Flow Increases***<br>Increases in flow were evaluated using the percent difference between predicted flow versus the summer high flow for mean hydrological conditions; e.g., April flow predictions were compared to the highest flow observed in a mean year (June for Goldslide Creek and July for all other creeks). This is because increased flows are unlikely to cause adverse effects unless they exceed the capacity of the stream channel to withstand high flow conditions without increased potential for erosion or other geomorphology changes. The magnitude of ratings for increases were based roughly on a seasonal frequency analysis for summer high flow conditions, which shows that a 5% increase in summer high flows corresponds to a return period of about 1:2 years, 10% increase corresponds to a return period of about 1:5 years, and a 15% increase corresponds to a return period of around 1:20 years. The ratings for flow increase are as follows:<br>**Negligible (flow increase):** less than 5% increase<br>**Low (flow increase):** 5 to 10% increase<br>**Moderate (flow increase):** 10 to 15% increase<br>**High (flow increase):** greater than 15% increase |
| Geographical Extent | Geographic extent of potential effects were defined relative to the study boundaries defined in Section 12.3.4.1, as follows:<br>**Discrete:** effect is limited to the Mine Site or Bromley Humps TSAs.<br>**Local:** effect is limited to the LSA.<br>**Regional:** effect occurs throughout the RSA.<br>**Beyond regional:** effect extends beyond the RSA. |
| Duration | **Short term (ST):** effect lasts less than 18 months (during the Construction Phase of the Project).<br>**Long- term (LT):** effect lasts greater than 18 months and less than 22 years (encompassing Operation, Reclamation and Closure, and Post-Closure Phases).<br>**Permanent (P):** effect lasts more than 22 years. |

| Criteria | Characterization for Hydrology |
|---|---|
| Frequency | The frequency of potential effects was defined as follows:<br>**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>**Seasonal / Continuous**: effect occurs seasonally or constantly (i.e., year-round). |
| Reversibility | The reversibility of potential effects was defined as follows:<br>**Reversible**: effect can be reversed.<br>**Partially reversible**: effect can be partially reversed.<br>**Irreversible**: effect cannot be reversed, is of permanent duration. |
| Direction | **Positive:** the residual effect has a beneficial effect (not assessed for significance)<br>**Neutral:** the residual effect has a neutral effect (not assessed for significance)<br>**Negative:** the residual effect has a negative effect (assessed for significance) |
| Context | The sensitivity and resilience of hydrology to change caused by the Project was defined as follows. This characterization included the context of existing conditions, cumulative effects, and trends.<br>**High**: the receiving environment has a high natural resilience to imposed stresses, and can respond and adapt to the effect.<br>**Neutral**: the receiving environment has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect.<br>**Low**: the receiving environment has a low resilience to imposed stresses, and will not easily adapt to the effect. |

### 12.7.2.2 Assessment of Likelihood

Likelihood refers to the probability of the predicted residual effect occurring, and is determined per the attributes listed in Table 12.7-2. The probabilities are based on qualitative judgment and common understanding of the hydrological system within the profession.

**Table 12.7-2: Attributes of Likelihood**

| Likelihood Rating | Quantitative Threshold |
|---|---|
| High | More than 50% chance of effect occurring |
| Moderate | Equal chances of occurring or not occurring |
| Low | Less than 50% chance of effect occurring |

#### 12.7.2.3 Confidence and Risk

Confidence, which can also be understood as the level of uncertainty associated with the residual effects assessment (including significance determination), is a measure of how well residual effects are understood and the quality of the input data. The reliability of data inputs and analytical methods used to predict Project effects, confidence regarding the effectiveness of mitigation measures, and certainty of the predicted outcome are all considered.

Confidence definitions are provided in the Assessment Methodology Section of the Application (Volume 3, Chapter 6, Table 6.10-1).

#### 12.7.2.4 Analytical Assessment Techniques for Hydrology

The residual effects of the Project were evaluated using modeled flow results reported in Appendix 14-C. The model was used specifically to evaluate the following:

- The quantities of surface water intercepted and re-routed by the mine and ultimately discharged from the mine during construction and operations;
- The potential reductions to creek flows during operations due to dewatering and water withdrawal;
- The potential increases to creek flows during operations due to the discharge of water from the underground mine and from the TMF; and
- Increases in groundwater baseflow reporting to surface water due to the increased hydraulic conductivity of the backfilled mine.

### 12.7.3 Potential Residual Effects Assessment

The residual effect of changes to Hydrology because of discharge was evaluated in two ways:

- Decreases in flow were evaluated using the percent difference between predicted flow versus baseline flow for each month (e.g., April flow predictions were compared to baseline flows in April), as shown in Table 12.7-3.
- Increases in flow were evaluated using the percent difference between predicted flow versus the summer high flow for mean hydrological conditions; e.g., April flow predictions were compared to the highest flow observed in a mean year (June for Goldslide Creek and July for all other creeks). This is because increased flows are unlikely to cause adverse effects unless they exceed the capacity of the stream channel to withstand high flow conditions without increased potential for erosion or other geomorphology changes. Flow increases from summer high flows are shown in Table 12.7-5.

**Table 12.7-3: Average Percent Change in Water Quantity from Baseline Conditions (by Month)**

| Location | Phase | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSC02 | Construction | -2.5% | -2.7% | -2.6% | -0.4% | -0.4% | -0.4% | -0.4% | -0.4% | -0.4% | -1.1% | -1.4% | -2.7% |
| | Operations | 180.9% | 146.8% | 73.8% | 21.3% | 10.6% | 12.3% | 21.6% | 30.5% | 33.6% | 82.5% | 290.4% | 392.2% |
| | Post-Closure | 4.8% | 6.7% | 4.5% | 1.3% | 2.1% | 5.2% | 4.9% | 4.2% | 3.3% | 4.0% | 5.7% | 6.0% |
| BC08 | Construction | 0.1% | 0.1% | 0.1% | 0.1% | -0.2% | -0.8% | -1.1% | -0.9% | -0.4% | 0.0% | 0.1% | 0.1% |
| | Operations | 3.3% | 2.7% | 1.4% | 0.1% | -0.2% | -0.2% | -1.1% | -0.8% | -0.1% | 1.2% | 5.4% | 6.9% |
| | Post-Closure | 2.1% | 3.0% | 2.1% | 0.3% | 0.4% | 1.8% | 0.8% | 0.7% | 0.9% | 1.7% | 2.5% | 2.3% |
| BC06 | Construction | 0.1% | 0.1% | 0.0% | 0.1% | -0.2% | -0.7% | -1.0% | -0.8% | -0.4% | 0.0% | 0.1% | 0.1% |
| | Operations | 2.5% | 2.1% | 1.5% | 0.2% | -0.2% | -0.2% | -1.0% | -0.6% | -0.1% | 1.4% | 4.1% | 5.3% |
| | Post-Closure | 2.5% | 3.2% | 2.0% | 0.3% | 0.4% | 1.6% | 0.8% | 0.7% | 0.9% | 1.9% | 3.5% | 3.9% |
| BC02 | Construction | 0.0% | 0.0% | 0.0% | 0.1% | -0.1% | -0.5% | -0.7% | -0.5% | -0.3% | 0.0% | 0.1% | 0.0% |
| | Operations | 1.7% | 1.4% | 1.0% | 0.1% | -0.1% | -0.1% | -0.6% | -0.4% | 0.0% | 0.9% | 2.8% | 3.5% |
| | Post-Closure | 1.6% | 2.1% | 1.4% | 0.2% | 0.3% | 1.1% | 0.5% | 0.5% | 0.6% | 1.3% | 2.4% | 2.6% |
| RBC02 | Construction | 0.0% | 0.0% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | -0.2% | -0.2% | 0.0% |
| | Operations | 0.0% | 0.0% | -0.3% | -0.9% | -0.3% | 0.7% | -0.4% | -0.4% | -0.3% | -0.5% | -0.7% | 0.0% |
| | Post-Closure | 5.3% | 7.8% | 5.4% | 1.9% | 2.3% | 5.3% | 5.4% | 4.5% | 3.6% | 4.4% | 5.7% | 5.9% |
| BR06 | Construction | 0.0% | 0.0% | 0.0% | 0.0% | -0.1% | -0.2% | -0.3% | -0.2% | -0.1% | 0.0% | 0.0% | 0.0% |
| | Operations | 0.6% | 0.5% | 0.3% | 0.0% | -0.1% | 0.0% | -0.2% | -0.2% | 0.0% | 0.3% | 1.0% | 1.3% |
| | Post-Closure | 0.6% | 0.8% | 0.5% | 0.1% | 0.1% | 0.4% | 0.2% | 0.2% | 0.2% | 0.4% | 0.9% | 1.0% |

Note: gray shading identifies flow decreases that are negligible (less than -10%). All predicted flow decreases are less than 10% (calculated by prediction minus baseline, divided by baseline). Flow increases are evaluated in Table 12.7-5.

**Table 12.7-4: Average Percent Change in Water Quantity from Summer High Flows**

| Location | Phase | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSC02 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | 11% | -- | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | 2.1% | -- | -- | -- | -- | -- | -- | -- |
| BC08 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | -- | 1.8% | -- | -- | -- | -- | -- | -- |
| BC06 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | -- | 1.6% | -- | -- | -- | -- | -- | -- |
| BC02 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | -- | 1.1% | -- | -- | -- | -- | -- | -- |
| RBC02 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | -- | 0.71% | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | -- | 5.3% | -- | -- | -- | -- | -- | -- |
| BR06 | Construction | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Operations | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Post-Closure | -- | -- | -- | -- | -- | 0.39% | -- | -- | -- | -- | -- | -- |

Notes: gray shading identifies flow increases that are negligible (less than 5%), yellow shading identifies flow increases that are low (between 5 and 10%), and orange shading identifies flow increases that are moderate (between 10 and 15%). No flow increases were rated as high.
"—" identifies flows in which the predicted flow is less than the summer high flow, and are not eligible for the analysis.

The results of the residual Project effect analyses were as follows (ratings are defined in Table 12.7-1):

- Flow decreases from baseline conditions are predicted for at least one month for construction for Goldslide Creek and for construction and operations for Bitter Creek, Rio Blanco Creek, and Bear River. These flow decreases are due to the construction and operation of various surface water management features. All flow decreases are much less than 10% different from baseline flows (Table 12.7-3). All the flow decreases have been rated as having negligible magnitude.

- Flow increases from summer high flow conditions are predicted for operations and post-closure for Goldslide Creek and Rio Blanco Creek and for post-closure only for Bitter Creek and Bear River.

  - During the Operation Phase, groundwater will be discharged from the mine into Goldslide Creek. The rate of groundwater discharge is assumed to be essentially unchanged throughout the year. The increase in flows at GSC02 will be 11% higher in May (Table 12.7-4). The increase in May above normal summer high flows is rated as moderate (between 10 and 15%). This change in flow is well within the inter-annual range in flows experienced at this location and is unlikely to result in significant changes in the rates of erosion or channel geomorphology.

  - During the Post-Closure Phase, the hydraulic conductivity of the backfilled mine will be greater than baseline conditions (Volume 3, Chapter 10, Appendix 10-A), which increases groundwater baseflow reporting to Goldslide Creek, Rio Blanco Creek, and upper Bitter Creek. The increase in flows at RBC02 will be 5.3% higher in June than normal summer high flows (Table 12.7-4), which is rated as low (between 5 and 10%). All other flow increases during post-closure have been rated as negligible (less than 5%). This change in flow is well within the inter-annual range in flows experienced at this location and is unlikely to result in significant changes in the rates of erosion or channel geomorphology.

- Overall, the residual effects of the Project on the hydrology outside of the Mine Site TSA are expected to be negligible, based on predicted flows downstream of the Mine Site on Bitter Creek at BC08, BC06 and BC02 and on Bear River at BR06.

## 12.7.4 Summary of Residual Effects Assessment

A summary of the residual effects assessment is provided in Table 12.7-5.

The magnitude of the residual effect was rated as negligible outside of the Mine Site TSA, because changes to flows in Bitter Creek and Bear River are within -10% to +5% of baseline conditions. The geographic extent is local because the effects are limited to the LSA. The duration is permanent, because the effect lasts more than 22 years, and the frequency is continuous. The residual effect is irreversible. The context and direction are both neutral.

### Table 12.7-5: Summary of the Residual Effects Assessment for Hydrology

| Residual Effect | Project Phase(s) | Mitigation Measures | Summary of Residual Effects Characterization Criteria | Likelihood *(High, Moderate, Low)* |
|---|---|---|---|---|
| Changes to stream flows from discharge | Construction<br>Operations<br>Closure and Reclamation<br>Post-Closure | Discharge will, to the extent possible, match the receiving environment hydrograph. | **Magnitude:**<br>Negligible (for LSA)<br>**Geographic Extent:**<br>Local<br>**Duration:**<br>Permanent<br>**Frequency:**<br>Continuous<br>**Reversibility:**<br>Irreversible<br>**Direction:**<br>Neutral<br>**Context:**<br>Neutral | High |

The assessment endpoints, maintenance of the quantity of stream flows in the receiving environment; and maintenance of other VCs that are influenced by Hydrology are achieved with the implementation of mitigation measures thus the potential residual effects for Hydrology are concluded to be Not Significant.

Confidence is considered moderate for the following reasons:

- Historical reports presented baseline hydrology information from the early 1990s used a completely different set of information to estimate the flows and calibrations with the current analyses. The hydrological analysis (described in Volume 8, Appendix 12-A, Section 5.4.6) was validated against the historical information to provide additional confidence.
- Sensitivity analyses conducted for the flow predictions (described in Volume 8, Appendix 14-C, Section 4.1.7) compared mean hydrological conditions, which were used for the flow predictions, to a 1:10 dry year and a 1:20 wet year. These additional hydraulic scenarios confirmed the findings of the mean hydrological conditions.
- Residual effects can be predicted to occur with a high degree of certainty, but factors influencing the timing, magnitude and direction of these effects are difficult to predict accurately.

# 12.8 Cumulative Effects

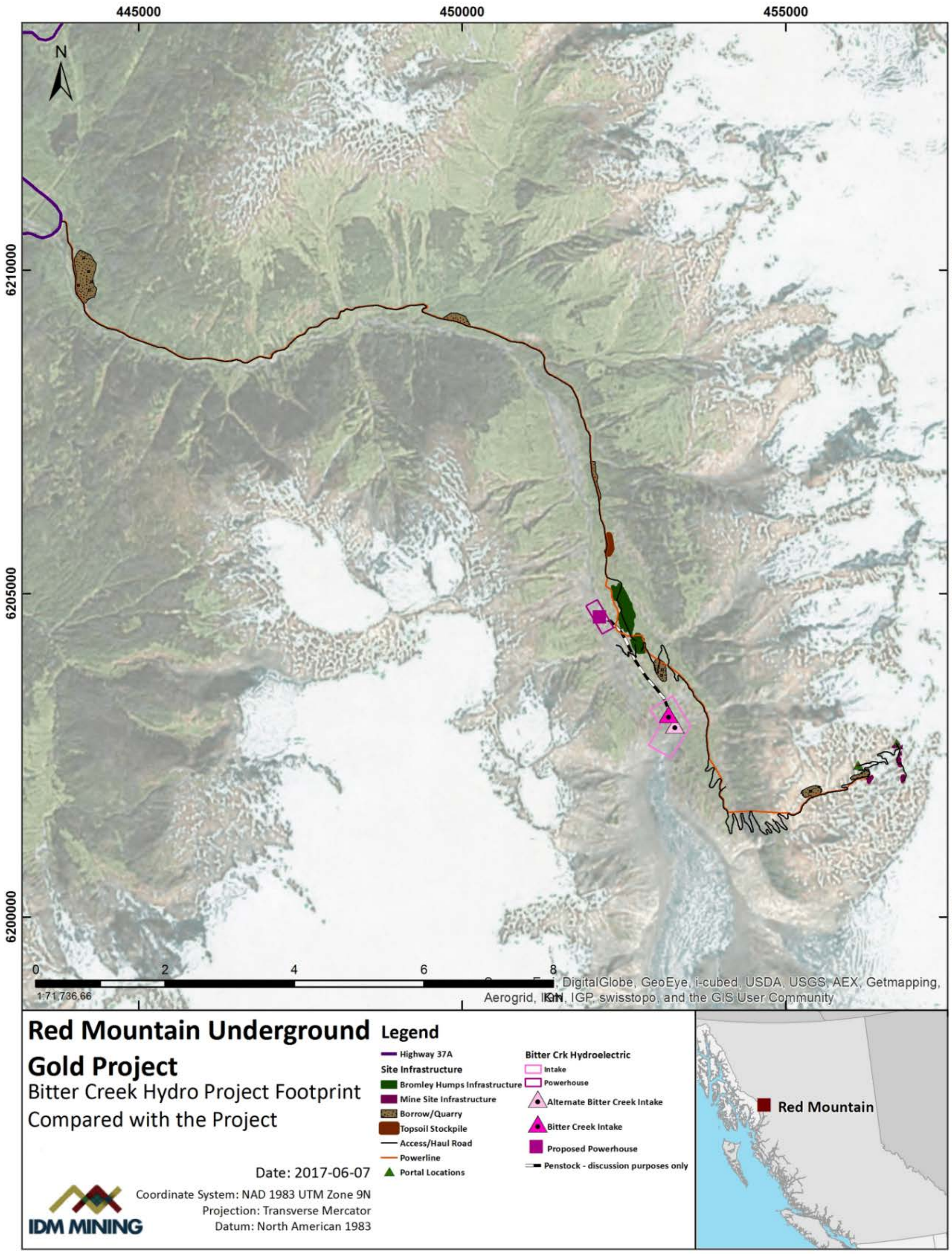
## 12.8.1 Cumulative Effects Assessment Boundaries

The cumulative effects assessment boundaries are identical to the spatial and temporal boundaries defined in Section 12.3.4 of this chapter.

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

Other projects within the spatial boundaries of the cumulative effects assessment are limited to the Bitter Creek Hydro Project, as shown in Figure 12.8-1. The Bitter Creek Hydro Project involves the construction of an intake and diversion structure in the Bitter Creek valley, near the Bromley Humps TSA.

## Figure 12.8-1: Bitter Creek Hydro Project Footprint Compared with the Project



## 12.8.3 Cumulative Effects Assessment

### 12.8.3.1 Review of Residual Effects

The residual effect of the Project on Hydrology was summarized in Table 12.7-5 and is: changes to stream flows from discharge from the mine and TMF.

### 12.8.3.2 Identification of Potential Cumulative Effects

The Project has negligible effects on Hydrology in Bitter Creek and Bear River. The Bitter Creek Hydro Project is also expected to have a negligible effect on Hydrology as it is a run-of-river Project, where water would be returned to Bitter Creek from the hydro plant.

### 12.8.3.3 Identification of Additional Mitigation Measures

No other additional mitigation measures are relevant.

### 12.8.3.4 Cumulative Effects Interaction Matrix

The cumulative effects interaction matrix is presented as Table 12.8-1.

**Table 12.8-1: Interaction with Effects of other Past, Present, or Reasonably Foreseeable Future Projects and Activities**

| Residual Effects of the Project | Future Projects and Activities<br>Bitter Creek Hydro Project |
|---|---|
| Changes to stream flows from discharge | 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

### 12.8.3.5 Residual Cumulative Effects Assessment

The Bitter Creek Hydro Project is expected to have a negligible effect on Hydrology. Consequently, the assessment of residual effects remains the same as those considered for the Project alone and match the residual effects assessment (Table 12.7-5).

### Table 12.8-2: Summary of Residual Cumulative Effects Assessment

| Project Phase | Residual Cumulative Effect | Characterization Criteria | Likelihood | Significance | Confidence |
|---|---|---|---|---|---|
| Construction<br>Operation<br>Closure and Reclamation<br>Post-Closure | Changes to stream flow from discharge | **Magnitude:** Negligible (for LSA)<br>**Geographic Extent:** Local<br>**Duration:** Permanent<br>**Frequency:** Continuous<br>**Reversibility:** Irreversible | High | Not Significant | High |

#### 12.8.3.6 Summary of Cumulative Effects Assessment

The Bitter Creek Hydro Project, which is reasonably foreseeable, is expected to have a negligible effect on Hydrology and thus the residual cumulative effects assessment is the same as the residual effects assessment conducted for the Red Mountain Underground Gold Project alone.

## 12.9 Follow-up Program

IDM has identified a follow-up strategy to evaluate the accuracy of effects predictions and effectiveness of proposed mitigation measures in regards to Hydrogeology. The strategy focuses on implementation of the Site Water Monitoring Program contained within the Site Water Management Plan (Volume 5, Chapter 29.18). The purpose of this program is to minimize the effects of the Project's activities on surface and groundwater, monitor the results of mitigation to ensure effectiveness, and adaptively manage for any unanticipated effects resulting from the Project.

The program involves the implementation of widely recognized BMPs and development of procedural mitigation measures during Project planning to minimize anticipated effects. The monitoring program is intended to detect unanticipated effects where adaptive management protocols will be triggered. Many mitigation measures have already been implemented during the planning stages of the Project. These include Project design such as site selection, selection of best available technologies to-date for Project infrastructure and mining equipment, and a commitment to progressive reclamation.

If original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented. Adaptive management will require consideration of monitoring results, management reviews, incident investigations, shared traditional, cultural, or local knowledge, new or improved scientific methods, regulatory changes, or other Project-related changes. Mitigation and monitoring strategies for groundwater will be updated to maintain consistency with action plans, management plans, and BMPs that may become available during the life of the Project. Key stakeholders, Aboriginal Groups, and government agencies will be involved, as necessary, in developing effective strategies and additional mitigation.

The follow-up strategy will also incorporate means to evaluate the effectiveness of implemented mitigation. Adaptive management principles rely on this evaluation to assess whether further mitigation is required to achieve desired outcomes. IDM will report on Project mitigation and monitoring activities related to the site water monitoring program part of reporting requirements stipulated in operational permits.

IDM will review the results of the monitoring program on a frequency to be stipulated by future permit conditions, and develop a detailed report on trends in monitoring indicators. Statistical analyses of the monitoring results will be performed, where appropriate.

A site-wide aquatic effects monitoring system will be designed and implemented in conjunction with surface water and groundwater monitoring, as part of the Environmental Management System, to support the design of effective mitigation systems. The Aquatic Effects Monitoring and Follow-up Program is described in Volume 5, Section 30.5.1, and the Site Water Monitoring and Follow-up Program is described in Volume 5, Section 30.5.2.

## 12.10 Conclusion

Alteration to the natural landscape and mining activities such as dewatering and discharging are expected to cause changes in surface water routing and flows. Flow is expected to change seasonally and in magnitude based on distance from the Project.

Cumulative effects to hydrology are not expected to occur in the RSA. Residual effects caused by the Project to hydrology can potentially impact surface water quality and have been evaluated in a site wide water and load balance model (Appendix 14-C). Linkages to other components include Hydrogeology (Volume 3, Chapter 10), Surface Water Quality (Volume 3, Chapter 13), Aquatic Resources (Volume 3, Chapter 17), and Fish and Fish Habitat (Volume 3, Chapter 18).

## 12.11 References

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