MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

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Glossary and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

7-day low flow	The minimum average 7-day flow that occurs over a specified period, such as a month, season or year.
ADCP	Acoustic Doppler current profiler.
Annual runoff	Annual runoff is a measure of the hydrological response of a watershed. It is often presented as a depth, in mm, over an entire catchment area allowing direct comparison with precipitation totals.
Arctic nival	Hydrological regime in which snow melt is the major hydrological event producing runoff and continuous permafrost impedes deep infiltration reducing base flow and winter flow.
AWR	All weather road
Base flow	The groundwater component of flow discharge that is attributed to soil moisture and groundwater drainage into a channel.
Break-up	The melting and dissipation of the ice cover on a waterbody.
CEA	Cumulative Effects Assessment
DFO	Fisheries and Oceans Canada
Discharge	The volume of flow moving through a cross section of a stream in a given unit of time; commonly expressed in cubic meters per second.
CRA fisheries	commercial, recreational, and Aboriginal fisheries
Watershed/ Catchment Area	The zone or portion of land that contributes water to the surface water runoff that flows past a given point along a stream channel.
EAAA	Existing and Approved Authorizations
EIS	Environmental Impact Statement
Ephemeral	A stream which flows only during or after rain or snow-melt and has no base flow component.
Freeze-up	The formation of an ice cover on a waterbody.
Freshet	In channels, the relatively high annual peak water discharge period resulting from spring/summer meltwater runoff of the snowpack accumulated over the winter.
Hydrograph	A graphic presentation of the variation in discharge with elapsed time, based on data of stream gauging at a given hydrometric station on a stream.

Intermittent	A stream which flows only part of the year.
LSA	Local Study Area
MAR	Mean Annual Runoff
masl	Metres Above Sea Level
NAD 83	North American Datum of 1983. The horizontal control datum for the U.S., Canada, Mexico, and Central America, based on a geocentric origin and the Geodetic Reference System 1980.
MOMB	Marine outfall mixing box
NIRB	Nunavut Impact Review Board
NSA	Nunavut Settlement Area
NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
Permafrost	Bedrock, organic or earth material that has temperatures below 0°C persisting over at least two consecutive years.
PDA	Potential Development Area
Project, the	Madrid-Boston Project
RSA	Regional Study Area
Stage	The height of the water surface in a stream above its bed or a fixed level near the bed.
Stage-Discharge Curve	A curve derived from concurrently measured stage and discharge data that is used to estimate the discharge for any given observed stage. Often referred to as a rating curve for a hydrometric station.
TIA	Tailings Impoundment Area
Unit Discharge	An index of discharge normalized by drainage area. This index allows for direct comparison of the potential rate of water volumes that can be expected from various sized watersheds.
UTM	Universal Transverse Mercator. A mathematical transformation (map projection) of the earth's surface to create a flat map sheet.
VEC	Valued Ecosystem Component
WRR	Winter road route
WRSA	Waste Rock Storage Areas
WSC	Water Survey of Canada

1. Surface Hydrology

Surface hydrology is a key component of the biophysical environment; it is linked to other ecosystem components including surface water quality, fish and fish habitat, and aquatic resources. Surface water is protected under federal legislation (e.g., *Canada Water Act* 1985). An understanding of the surface hydrology, and its interactions with a project, is critical to support an environmental effects assessment as well as to contribute to engineering analysis and the design of water management features.

In this chapter, the potential effects of the proposed Madrid-Boston Project (the Project), in combination with existing and approved projects, on surface hydrology are assessed by comparing predicted project-affected streamflows with pre-development (i.e., baseline) streamflows.

Alteration of surface hydrology could potentially affect other Valued Ecological Components (VECs); effects on these VECs are assessed in the following effects assessment chapters:

- Volume 5, Chapter 4, Freshwater Water Quality;
- Volume 5, Chapter 5, Freshwater Sediment Quality; and
- Volume 5, Chapter 6, Freshwater Fish.

This chapter follows the effects assessment methodology described in Volume 2, Chapter 4 of the Environmental Impact Statement (EIS; TMAC 2017)

1.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

Traditional Knowledge (TK) information was gathered by the Kitikmeot Inuit Association (KIA) in a report titled *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (Banci and Spicker 2016; hereafter referred to as the TK report). The TK report provides recorded and georeferenced TK pertaining to the Hope Bay Project.

1.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The TK report was reviewed for information pertinent to surface water hydrology. According to the information provided in the TK report, Inuit have seen changes in hydrology over the past few decades. The TK report reflects observations of some hydrologic processes including the ice break-up process in the streams:

> *Around the falls in the rivers, where the water is deeper, there are always fish during the winter, such as at Kugyoak and Kunayok. The smaller rivers dry up. The fish can't go up river or go downstream because the rivers are frozen.*
>
> *These rivers that we call flooded sometimes overflow before the land melts. The river is flowing under the snow and over top of the ice. That is what we call flooded. The ice and river would be flooded and the ice would be opening up when the river overflows. Once the rivers overflow, it's hard on the people who are hunting because they get stuck in between the rivers. If they didn't have a boat they would have to wait for the water to subside.*

> *When we used to walk around south of here, there used to be lots of natural water spring everywhere. These are not as visible anymore and the land seems to be getting dry every year.*
>
> *I can see some differences from the 1940s and 1950s until now. There has been a very big difference because of climate change already from the 1940s right up until now. It's because permafrost is receding very fast and the permafrost is melting. Permafrost is coming up to the surface in some places.*

1.1.2 Incorporation of Traditional Knowledge for VEC Selection

The TK report was reviewed to refine the potential VEC list for freshwater environment. Rivers and lakes were identified in the TK report as Inuit's source of water and important fish habitat. TK was combined with data from public consultation and baseline surveys to determine which valued components would potentially interact with the proposed Project, and should therefore be evaluated for inclusion in the candidate VEC list.

As a result of this process, and in consideration of the EIS guidelines (NIRB 2012a), Surface Hydrology was selected as a candidate VEC for the EIS (Volume 2, Chapter 4, Effects Assessment Methodology).

1.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the TK report were considered when developing the spatial and temporal boundaries for the Project. The TK report showed that specific and general fishing locations extend along both shores of Melville Sound, but are concentrated along the southern shore extending both east and west of Roberts Bay. General fishing areas also extend inland along the entire length of the Hope Bay Greenstone Belt. Therefore, the entire Project area was included within the spatial boundaries of the assessment. The temporal boundary of the assessment was extended into the future to simulate the hydrologic recovery at Post-closure.

1.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the TK report were considered when developing the effects assessment for surface hydrology. Fish and fish habitat is important to Inuit and, therefore, fish habitat (including water quantity) was considered in selecting the surface hydrology effects assessment locations.

1.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The importance of lakes and rivers as Inuit's source of water and important fish habitat was considered when developing mitigation and adaptive management plans for surface hydrology.

1.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

The Project will occur in the Hope Bay Greenstone Belt area, situated within the Queen Maud Gulf Lowlands, which covers the east-central portion of the West Kitikmeot region (Figure 1.2-1). The entire Project watersheds drain into Roberts Bay and Hope Bay (Figure 1.2-2). The northern portion of the Hope Bay Belt consists of several watersheds (including Windy, Doris, and Roberts watersheds) that drain into Roberts Bay near the existing mine infrastructure. The southern portion of the belt (including the Aimaokatalok watershed and its tributaries) flows into the Koignuk River that drains into Hope Bay west of the existing Doris infrastructure.

Figure 1.2-1
Madrid-Boston Project Location

The Project area is characterized by extensive networks of lakes, low relief hummocky topography, and exposed bedrock uplands. The local topography ranges from sea level at Roberts Bay to 158 m at the summit of Doris mesa, 3 km inland.

Climate in the region can be described as a subarctic desert with limited rainfall. The region is characterized by long dark winters and short bright summers. The ground is covered in snow from October to June in most years.

Rivers in the region have streamflow typical of the Arctic nival regime (Church 1974). The long and severe Arctic winter, and brief time when air temperatures are above freezing, limit surface water flow to a short period. Surface water flow typically begins in late May or early June and rapidly rises to peak annual flow by early- to mid-June. Snow that accumulated over the winter is usually the dominant contributor of water to streamflow on an annual basis. Shortly after air temperature rises above freezing, the snow melts rapidly.

After the snowmelt-fed freshet, streamflow steadily decreases to a minimum, which typically occurs in August. Due to the presence of continuous permafrost there is limited groundwater supply to smaller streams; however, there may be interaction between groundwater systems and larger rivers and/or lakes through taliks. Fall rain events often augment streamflow and produce moderate flow after the summer minimum. In October, air temperature normally dips below freezing, precipitation begins to fall as snow, and streamflow ceases for the winter except in rivers with very large watersheds.

Lakes are common in the region. Runoff is stored in lakes and gradually released, attenuating hydrologic events that would otherwise cause a rapid response in streamflow, such as the snowmelt peak flow and responses to precipitation events. Evaporation from lake surfaces is greater than evaporation from tundra, so runoff is generally lower in watersheds with extensive open water. Lakes are ice-covered from approximately November to June most years.

1.2.1 Regulatory Framework

Surface hydrology is protected under federal legislation, including the *Canada Water Act (1985)* and *Fisheries Act (1985)*.

Canada Water Act (1985) provides a framework for collaboration among the federal and provincial or territorial governments in management of the water resources including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources.

Fish and fish habitat are protected under the *Fisheries Act (1985)*, which was amended in 2012. The *Fisheries Act* includes a prohibition against causing serious harm to fish that are part of, or support commercial, recreational, and Aboriginal fisheries (CRA fisheries). The *Fisheries Act* regulates surface hydrology by provisioning for flow and passage.

1.2.2 Data Sources

1.2.2.1 Available Onsite Hydrologic Data

Project hydrometric monitoring began in 1993 at several sites where streamflow and water levels were manually measured. Automated hydrometric monitoring began in 1996 and has continued to the present, although the size of the monitoring network has varied throughout this time. Hydrometric stations are identified in Figure 1.2-3 and Table 1.2-1.

Figure 1.2-2
Watersheds in the Hope Bay Project Area

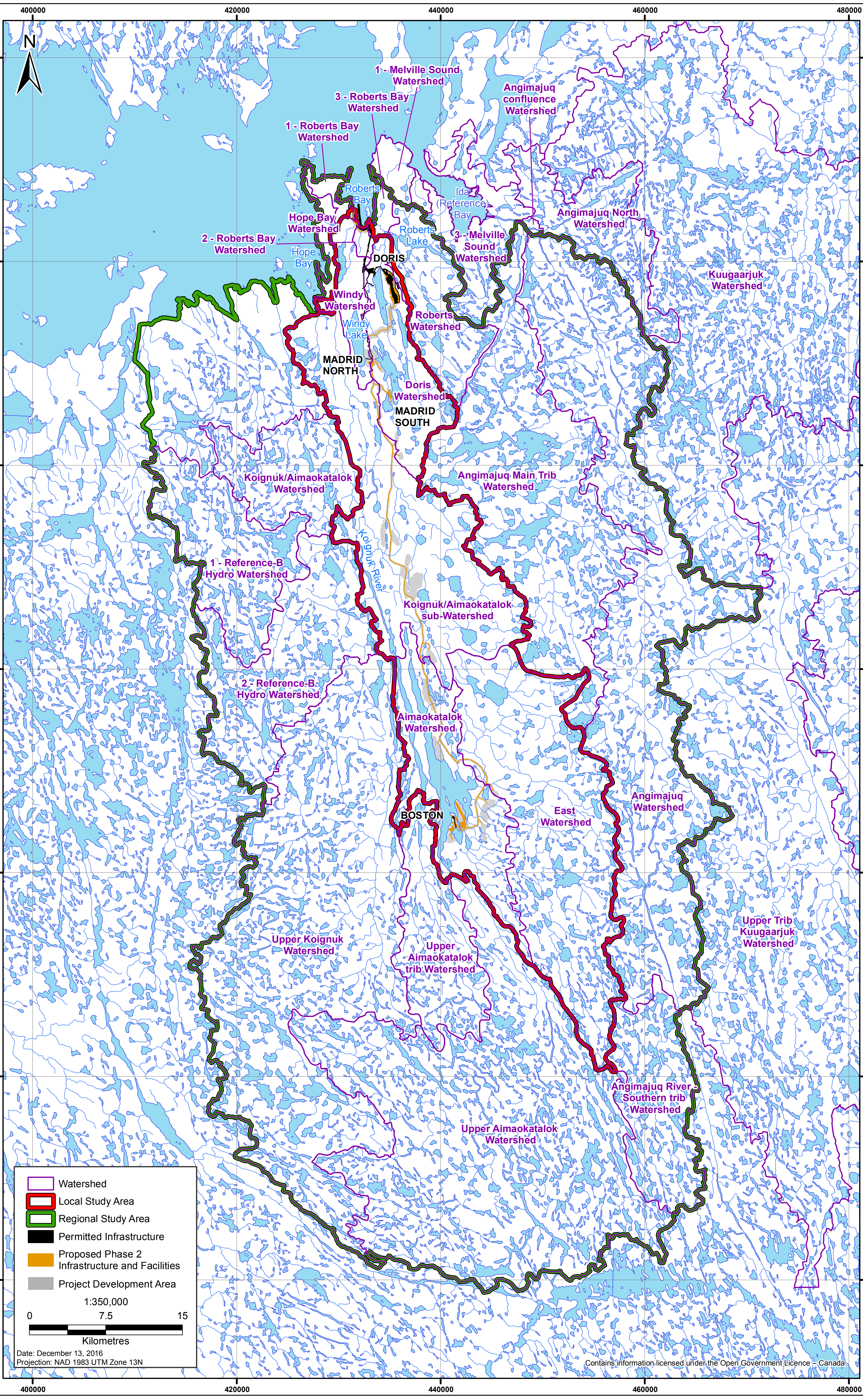


Figure 1.2-3a
Hydrometric Monitoring Stations in the Northern Part of the Project Area

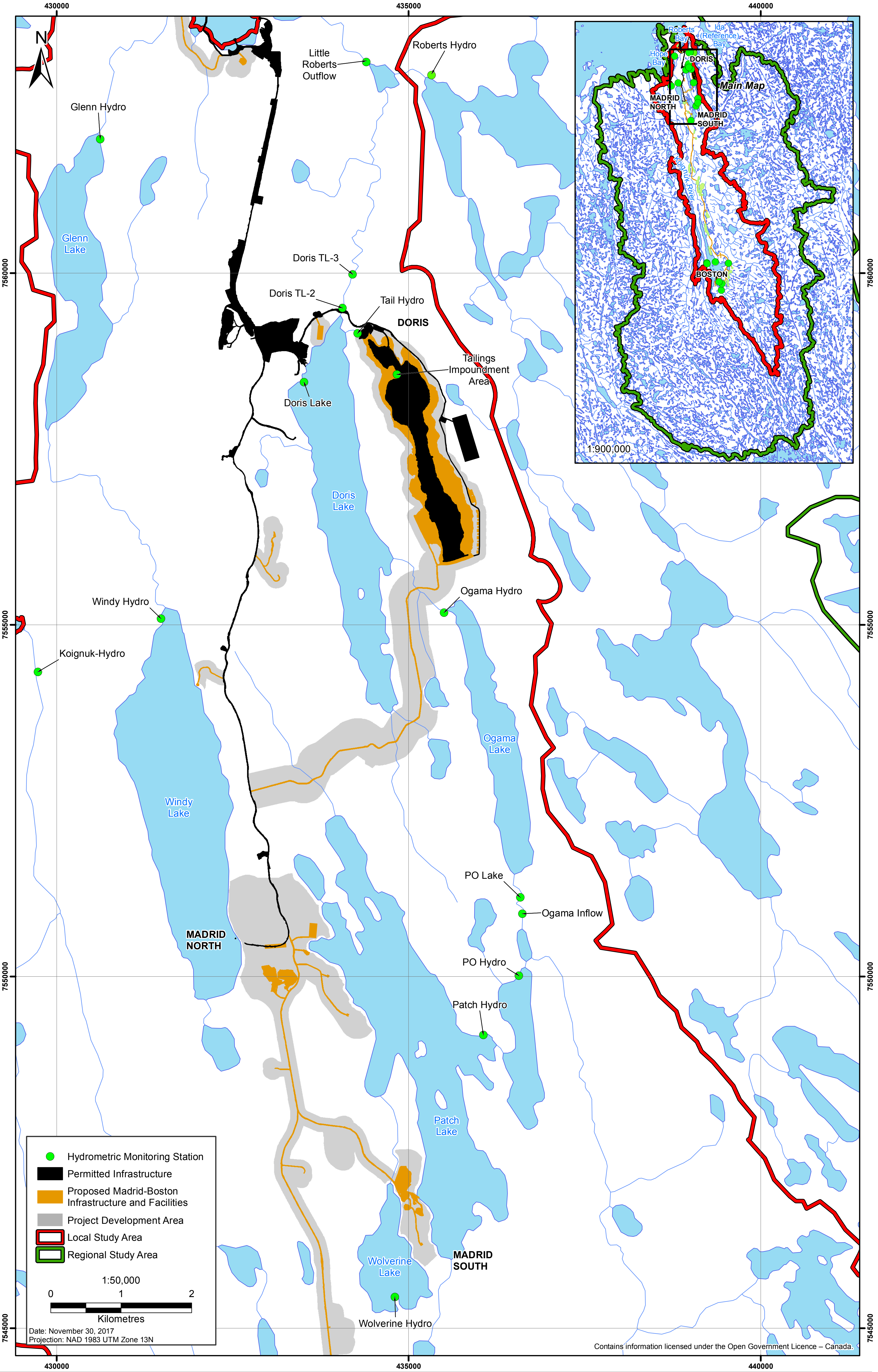


Figure 1.2-3b
Hydrometric Monitoring Stations in the Southern Part of the Project Area

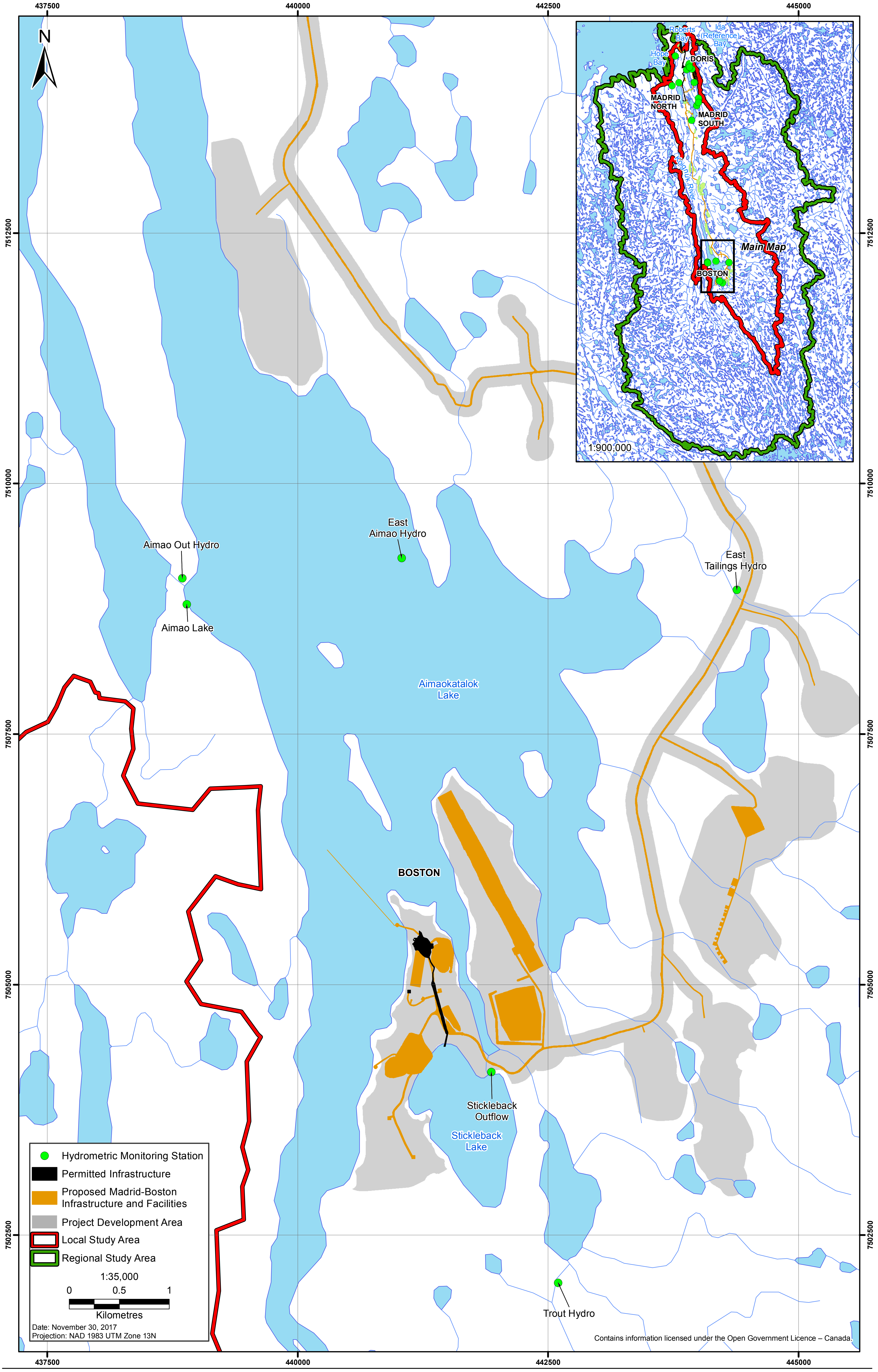


Table 1.2-1. Hydrometric Monitoring Stations

Hydrometric Station	Monitoring Type	UTM Coordinates*		Drainage Area (km^2)	Years of Automated Data Collection
		Easting	Northing		
Roberts Hydro	Lake/Stream Water Level	435,325	7,562,815	98	2003-2017
Doris Lake	Lake Water Level	433,512	7,558,452	n/a	2004-2017
Doris Hydro and Doris TL-2	Stream Water Level	434,059	7,559,504	95	1996-1998, 2000, 2003-2017
Doris TL-3	Stream Water Level	434,204	7,559,985	95	2011-2016
Little Roberts Outflow	Stream Water Level	434,271	7,563,159	199	2003-2008
Ogama Hydro	Lake/Stream Water Level	435,501	7,555,173	75	1996-1998, 2006-2011
Ogama Inflow	Stream Water Level	436,617	7,550,891	65	1997
Patch Hydro	Lake/Stream Water Level	436,062	7,549,169	32	2006-2011
PO Lake	Lake Water Level	436,584	7,551,126	n/a	2007-2011
PO Hydro	Stream Water Level	436,565	7,550,014	68	2007-2011
Wolverine Hydro	Lake Water Level	434,802	7,545,443	n/a	2006-2011
Tailings Impoundment Area (Tail Lake)	Lake Water Level	434,832	7,558,560	n/a	2004-2016
Tail Hydro	Stream Water Level	434,273	7,559,147	4.4	2000, 2004-2010
Windy Hydro	Lake/Stream Water Level	431,481	7,555,089	14	2006-2017
Glenn Hydro	Lake/Stream Water Level	430,616	7,561,906	32	1996-1998, 2000, 2006-2009
Koignuk-Hydro	Stream Water Level	429,731	7,554,332	2,937	2006-2011
Aimao Out Hydro	Stream Water Level	438,847	7,509,056	1,224	2006-2008, 2010
Aimao In Hydro	Stream Water Level	441,637	7,499,326	725	2006-2008, 2010
Aimao Lake	Lake Water Level	438,892	7,508,794	n/a	
East Aimao Hydro	Stream Water Level	441,038	7,509,257	363	2006-2008, 2010-2011
East Tailings Hydro	Stream Water Level	444,385	7,508,941	8	2010-2011
Trout Hydro	Stream Water Level	442,599	7,502,024	27	2011
Stickleback Outflow	Stream Water Level	441,934	7,504,127	2.8	1998, 2006-2008, 2011

** UTM Zone 13W, NAD83*
n/a = Drainage area is not applicable; the station only monitors lake elevation.

This hydrologic data set includes:

- stream water level (stage) measurements during the open-water season;
- manual stream discharge measurements and water level surveys;
- development of stage-discharge relationships (rating curves) and production of annual hydrographs at each of the monitoring locations;
- analysis of flow duration and calculation of hydrologic indices (runoff, monthly distribution, unit discharge, and mean annual discharge) at monitoring locations; and
- channel geometry surveys.

A summary description of the methods used to collect these data is provided in Section 1.2.3. These data, in conjunction with other data sources (such as long-term regional data), were used to the characterize baseline surface hydrology conditions (Section 1.2.4). Full details of the baseline programs used to collect hydrometric information are described in the following reports:

- 1993-2002 Data Compilation Report for Meteorology and Hydrology (Volume 5, Appendix V5-1A; Rescan 2002);
- Doris North 2003 Meteorology and Hydrology Baseline (V5-1B; AMEC, 2003);
- Doris 2008 Hydrology Baseline Update, 2004-2008, draft Report (V5-1C; Golder 2009);
- Hope Bay Belt 2009 Hydrology Baseline Report (V5-1D; Rescan 2009);
- Doris North 2010 Hydrology Compliance Report (V5-1F; Rescan 2010);
- Hope Bay Belt 2010 Hydrology Baseline Report (V5-1E; Rescan 2011a);
- Doris North 2011 Hydrology Compliance Report (V5-1H; Rescan 2011b);
- Hope Bay Belt 2011 Hydrology Baseline Report (V5-1G; Rescan 2012a);
- Doris North 2012 Hydrology Compliance Report (V5-1I; Rescan 2012b);
- Doris North 2013 Hydrology Compliance Monitoring Report (V5-1J; ERM Rescan 2014);
- Doris North 2014 Hydrology Compliance Monitoring Program Memorandum (V5-1K; ERM 2015); and
- Doris North 2015 Hydrology Compliance Monitoring Program Memorandum (V5-1L; ERM 2016).

1.2.2.2 Available Regional Hydrologic Data

Data are available from hydrometric stations operated by the Water Survey of Canada (WSC) (Table 1.2-2 and Figure 1.2-4). The drainage areas of these stations range from 217 km^2 to 46,200 km^2. Data from these stations provide background information on the regional surface water hydrology.

1.2.3 Methods

This section provides a description of methods used to collect and analyze surface hydrology baseline information, including standards, field collection, analysis, and modelling.

Figure 1.2-4

WSC Hydrometric Stations Near the Regional Study Area with >5 Year Records

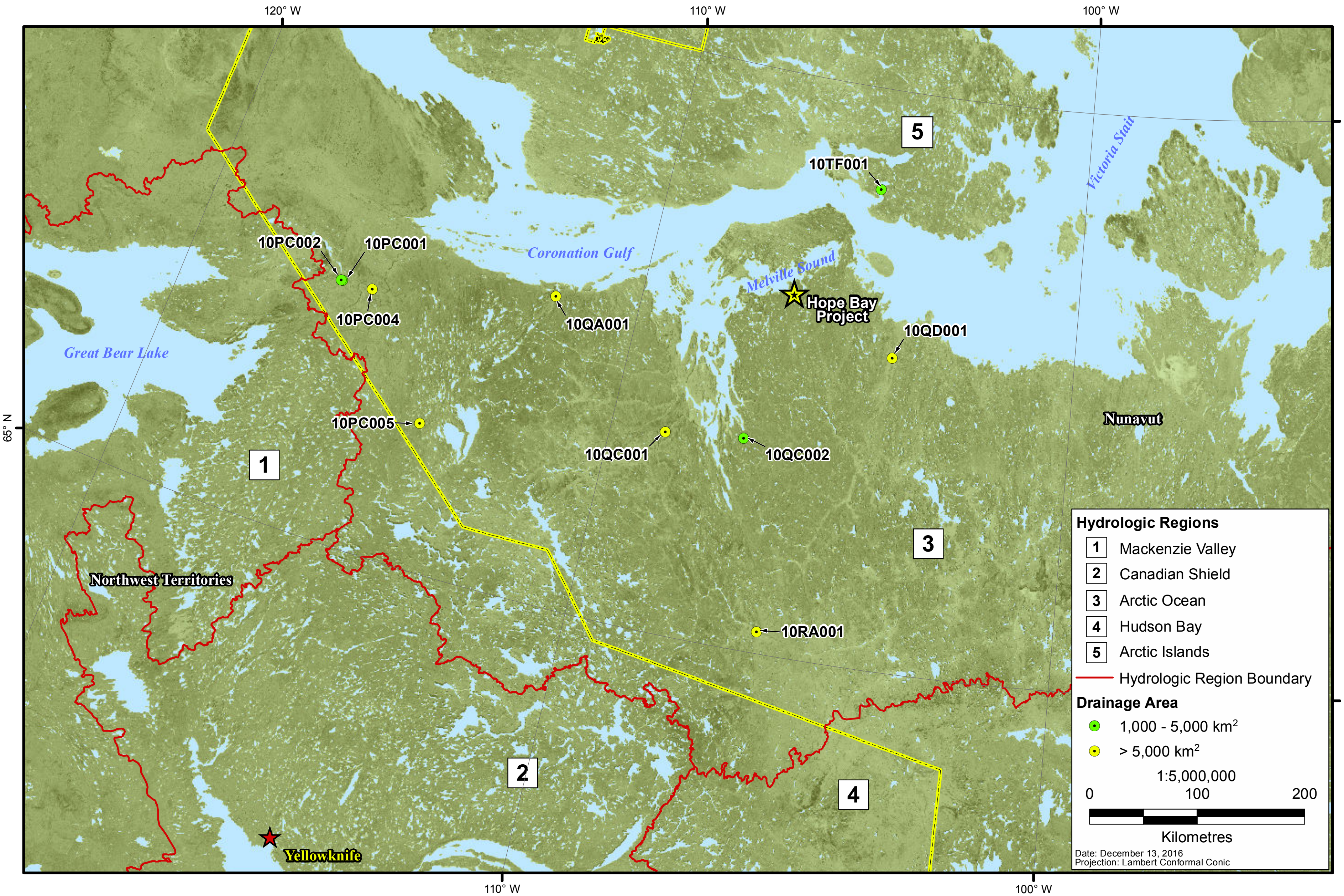


Table 1.2-2. Water Survey of Canada Stations Relevant to the Region

WSC Station ID	Station Name	Latitude	Longitude	Drainage Area (km^2)	Period of Record
10PC001	Kendall River near outlet of Dismal Lakes	67°12'31" N	116°34'20" W	2,790	1969-2008
10PC002	Atitok Creek near Dismal Lakes	67°12'52" N	116°36'32" W	217	1979-1990
10PC004	Coppermine River above Copper Creek	67°13'44" N	115°53'12" W	46,200	1987-present
10PC005	Fairy Lake River near outlet of Napaktulik Lake	66°15'7" N	113°59'7" W	6,442	1993-present
10QA001	Tree River near the mouth	67°38'6" N	111°54'8" W	5,810	1968-present
10QC001	Burnside River near the mouth	66°43'34" N	108°48'47" W	16,800	1976–present
10QC002	Gordon River near the mouth	66°48'36" N	107°06'04" W	1,530	1977–1994
10QD001	Ellice River near the mouth	67°42'30" N	104°8'21" W	16,900	1971-present
10RA001	Back River below Beechey Lake	65°11'14" N	106°05'09" W	19,600	1978–present
10TF001	Freshwater Creek near Cambridge Bay	69°7'52" N	104°59'26" W	1,490	1970-present

1.2.3.1 Hydrometric Data Collection and Analysis

Water Level Monitoring

The hydrometric stations operated during the open-water season, from June to late-September. Hydrometric stations consist of a staff gauge and reference bench marks, pressure transducer, and data logger. The staff gauge is a semi-permanent installation that provides a visual indication of water level in the stream or lake. The pressure transducer and datalogger automatically record water level at 10 to 15 minute intervals.

The basic assumption of hydrometric monitoring is that for a given channel cross-section, there is a direct relationship between observed water level (stage), and the streamflow (discharge). This relationship is site-specific, and must be developed by collecting manual measurements of discharge over a range of observed stages. An empirical stage-discharge relationship is developed and used to convert the recorded water levels to streamflow and produce an annual hydrograph (record of discharge versus time).

Streamflow Measurement

Manual streamflow measurements were completed at all the hydrometric stations during the open-water season. Where streamflow allowed, velocity measurements were obtained using the area-velocity technique, with either a vane or propeller driven current meter (Swoffer 2100™) or an electromagnetic velocity flow meter (Marsh-McBirney Flo-mate™ or Hach FH950). This technique involves wading across the channel and measuring the depth and velocity at regular intervals. Hence, the cross-sectional area of the stream (m^2), with the velocity of the water (m/s), is used to calculate discharge (m^3/s; Herschy 2009).

Where water depth or velocity conditions were too high to allow for safe wading, velocity was determined using a StreamPro™ (Teledyne RD Instruments) Acoustic Doppler Current Profiler (ADCP). An ADCP uses acoustic-Doppler technology to measure both water depths and current velocities as the instrument is ferried across the channel. The results are sent via Bluetooth to a laptop and can be viewed in real-time. Flow velocities were measured at a single section or transect across the channel. Multiple traverses of the section were completed during each site visit to reduce the effects of turbulence, directional bias, or other random errors. The standard for both the United States

Geological Survey (USGS; 2005) and WSC (2004) with a minimum of four transects (two in each direction) were followed.

Stage-discharge Relationship

Rating curves were developed using standards outlined by the USGS (Rantz et al. 1982) and the International Organization for Standardization (ISO 2010). Once developed, the rating curve can to be used to convert water level data recorded by a hydrometric monitoring station into a continuous discharge time-series, otherwise known as a discharge hydrograph. The quality of a rating curve is a function of the number and accuracy of the individual data points (measurements) that are used to generate the curve. To develop a robust rating curve for each hydrometric station, a minimum of 10 manual streamflow measurements, well distributed through the range of flows, should be collected.

It is common to have limited measurements corresponding to high flow conditions, and the rating curve is often extrapolated to a high flow value that is beyond the range of the observed data used to generate the curve. In general, rating curves can be reliably extrapolated to a value equal to 1.5 times the greatest measured discharge. Any discharge extrapolation beyond that limit is not recommended as the resulting value will have greater uncertainty (ISO 2010).

Rating curves were developed using Aquarius™ Time Series Hydrologic Software (Aquatic Informatics Inc.). The software uses standard methods outlined by the USGS and ISO (Kennedy 1984, ISO 2010). Rating curves are typically represented as a power function equation of the form:

$$Q = C \times (h - a)^n$$

Where Q is the discharge [m^3/s], C and n are regression coefficients, h is the stage [m], and a is the stage at zero flow (datum correction) [m]). Normally, channel cross-sectional information at each monitoring site is used to determine the stage at zero flow.

Rating curves can be exceptionally complicated, with changes to curves being common and occurring as a result of many factors. For example, erosion of channel beds and banks can cause a change in the rating curve. Such alterations are called shifts and result in rating curves having a finite temporal period of applicability. Alterations can occur gradually over time such as a progressive degradation of a channel, while others can be instantaneous as in the case of a high flow causing a slump in the bank. Other complications arise when the geometry of a channel is such that the rating curve is not a single curve, but a combination of multiples curves, with applicability at different ranges of stage. The change from one curve to another usually corresponds to a notable change in channel geometry, or in downstream channel controls. These factors, among many others, rarely occur in isolation and are frequently inter-related, thereby complicating rating curve development and sometimes increasing uncertainty.

Monthly and Annual Runoff

The annual hydrograph of daily discharge estimates were used to calculate mean monthly and annual discharge for hydrometric stations. Mean annual discharge values were divided by drainage area to estimate annual runoff (as a depth), which is a measure of the hydrological response of a watershed. Because it is normalized by drainage area, annual runoff is a useful index for comparing the hydrologic response of different sized watersheds.

1.2.3.2 Water Balance Modelling Approach for Baseline Characterization

A water balance for the Hope Bay Project, including the Madrid-Boston project as well as existing and approved projects, was developed to simulate both baseline and project-affected flows at

13 assessment nodes (Table 1.2-3; Figure 1.2-5) using a long-term precipitation dataset that was generated for the life of project (Volume 1, Annex V1-7, Package P5-4).

Table 1.2-3. Surface Hydrology Assessment Nodes

Assessment Node	Latitude	Longitude	Drainage Area (km^2)
Wolverine Lake Outflow East*	68° 1' 1"	106° 32' 47"	3.1
Wolverine Lake Outflow North*	68° 1' 49"	106° 33' 48"	3.1
Patch Lake Outflow	68° 2' 51"	106° 31' 35"	30.0
PO Lake Outflow	68° 3' 31"	106° 31' 7"	34.9
Ogama Lake Outflow	68° 6' 11"	106° 33' 1"	74.8
Doris Lake Outflow	68° 8' 40"	106° 35' 10"	89.8
Little Roberts Lake Outflow	68° 10' 23"	106° 34' 52"	197
Windy Lake Outflow	68° 6' 13"	106° 38' 51"	14.1
Glenn Lake Outflow	68° 9' 51"	106° 40' 16"	33.6
Trout Lake Outflow	67° 38' 40"	106° 21' 16"	33.7
Stickleback Lake Outflow	67° 38' 49"	106° 22' 6"	2.7
Aimaokatalok Lake Outflow	67° 41' 25"	106° 26' 40"	1,293
Koignuk River 1	67° 48' 6"	106° 31' 51"	1,472
Koignuk River 2	67° 53' 56"	106° 37' 23"	2,171

** Wolverine Outflow East and North were modelled as one outflow node (Package P5-4).*

The model was calibrated using observed streamflows between 2010 and 2016. The water balance was run using probabilistic simulations, with multiple realizations and variable hydrology. This approach allowed for simulating baseline and project-affected flows under average hydrological conditions, as well as the 1-in-20-year dry and wet conditions (P5-4).

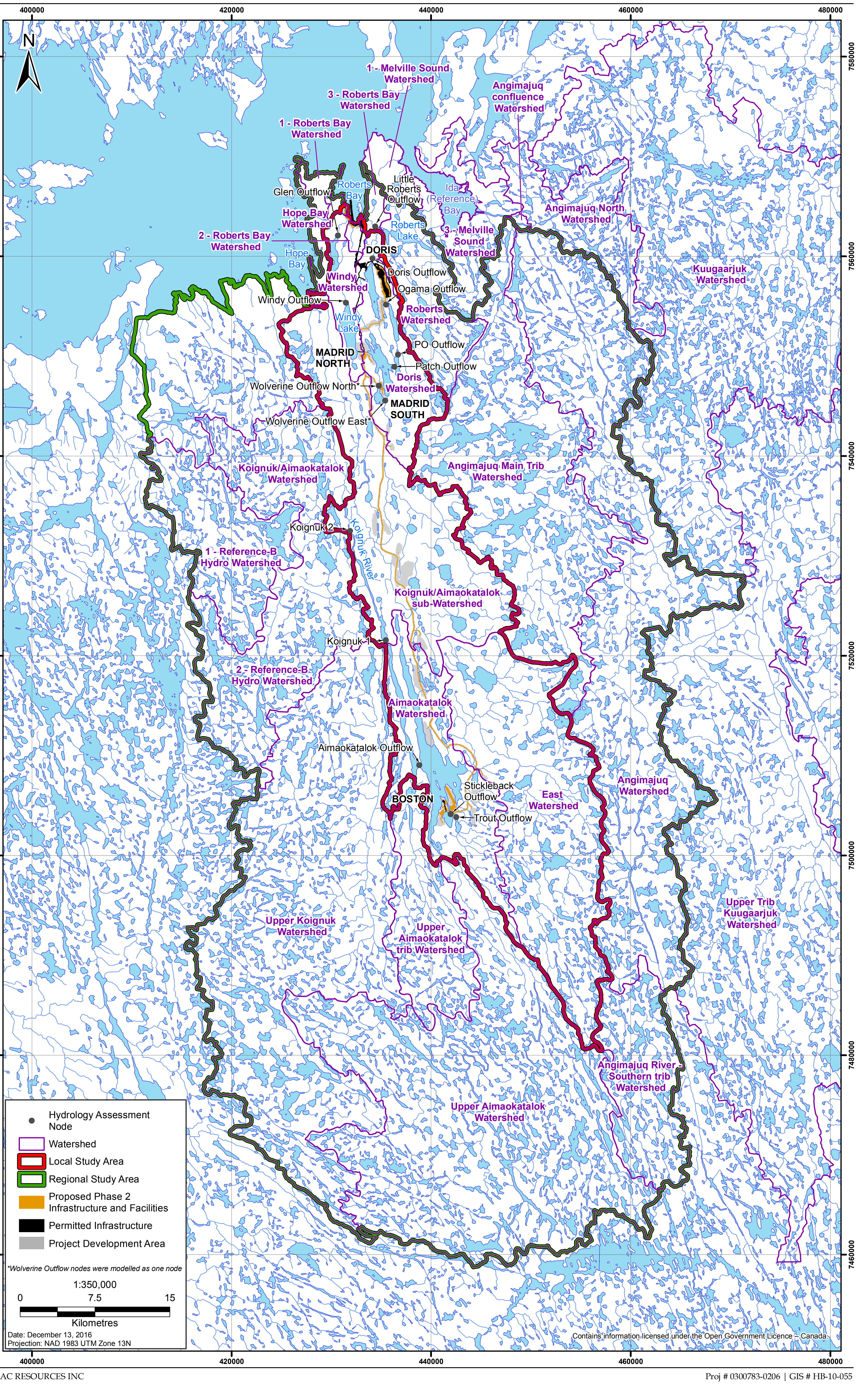
Climate change was accounted for in the water balance model with predicted increases to temperature and precipitation. The values incorporated into the model were based on the results of the climate change analysis (P5-1) and interpolated between years within the model (Table 1.2-4).

Table 1.2-4. Climate Change Trends, Compared to 1979-2005 Conditions

	Doris and Madrid Watersheds		Boston Watersheds	
Year	Average Annual Temperature Increase[1]	Average Annual Precipitation Increase	Average Annual Temperature Increase[1]	Average Annual Precipitation Increase
2020	1.0%	6.4%	0.8%	6.4%
2050	1.8%	13.0%	1.4%	13.0%
2080	2.6%	19.0%	2.1%	18.0%

[1] *Temperature increases are applied in Kelvin.*

Figure 1.2-5
Surface Hydrology Assessment Nodes



1.2.4 Characterization of Baseline Conditions

1.2.4.1 Hydrological Processes

The hydrologic regime of the Project is typical of high latitude regions of the continental Canadian Arctic and is strongly influenced by long cold winters, relatively low precipitation, and low relief topography generally with high watershed storage (i.e., lakes and wetlands). Extremely cold temperatures in the region, combined with permafrost, result in a short period of runoff that typically occurs from June to October. Compared to non-permafrost regions, permafrost watersheds tend to have higher peak flow and lower base flow (Kane et al 1997).

The physiography of the region is dominated by vegetated tundra hillslopes with lakes and scattered wetlands. The presence of permafrost is hydrologically significant, as it has very low hydraulic conductivity, and thus acts as a barrier to deep groundwater recharge. This physical restriction tends to increase surface water runoff and decrease sub-surface flows.

A number of factors influence the volume of freshet runoff and temporal and spatial variation of annual flows in Arctic watersheds:

- *Amount of snowpack in spring.* Snowpack depth is dependent on the amount of snowfall during the previous winter and the amount of snow remaining in each watershed prior to freshet. Snow can be lost or redistributed due to sublimation, melting, or wind.
- *Air temperature.* Above freezing air temperatures combined with a rapid air temperature increase can produce a high melt rate and streamflow. Different melt rates occur on north and south facing slopes, which may affect the timing of melt and size of the contributing area. Warm air temperatures can increase evapotranspiration and sublimation, reducing surface water availability.
- *Timing for opening of stream channels at lake outlets.* Snowmelt from hillslopes surrounding lakes can occur before the stream channels draining the lakes become ice free. In this case, meltwater can be stored in the lake and then released once the channels are open to flow.
- *Soil moisture conditions and lake levels at the end of the previous summer.* A dry summer in the previous year can lead to a significant soil moisture deficit and lower lake levels. As a result, a portion of the annual runoff will recharge the lakes and soil moisture before surface waters are transmitted as streamflow from a drainage area.
- Other watershed-specific physiographic controls include watershed size, slope, substrate type, and vegetation.

Arctic hydrographs are characterized by a steep rising limb leading to a peak flow discharge that occurs during the spring, shortly after air temperature rises above freezing (Figure 1.2-6). During freshet, water that is stored in the winter snowpack melts and is released quickly, generating high flows that are typically the annual peak. In small watersheds, high flows can last as little as a few days. Peak flow typically occurs immediately after ice break-up in lakes and channel reaches, especially in smaller watersheds. Due to the presence of permafrost, small streams do not receive groundwater contributions, and flow discharges from these watersheds may cease after freshet until late summer rains (Figure 1.2-6). For rivers draining larger watersheds, the freshet peak may be delayed relative to smaller drainages as snowmelt from upper portions of the watershed is routed through the drainage network. Precipitation events in the late summer and early fall may lead to a second hydrograph peak, but this peak is generally lower magnitude than the freshet peak (Figure 1.2-6). This secondary rain-driven peak is not visible when daily flow hydrographs are averaged into monthly runoff values (Figure 1.2-7).

Figure 1.2-6

A Typical Example of Discharge and Runoff in an Arctic Nival River (Atitok Creek near Dismal Lake, 1988), with Air Temperature and Precipitation

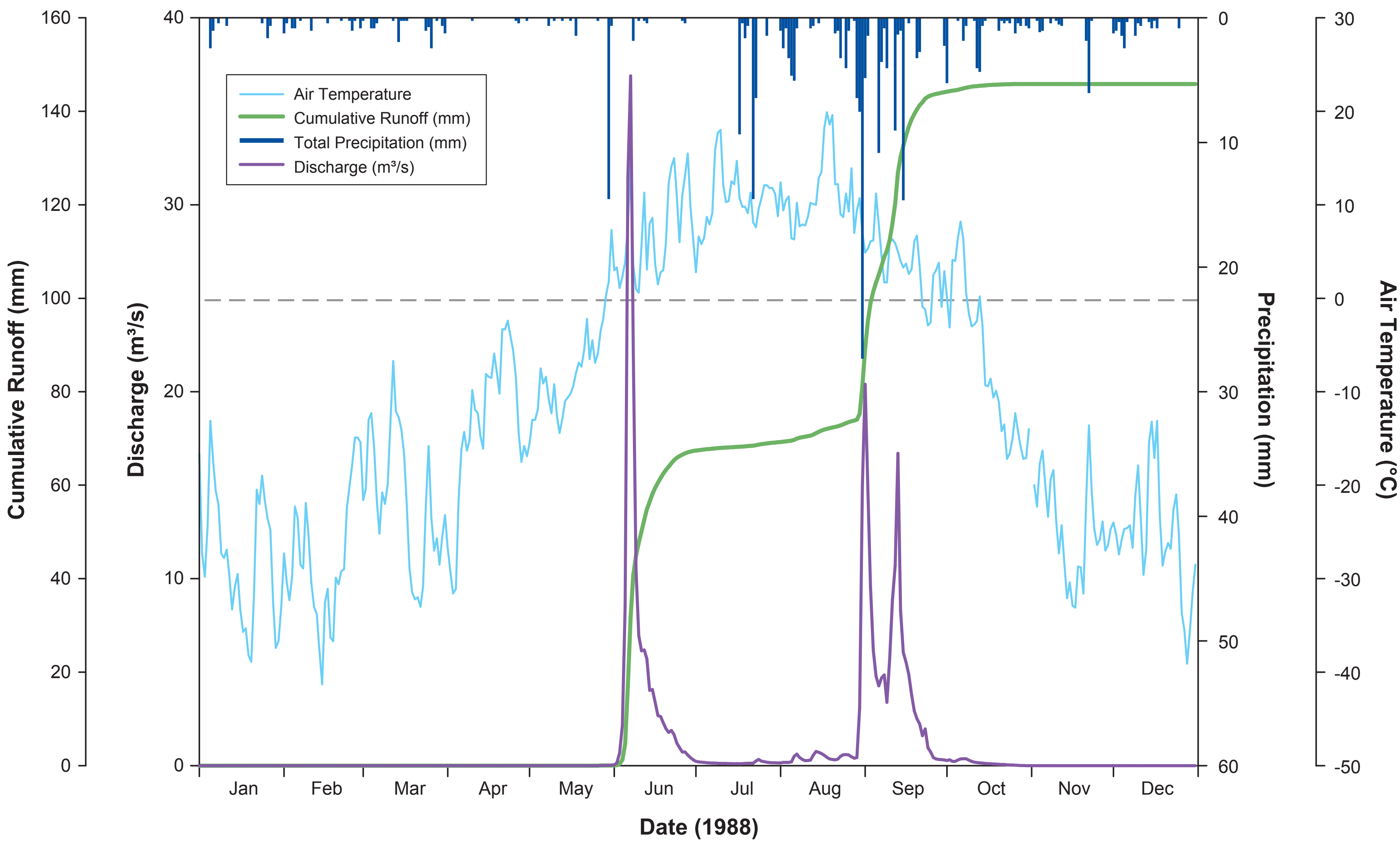
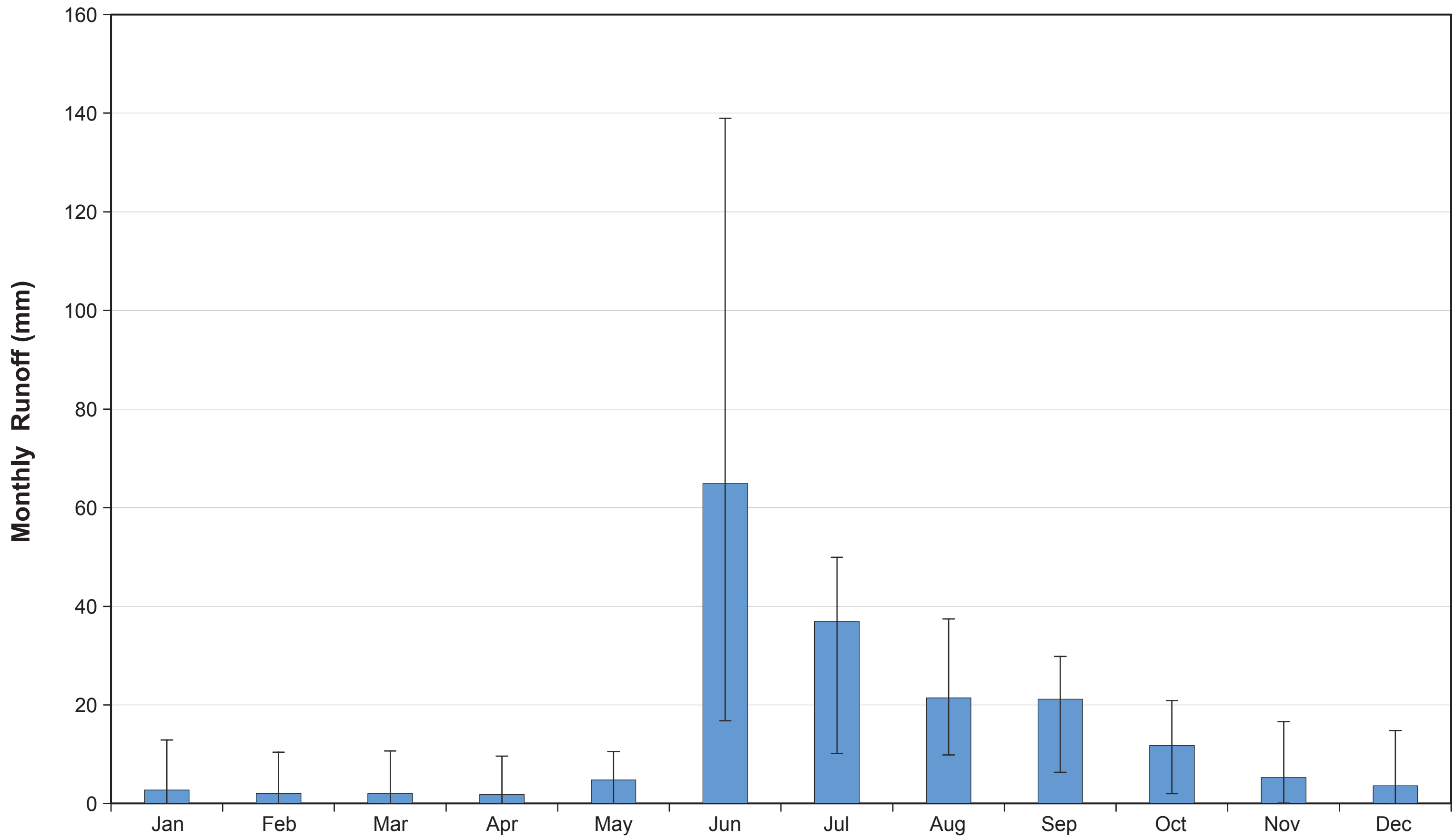


Figure 1.2-7

Historical Monthly Runoff at Regional Water Survey of Canada Stations - Average Monthly Runoff during Period of Record



Notes: Bars represent the average value of 10 regional stations.
Whiskers show the variation of average monthly runoff among 10 regional stations.

After snowmelt-generated runoff ends in summer and fall, the remaining runoff is controlled by rainfall, evaporation, and release of stored water in lakes and the active layer of soil. Smaller watersheds with minimal lake area tend to exhibit a more rapid response to precipitation than larger watersheds. Open-water evaporation rates in the summer often exceed total rainfall, causing soil moisture deficits in the shallow active layer of the soil. In October, air temperature normally dips below freezing, precipitation begins to fall as snow, and streamflow ceases for the winter except in rivers with very large watersheds.

1.2.4.2 Baseline Data Collection Results

Streamflow data collected from hydrometric stations (Section 1.2.2.1) were analyzed based on the methods described in Section 1.2.3. Annual runoff estimates for hydrometric monitoring stations and annual fluctuation of lake levels are summarized in Tables 1.2-5 and 1.2-6, respectively. Details, including analyses and further hydrologic indices are available in Appendices V5-1A to V5-1K. These results were used in the water balance model (P5-4) to generate long-term estimates for monthly baseline flow estimates at different assessment nodes within the Project area. These estimates are presented in the following section.

1.2.4.3 Baseline Streamflow Estimates

Long-term baseline monthly streamflow estimates for the average, 1-in-20-year wet, and 1-in-20-year dry runoff conditions at 13 modelling nodes, based on the methodology described in Section 1.2.3.2 (P5-4), are summarized in Table 1.2-7. These baseline streamflow estimates represent natural flows under existing climate conditions.

Baseline flow projections (i.e., future natural flows if no project were developed in the region), incorporating the climate change trends (described in Section 1.2.4.6; P5-1), are provided in Appendix V5-1M. These baseline streamflow estimates are used for effects assessment in this chapter.

In addition, long-term average baseline monthly lake elevation and volume estimates for nine lakes are summarized in Appendices V5-1N and V5-1O. These baseline lake elevation and volume estimates are used in the fish habitat effects assessment (Volume 5, Chapter 6).

1.3 VALUED COMPONENTS

1.3.1 Potential Valued Components and Scoping

VECs are those components of the biophysical environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Chapter 4). The selection and scoping of VECs considers biophysical conditions and trends that may interact with the proposed Project, variability in biophysical conditions over time, and data availability. This selection also considers the ability to measure biophysical conditions that may interact with the Project and are important to the communities potentially impacted by the Project. For an interaction to occur there must be spatial and temporal overlap between a VEC and Project component and/or activities. The selection and scoping of VECs also considers their importance to the communities potentially impacted by the Project.

Table 1.2-5. Annual Runoff Estimates for Hydrometric Monitoring Stations (2004 to 2015)

Hydrometric Station	Drainage Area (km^2)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Roberts Hydro	98	61	100	72	72	170	98	146	162	99	61	138	168
Little Roberts Hydro	199	64	90	68	83	158	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Doris Hydro and TL-2	95	62	83	73	80	153	99	129	191	107	41	113	187
Doris TL-3	95	n/a	n/a	n/a	n/a	n/a	n/a	n/a	190	109	47	120	190
Ogama Hydro	75	n/a	n/a	78	97	136	99	129	160	n/a	n/a	n/a	n/a
Patch Hydro	32	n/a	n/a	40	n/a	150	95	98	175	n/a	n/a	n/a	n/a
PO Hydro	68	n/a	n/a	n/a	n/a	n/a	125	120	213	n/a	n/a	n/a	n/a
Tail Hydro	4.4	42	84	53	82	152	109	168	n/a	n/a	n/a	n/a	n/a
Windy Hydro	14	n/a	n/a	n/a	n/a	n/a	168	222	n/a	118	43	98	n/a
Glenn Hydro	32	n/a	n/a	63	n/a	132	130	n/a	n/a	n/a	n/a	n/a	n/a
Koignuk Hydro	2,937	n/a	n/a	n/a	n/a	n/a	137	140	191	n/a	n/a	n/a	n/a
Aimo Out Hydro	1,224	n/a	n/a	n/a	n/a	n/a	n/a	144	206	n/a	n/a	n/a	n/a
Aimo In Hydro	725	n/a	n/a	n/a	n/a	n/a	n/a	n/a	134	n/a	n/a	n/a	n/a
East Aimo Hydro	363	n/a	n/a	n/a	n/a	n/a	n/a	147	172	n/a	n/a	n/a	n/a
East Tailings Hydro	8	n/a	n/a	n/a	n/a	n/a	n/a	46	113	n/a	n/a	n/a	n/a
Trout Hydro	27	n/a	n/a	n/a	n/a	n/a	n/a	n/a	147	n/a	n/a	n/a	n/a
Stickleback Outflow	2.8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	197	n/a	n/a	n/a	n/a

Notes:
Lake level fluctuation values were not provided in the baseline reports prior to 2004.
n/a = Either data were not collected or total runoff value for the year was not provided in the baseline report.

Table 1.2-6. Recorded Ranges of Seasonal Lake Levels for Lake Monitoring Stations (2004 to 2015)

Lake Monitoring Station	Water Level Fluctuation (m)											
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Wolverine Lake	n/a	n/a	0.16	n/a	0.06	0.25	0.24	0.26	n/a	n/a	n/a	n/a
Monitoring Period	n/a	n/a	Jun 1 - Sep 7	n/a	Jun 18 - Sep 9	Jun 20 - Jul 26	Jun 13 - Sep 28	Jun 21 - Sep 21	n/a	n/a	n/a	n/a
Patch Lake	n/a	n/a	0.20	0.10	0.23	0.18	0.30	0.44	n/a	n/a	n/a	n/a

Lake Monitoring Station	Water Level Fluctuation (m)											
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Monitoring Period	n/a	n/a	Jun 1 - Sep 9	Jun 25 - Sep 12	Jun 23 - Sep 9	Jun 19 - Sep 22	Jun 14 - Sep 29	Jun 22 - Sep 22	n/a	n/a	n/a	n/a
PO Lake	n/a	n/a	n/a	0.34	0.58	0.22	0.34	0.64	n/a	n/a	n/a	n/a
Monitoring Period	n/a	n/a	n/a	Jun 18 - Sep 14	Jun 23 - Sep 9	Jun 18 - Sep 21	Jun 14 - Sep 29	Jun 8 - Sep 22	n/a	n/a	n/a	n/a
Ogama Lake	n/a	n/a	0.46	0.23	0.28	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Monitoring Period	n/a	n/a	Jun 31 - Sep 8	Jun 19 - Sep 14	Jul 2 – Sep 9	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Doris Lake	0.40	0.58	0.59	0.29	0.66	0.35	0.68	0.74	0.63	0.35	0.68	0.42
Monitoring Period	Jun 12 - Sep 10	Jun 8 - Dec 31	Jan 1 - Dec 31	Jan 1 - Dec 31	Jan 1 - Sep 12	May 27 - Sep 21	May 30 - Oct 4	Jan 1 - Sep 29	Jan 1 - Sep 7	May 22 - Sep 10	Jan 1 - Sep 21	Jul 15 – Sep19
Tailings Impoundment Area (Tail Lake)	0.17	0.19	0.25	0.23	0.20	0.14	0.17	0.63	0.50	0.34	0.41	0.36
Monitoring Period	Jun 13 - Dec 31	Jan 1 - Dec 31	Jan 1 - Dec 31	Jan 1 - Dec 31	Jan 1 - Sep 12	Jan 1 - Sep 21	Jun 2 - Oct 4	May 12 - Sep 29	Jan 1 - Sep 12	May 22 - Sep 9	Mar 16 - Sep 18	Jul 15 – Sep 19
Little Roberts Lake	0.44	0.59	0.49	0.55	0.63	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Monitoring Period	Jun 6 - Sep 7	Jun 7 - Sep 29	Jun 30 - Sep 8	Jun 13 - Sep 14	Jun 19 - Sep 12	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Roberts Lake	0.36	0.26	0.58	0.52	0.36	0.20	0.40	0.56	n/a	n/a	n/a	n/a
Monitoring Period	Jun 18 - Sep 13	Jun 29 - Sep 17	Jun 3 - Sep 6	Jun 15 - Sep 14	Jun 22 - Sep 12	Jun 17 - Sep 20	Jun 14 - Oct 2	Jun 21 - Sep 25	n/a	n/a	n/a	n/a
Windy Lake	n/a	n/a	n/a	0.24	0.06	0.23	0.10	0.24	0.18	0.10	0.13	0.21
Monitoring Period	n/a	n/a	n/a	Jun 21 - Aug 4	Jul 2 -Sep 9	Jun 16 - Sep 23	Jun 10 - Sep 24	Jun 21 - Sep 22	Jun 7 - Sep 13	Jun 5 - Sep 8	Jun 5 - Sep 8	Jun 12 – Sep 19
Glenn Lake	n/a	n/a	0.19	0.22	0.18	0.26	n/a	n/a	n/a	n/a	n/a	n/a
Monitoring Period	n/a	n/a	Jun 1 - Sep 11	May 24 - Jul 3	Jun 23 - Sep 9	Jun 17 - Sep 19	n/a	n/a	n/a	n/a	n/a	n/a
Aimaokatalok Lake	n/a	n/a	n/a	1.99	3.04	2.23	2.13	n/a	n/a	n/a	n/a	n/a
Monitoring Period	n/a	n/a	n/a	n/a	n/a	n/a	Jun 1 – Sep 26	n/a	n/a	n/a	n/a	n/a

Notes:
Lake level fluctuation values were not provided in the baseline reports prior to 2004.
n/a = Either data were not collected or total runoff value for the year was not provided in the baseline report.

Table 1.2-7. Baseline Monthly Streamflow Estimates under the Average, 1-in-20-Year Wet, and 1-in-20-Year Dry Conditions

Assessment Node	Drainage Area (km^2)	Climate Condition	Monthly Flow (m^3/s)												Annual Flow (m^3/s)	Annual Runoff (mm)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Wolverine Lake Outflow	**3.1**	Average	0	0	0	0	0	0.053	0	0	0	0	0	0	**0.004**	**44**
		Dry[1]	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
		Wet[2]	0	0	0	0	0.081	0.086	0	0	0.013	0.020	0	0	**0.017**	**170**
Patch Lake Outflow	**30.0**	Average	0	0	0	0	0	0.427	0.230	0.122	0.104	0	0	0	**0.074**	77
		Dry[1]	0	0	0	0	0	0.231	0.105	0.062	0.062	0	0	0	**0.038**	40
		Wet[2]	0	0	0	0	0.040	0.790	0.297	0.234	0.204	0.000	0	0	**0.130**	137
PO Lake Outflow	**34.9**	Average	0	0	0	0	0	0.552	0.250	0.138	0.125	0	0	0	**0.089**	80
		Dry[1]	0	0	0	0	0	0.297	0.107	0.066	0.080	0	0	0	**0.046**	41
		Wet[2]	0	0	0	0	0.078	0.956	0.339	0.287	0.247	0	0	0	**0.159**	143
Ogama Lake Outflow	**74.8**	Average	0	0	0	0	0	1.776	0.476	0.314	0.291	0.000	0	0	**0.237**	100
		Dry[1]	0	0	0	0	0	0.799	0.204	0.154	0.156	0	0	0	**0.109**	46
		Wet[2]	0	0	0	0	1.003	2.459	0.721	0.741	0.591	0.146	0	0	**0.472**	199
Doris Lake Outflow	**89.8**	Average	0	0	0	0	0	1.943	0.638	0.344	0.345	0.196	0.005	0	**0.288**	101
		Dry[1]	0	0	0	0	0	0.948	0.251	0.150	0.162	0.129	0	0	**0.136**	48
		Wet[2]	0	0	0	0	1.405	2.746	0.952	0.926	0.740	0.383	0.123	0	**0.608**	213
Little Roberts Lake Outflow	**197**	Average	0	0	0	0	0	7.091	1.802	1.159	1.166	0.612	0.011	0	**0.983**	161
		Dry[1]	0	0	0	0	0	2.209	0.728	0.748	0.621	0.396	0	0	**0.392**	64
		Wet[2]	0	0	0	0	6.325	8.665	2.762	3.065	2.364	1.786	0.246	0	**2.110**	347
Windy Lake Outflow	**14.1**	Average	0	0	0	0	0	0.183	0.079	0.027	0.025	0	0	0	**0.026**	58
		Dry[1]	0	0	0	0	0	0.084	0.019	0.003	0.005	0	0	0	**0.009**	21
		Wet[2]	0	0	0	0	0	0.357	0.114	0.087	0.082	0	0	0	**0.053**	119
Glenn Lake Outflow	**33.6**	Average	0	0	0	0	0	0.728	0.111	0.075	0.115	0.045	0	0	**0.089**	83
		Dry[1]	0	0	0	0	0	0.105	0.005	0.026	0.031	0.025	0	0	**0.016**	15
		Wet[2]	0	0	0	0	0.550	0.892	0.264	0.305	0.229	0.206	0	0	**0.205**	192
Trout Lake Outflow	**33.7**	Average	0	0	0	0	0	0.94	0.13	0.12	0.13	0.07	0	0	**0.12**	108
		Dry[1]	0	0	0	0	0	0.03	0.02	0.06	0.05	0.04	0	0	**0.02**	16
		Wet[2]	0	0	0	0	0.83	1.05	0.31	0.34	0.20	0.33	0	0	**0.26**	240

Assessment Node	Drainage Area (km²)	Climate Condition	Monthly Flow (m³/s)												Annual Flow (m³/s)	Annual Runoff (mm)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Stickleback Lake Outflow	**2.7**	Average	0	0	0	0	0	0.03	0.01	0.00	0.00	0	0	0	**0.00**	44
		Dry[1]	0	0	0	0	0	0.01	0.00	0.00	0	0	0	0	**0.00**	13
		Wet[2]	0	0	0	0	0	0.06	0.02	0.01	0.01	0	0	0	**0.01**	99
Aimaokatalok Lake Outflow	**1,293**	Average	0	0	0	0	0	32.75	8.53	4.81	4.68	2.06	0.45	0	**4.42**	108
		Dry[1]	0	0	0	0	0	13.09	3.27	2.54	2.20	0.52	0	0	**1.79**	44
		Wet[2]	0	0	0	0	19.17	41.74	12.16	11.79	9.46	8.16	2.25	0	**8.75**	213
Koignuk River 1	**1,472**	Average	0	0	0	0	0	37.86	9.27	5.46	5.41	2.44	0.45	0	**5.05**	108
		Dry[1]	0	0	0	0	0	13.40	3.72	3.06	2.60	0.69	0	0	**1.95**	42
		Wet[2]	0	0	0	0	22.88	47.11	13.50	13.56	10.50	9.85	2.25	0	**10.00**	214
Koignuk River 2	**2,171**	Average	0	0	0	0	0	57.83	12.14	8.03	8.24	3.93	0.45	0	**7.51**	109
		Dry[1]	0	0	0	0	0	14.64	4.94	4.61	4.17	1.50	0	0	**2.49**	36
		Wet[2]	0	0	0	0	37.60	66.55	18.18	21.60	14.62	17.14	2.35	0	**14.89**	216

[1] *1-in-20-Year Dry Condition*
[2] *1-in-20-Year Wet Condition*

1.3.1.1 The Scoping Process and Identification of VECs

The scoping of *VECs* follows the process outlined in the Assessment Methodology (Volume 2, Chapter 4). VECs proposed in the EIS guidelines (NIRB 2012a) were further informed through consultation with communities, regulatory agencies, available TK, and professional expertise. The EIS guidelines (NIRB 2012a) propose that surface hydrology be considered for inclusion in the effects assessment. The selection of surface hydrology as a VEC was also informed by:

- review of recently completed Nunavut EAs (e.g., Back River, Mary River);
- consultation and engagement with local and regional Inuit groups (e.g., the KIA); and
- public consultation and open house meetings held in the Kitikmeot communities in May 2016 (see Volume 2, Chapter 3, Public Consultation and Engagement).

1.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to the Project. Comments made during these sessions were compiled and analysed as part of *VEC* scoping. No remarks were made about surface hydrology.

1.3.1.3 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the Madrid-Boston Project were conducted in each of the five Kitikmeot communities as described in Chapter 3 of Volume 2. The meetings are a central component of engagement with the public and an opportunity to share information and seek public feedback. Overall, the community meetings were well attended. Public feedback (questions, comments, and concerns) about the proposed Project was obtained through open dialogue during Project presentations, through discussions that arose during the presentation of Project materials and comments provided in feedback forms. No specific feedback was provided about surface hydrology.

1.3.2 Valued Components Included in the Assessment

The scoping analysis identified the surface hydrology VEC for inclusion in the assessment (Table 1.3-1). The surface hydrology VEC was selected as a component of the assessment of the potential effects of the Project on freshwater environment because of the following:

- the potential to interact with the activities and components of the Project;
- importance identified in the TK report;
- identification as a potential VEC by government regulators and the NIRB;
- inclusion in recently completed Nunavut EISs (e.g., Back River, Mary River); and
- professional judgement.

Table 1.3-1. Valued Ecosystem Components Included in the Surface Hydrology Assessment

Species or Group	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Government	
Surface Hydrology	x	x	x	Key component of the biophysical environment Essential to the integrity of fish and aquatic habitat

1.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries selected to shape this assessment are determined by the Project's potential impacts on the freshwater environment. Spatial and temporal boundaries were defined as the maximum limits within which the effects assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2012a), and described in the Effects Assessment Methodology (Volume 2, Chapter 4).

Temporal boundaries are selected that consider the different phases of the Project and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect the freshwater environment.

The determination of spatial and temporal boundaries also takes into account the development of the entire Hope Bay Greenstone Belt. The assessment considers both the incremental potential effects of the Madrid-Boston Project as well as the total potential effects of the additional Madrid-Boston Project activities in combination with the existing and approved projects including the Doris Project and advanced exploration activities at Madrid and Boston.

1.4.1 Project Overview

The Madrid-Boston Project consists of proposed mine operations at the Madrid North, Madrid South and Boston deposits. The Madrid-Boston Project is part of a staged approach to continuous development of the Hope Bay Project, comprised of existing operations at Doris and bulk samples followed by commercial mining at Madrid North, Madrid South, and Boston deposits. The Madrid-Boston Project would use and expand upon the existing Doris Project infrastructure.

The Madrid-Boston Project is the focus of this application. Because the infrastructure of existing and approved projects will be utilized by the Madrid-Boston Project, and because the existing and approved projects have the potential to interact cumulatively with the Madrid-Boston Project, existing and approved project are described below.

1.4.1.1 Existing and Approved Projects

Existing and approved projects include:

- the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
- the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
- the Madrid Advanced Exploration Program (NWB Type B Water Licence 2BB-MAE1727); and
- the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1727).

<u>The Doris Project</u>

The Doris Project was approved by NIRB in 2006 (NIRB Project Certificate 003) and licenced by NWB in 2007 (Type A Water Licence 2AM-DOH0713). The Type A Water Licence was amended in 2010, 2011 and 2012 and received modifications in 2009, 2010, and 2011.

Construction of the Doris Project began in early 2010. In early 2012, the Doris Project was placed into care and maintenance, suspending further Project-related construction and exploration activity along the Hope Bay Greenstone Belt. Following TMAC's acquisition of the Hope Bay Project in March of 2013, NWB renewed the Doris Project Type A Water Licence (Type A Water Licence 2AM-DOH1323), and TMAC advanced planning, permitting, exploration, and construction activities. In 2016, NIRB approved an amendment to Project Certificate 003 and NWB granted Amendment No. 1 to Type A Water Licence 2AM-DOH1323, extending operations from two to six years through mining two additional mineralized zones (Doris Connector and Doris Central zones) to be accessed via the existing Doris North portal. Amendment No. 1 to Type A Water Licence 2AM-DOH1323 authorizes a mining rate of approximately 2,000 tonnes per day of ore and a milling throughput of approximately 2,000 tonnes per day of ore. The Doris Project began production early in 2017.

The Doris Project includes the following components and facilities:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach laydown area, access roads, weather havens, fuel tank farm/transfer station, waste storage facilities and incinerator, and quarry;
- The Doris site: 280 person camp, laydown areas, service complex (e.g., workshop, wash bay, administration buildings, mine dry), two quarries (mill site platform and solid waste landfill), core storage areas, batch plant, brine mixing facilities, vent raise (3), air heating units, reagent storage, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerator, landfarm and handling/temporary hazardous waste storage, explosives magazine, and diesel power plant;
- Doris Mine works and processing: underground portal, overburden stockpile, temporary waste rock pile, ore stockpile, and ore processing plant (mill);
- Tailings Impoundment Area (TIA): Schedule 2 designation for Tail Lake with two dams (North and South dams), sub-aerial deposition of flotation tailings, emergency tailings dump catch basins, pump house, and quarry;
- All-season main road with transport trucks: Roberts Bay to Doris site (4.8 km, 150 to 200 tractor and 300 fuel tanker trucks/year);
- Access roads from Doris site used predominantly by light-duty trucks to: the TIA, the explosives magazine, Doris Lake float plane dock (previously in use), solid waste disposal site, and to the tailings decant pipe,from the Roberts Bay offloading facility to the location where the discharge pipe enters the ocean; and
- All-weather airstrip (914 m), winter airstrip (1,524 m), helicopter landing site and building, and Doris Lake float plane and boat dock.

Water is managed at the Doris Project through:

- freshwater input from Doris Lake for mining, milling, and associated activities and domestic purposes;
- freshwater input from Windy Lake for domestic purposes;
- process water input primarily from the TIA reclaim pond;
- surface mine contact water discharged to the TIA;
- underground mine contact water directed to the TIA or to Roberts Bay via the marine outfall mixing box (MOMB);
- treated waste water discharged to the TIA; and
- water from the TIA treated and discharged to Roberts Bay via a discharge pipeline, with use of a MOMB.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been renewed several times since 1995. The current extension expires in June 2022. Much of the previous work for the program was based out of Windy Lake and Boston camps. These camps were closed in October 2008 with infrastructure either decommissioned or moved to the Doris site. All exploration activities are now based from the Doris site. Components and activities for the Hope Bay Regional Exploration Project include:

- operation of helicopters from Doris; and
- the use of exploration drills, which are periodically moved by roads and by helicopter as required.

Madrid Advanced Exploration

In 2017, the NWB issued a Type B Water Licence (2BB-MAE1727) for the Madrid Advanced Exploration Program to support continued exploration and a bulk sample program at the Madrid North and Madrid South sites, located approximately 4 km south of the Doris site. The program includes extraction of a bulk sample totaling 50 tonnes from each of the Madrid North and South locations, which will be trucked to the mill at the Doris site for processing and placement of tailings in the tailings impoundment area (TIA). All personnel will be housed in the Doris camp.

The Madrid Advanced Exploration Program includes the following components and activities.

- Use of existing infrastructure associated with the Doris Project:
  - camp facilities to support up to 70 personnel as required to undertake the advanced exploration activities;
  - mill to process ore;
  - TIA;
  - landfill and hazardous waste areas, particularly if closure and remediation becomes required for the Madrid Advanced Exploration Program infrastructure;
  - fuel tank farms; and
  - Doris airstrip and Roberts Bay facility for transport of personnel and supplies.
- Use of existing infrastructure at the Madrid and Boston areas:
  - borrow and rock quarry facilities: existing Quarries A, B, and D along the Doris-Windy all-weather road (AWR);
  - AWR between Doris and Windy Lake for transportation of personnel, ore, waste, fuel, and supplies; and
  - future mobilization of existing exploration site infrastructure, should it become necessary.
- Construction of additional facilities at Madrid North and South:
  - access portals and ramps for underground operations at Madrid North and at Madrid South;
  - 4.7 km extension of the existing AWR originating from the Doris to the Windy exploration area (Madrid North) to the Madrid South deposit, with branches to Madrid North, Madrid North vent raise, and the Madrid South portal;
  - development of a winter road route (WRR) from Madrid North to access Madrid South until AWR has been constructed;
  - borrow and rock quarry facilities; two quarries referenced as Quarries G and H;

    - waste rock and ore stockpiles;
    - water and waste management structures; and
    - additional site infrastructure, including compressor building, brine mixing facility, saline storage tank, air heating facility, four vent raises, workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station.
- Undertaking of advanced exploration access to aforementioned deposits through:
    - continue field mapping and sampling, as well as airborne/ground/downhole geophysics;
    - diamond drilling from the surface and underground; and
    - bulk sampling through underground mining methods and mine development.

<u>Boston Advanced Exploration</u>

The Boston Advanced Exploration Project Type B Water Licence No. 2BB-BOS1217 was renewed as Water Licence No. 2BB-BOS1727 in July 2017 and includes:

- the Boston camp (65 person), maintenance shops, workshops, laydown areas, water pumphouse, vent raise, warehouse, site service roads, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, solid waste landfill and a heli-pad;
- mine works, consisting of underground development for exploration drilling and bulk sampling, waste rock and ore stockpiles;
- potable water and industrial water from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

1.4.1.2 The Madrid-Boston Project

The Madrid-Boston Project includes: the Construction and Operation of commercial mining at the Madrid North, Madrid South, and Boston sites; the continued operation of Roberts Bay and the Doris site to support mining at Madrid and Boston; and the Reclamation and Closure and Post-closure phases of all sites. Excluded from the Madrid-Boston Project for the purposes of the assessment are the Reclamation and Closure and Post-closure components of the Doris Project as currently permitted and approved.

<u>Construction</u>

Madrid-Boston construction will use the infrastructure associated with Existing and Approved Projects. This may include:

- an all-weather airstrip at the Boston exploration area and helicopter pad;
- seasonal construction and/or operation of a winter ice strip on Aimaokatalok Lake;
- Boston camp with expected capacity for approximately 65 people during construction
- Quarry D Camp with capacity for up to 180 people;
- seasonal construction/operation of Doris to Boston WRR;
- three existing quarry sites along the Doris to Windy AWR;
- Doris camp with capacity for up to 280 people;
- Doris airstrip, winter ice strip, and helicopter pad;
- Roberts Bay offloading facility and road to Doris; and

- Madrid North and Madrid South sites and access roads.

Additional infrastructure to be constructed for the proposed Madrid-Boston Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, development of a west road to facilitate access, and quarrying, crushing, and screening of aggregate for the construction);
- construction of a cargo dock at Roberts Bay (including a fuel pipeline, mooring points, beach landing and gravel pad, shore manifold);
- construction of an additional tank farm at Roberts Bay (consisting of two 10 ML tanks);
- expansion of Doris accommodation facility (from 280 to 400 person), mine dry and administrative building, water treatment at Doris site;
- expansion of the Doris mill to accommodate concentrate handling on the south end of the building facility and rearrangement of indoor crushing and processing within the mill building;
- complete development of the Madrid North and Madrid South mine workings;
- incremental expansion of infrastructure at Madrid North and Madrid South to accommodate production mining, including vent raise, access road, process plant buildings;
- construction of a 1,200 tpd concentrator, fuel storage, power plant, mill maintenance shop, warehouse/reagent storage at Madrid North;
- all weather access road and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston (approximately 53 km long, nine quarries for permitting purposes, four of which will likely be used);
- all-weather airstrip, airstrip building, helipad and heliport building at Boston;
- construction of a 2,400 tpd process plant at Boston;
- all infrastructure necessary to support mining and processing activities at Boston including construction of a new 300-person accommodation facility, mine office and dry and administration buildings, additional fuel storage, laydown area, ore pad, waste rock pad, diesel power plant and dry-stack tailings management area (TMA);
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston; and
- wind turbines near the Doris (2), Madrid (2), and Boston (2) sites.

<u>Operation</u>

The Madrid-Boston Project Operation phase includes:

- mining of the Madrid North, Madrid South, and Boston deposits by way of underground portals and Crown Pillar Recovery;
- operation of a concentrator at Madrid North;
- transportation of ore from Madrid North, Madrid South, and Boston to the Doris process plant, and transporting the concentrate from the Madrid North concentrator to the Doris process plant;
- extending the operation at Roberts Bay and Doris;

- processing the ore and/or concentrate from Madrid North, Madrid South, and Boston at the Doris process plant with disposal of the detoxified tailings underground at Madrid North, flotation tailings from the Doris process plant pumped to the expanded Doris TIA, and discharge of the TIA effluent to the marine environment;
- operation of a concentrator at Madrid North and disposal of tailings at the Doris TIA;
- operation of a process plant and wastewater treatment plant at Boston with disposal of flotation tailings to the Boston TMA and a portion placed underground and the detoxified leached tailings placed in the underground mine at Boston;
- operation of two wind turbines for power generation; and
- on-going maintenance of transportation infrastructure at all sites (cargo dock, jetty, roads, and quarries).

<u>Reclamation and Closure</u>

Areas which are no longer needed to carry out Madrid-Boston Project activities may be reclaimed during Construction and Operation.

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Chapter 5):

- Camps and associated infrastructure will be disassembled and/or disposed of in approved non-hazardous site landfills.
- Non-hazardous landfills will be progressively covered with quarry rock, as cells are completed. At final closure, the facility will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Rockfill pads occupied by construction camps and associated infrastructure and laydown areas will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Quarries no longer required will be made physically and geotechnically stable by scaling high walls and constructing barrier berms upstream of the high walls.
- Landfarms will be closed by removing and disposing of the liner, and re-grading the berms to ensure the area is physically and geotechnically stable.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered waste rock. Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston AWR and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.
- A low permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached and the liner will be cut to prevent collecting any water. The balance of the berms will be left in place to prevent localized permafrost degradation.

1.4.2 Spatial Boundaries

1.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 1.4-1 and is defined as the area which has the potential for infrastructure to be developed as part of the Madrid-Boston Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for refinement in the final placement of a structure through detailed design and necessary in-field modifications during Construction phase. Areas with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Madrid-Boston Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Chapter 2 (Project Design Considerations).

1.4.2.2 Local Study Area

The Local Study Area (LSA) is shown in Figure 1.4-1 and is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on the freshwater environment due to an interaction with a Project component(s) or physical activity. The LSA includes the watersheds for key waterbodies that have a potential for interaction with the Project. The same LSA was used for the freshwater water quality and fish and fish habitat VECs.

1.4.2.3 Regional Study Area

The Regional Study Area (RSA) is shown in Figure 1.4-1 and is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur. The RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA for the surface hydrology VEC includes portions of the Angimajuq watershed and sections of the Koignuk River watershed located to the west of the PDA, and is the same used for the freshwater water quality and fish and fish habitat VECs.

1.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, the Madrid-Boson Project is a continuation of development currently underway. The Project has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston. The development of these sites is planned to be sequential. As such, the temporal boundaries of this Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 1.4-1). It is understood that Construction, Operation and Closure activities will, in fact, overlap among sites; this is outlined in Table 1.4-1 and further described in Volume 3, Chapter 2 (Project Design Considerations).

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, the Project would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (one to two year duration would be typical).

Figure 1.4-1
Project Development Area, Local Study Area, and Regional Study Area for Surface Hydrology

Table 1.4-1. Temporal Boundaries for the Effects Assessment for Surface Hydrology

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 - 4	2019 - 2022	4	• **Roberts Bay:** construction of access road (Year 1), marine dock and additional fuel facilities (Year 2 – Year 3); • **Doris**: expansion of the Doris TIA and accommodation facility (Year 1); • **Madrid North:** construction of concentrator and road to Doris TIA (Year 1 – Year 2); • **All-weather Road**: construction (Year 1 – Year 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5).
Operation	5 - 14	2023 - 2032	10	• **Roberts Bay**: shipping operations (Year 1 – Year 14) • **Doris**: processing and infrastructure use (Year 1 – Year 14); • **Madrid North:** mining (Year 1 – 13); ore transport to Doris process plant (Year 1 -13); ore processing and concentrate transport to Doris process plant (Year 2 – Year 13); • **Madrid South:** mining (Year 11 – Year 14); ore transport to Doris process plant (Year 11 – Year 14); • **All-weather Road**: operational (Year 4 – Year 14); • **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 11); ore transport to Doris process plant (Year 4 – Year 6); and processing ore (Year 5 – Year 11).
Reclamation and Closure	15 - 17	2033 - 2035	3	• **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17); • **Doris**: camp and facilities will be operational during closure (Year 15 – Year 17); mine, process plant, and TIA decommissioning (Year 15 – Year 17); • **Madrid North:** all components decommissioned (Year 15 – Year 17); • **Madrid South:** all components decommissioned (Year 15 – Year 17); • **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 – Year 17).
Post-Closure	18 - 22	2036 - 2040	5	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

1.5 PROJECT-RELATED EFFECTS ASSESSMENT

1.5.1 Methodology Overview

This assessment was informed by a methodology used to identify and assess the potential environmental effects of the Project and is consistent with the requirements of Section 12.5.2 of the Nunavut Agreement and the EIS Guidelines. The effects assessment evaluates the potential direct and indirect effects of the Project on the environment and follows the general methodology provided in Volume 2, Chapter 4 (Effects Assessment Methodology), and comprises a number of steps that collectively assess the manner in which the Project will interact with the surface hydrology VEC defined for the assessment (Section 1.3).

To provide a comprehensive understanding of the potential effects for the Project, components and activities of the Madrid-Boston Project are assessed on their own as well as in the context of the Approved Projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Madrid-Boston Project and the VECs or VSECs;

Identify the resulting potential effects of those interactions;

Identify mitigation or management measures to eliminate or reduce the potential effects;

Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for the Madrid-Boston Project in isolation;

Identify residual effects of the Madrid-Boston Project in combination with the residual effects of Approved Projects; and

2. Determine the significance of combined residual effects.

After the identification of potential interactions effects (Steps 1; Section 1.5.2), mitigation and management measures were considered (Step 2, Section 1.5.3). Alteration of streamflow was used as an indicator for assessment of the potential effects of the Project on surface hydrology. Streamflow predictions of a water balance model (P5-4) were used to quantify the potential effects of the Project on surface hydrology (Steps 3 and 4; Section 1.5.4). If results of Steps 3 and 4 predicted residual effects on surface hydrology, such effects were characterized in terms of *direction*, *magnitude*, *duration*, *frequency*, *geographic extent*, and *reversibility*, (Step 5, Section 1.5.5), and the significance of residual effects was determined (Step 6, Section 1.5.5).

1.5.2 Identification of Potential Effects

The Project has the potential to interact with surface hydrology through a number of activities and pathways. Project activities that have the potential to interact with surface hydrology and alter baseline streamflows were identified and shown in Table 1.5-1. These components were judged to have probable or likely interactions with surface hydrology, and this screening step did not consider application of mitigation and management measures. These interactions can cause the following potential effects on surface hydrology:

- *Alteration of streamflow in Doris Watershed*: Streamflow at assessment nodes Wolverine Lake Outflow, Patch Lake Outflow, PO Lake Outflow, Ogama Lake Outflow, Doris Lake Outflow, and Little Roberts Lake Outflow are considered in the Doris Watershed (Figure 1.2-5) category for the purpose of this effects assessment.

- *Alteration of streamflow in Windy Watershed*: Streamflow at assessment nodes Windy Lake Outflow and Glenn Lake Outflow are considered in the Windy Watershed (Figure 1.2-5) category for the purpose of this effects assessment.
- *Alteration of streamflow in Aimaokatalok Watershed*: Streamflow at assessment nodes Trout Lake Outflow, Stickleback Lake Outflow, Aimaokatalok Lake Outflow, Koignuk River 1, and Koignuk River 2 are considered in the Aimaokatalok Watershed (Figure 1.2-5) category for the purpose of this effects assessment.

The activities that have the potential to interact with surface hydrology (Table 1.5-1) can be grouped into the following three broad categories:

1. *Water withdrawal from lakes*: Water withdrawal from Doris, Windy, and Aimaokatalok lakes for domestic and industrial uses could affect lake outflows by lowering the water level in these lakes. Therefore, streamflows at Doris, Windy, and Aimaokatalok watersheds can be affected.

Construction and use of underground mines: Doris, Madrid North, and Madrid South mines are expected to intercept taliks (P5-4). Water level in lakes can drawdown through taliks and, therefore, streamflows at Doris and Windy watersheds can be affected.

Modification of natural drainages: Contact water diversion and discharge (e.g., water transfer to, and discharge from, the TIA), modification of runoff coefficient at disturbed surfaces (e.g., stockpiles), and access roads where crossings are not sized to pass natural flows could affect drainage pathways. Therefore, these activities have the potential to alter streamflows at Doris, Windy, and Aimaokatalok watersheds.

The water balance model (P5-4) collectively characterized the potential effects of all these activities on surface hydrology.

Table 1.5-1. Project Interaction with Surface Hydrology VEC

	Surface Hydrology		
Project Component/Activity	**Alteration of Doris Watershed Streamflows**	**Alteration of Windy Watershed Streamflows**	**Alteration of Aimaokatalok Watershed Streamflows**
Roberts Bay			
Construction and Operation - use of existing approved and permitted infrastructure			
Marine discharge for TIA water	X		
Roberts Bay - Doris road use and maintenance	X		
Site roads use and maintenance	X		
Water management system	X	X	X
Reclamation and Closure - use of existing approved and permitted infrastructure			
Site surface infrastructure	X		
Roberts Bay - Doris road	X		
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Site surface infrastructure	X		

Project Component/Activity	Surface Hydrology: Alteration of Doris Watershed Streamflows	Alteration of Windy Watershed Streamflows	Alteration of Aimaokatalok Watershed Streamflows
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring	X		
Doris			
Construction - proposed Madrid-Boston infrastructure			
Expansion of accommodations	X		
Raising the TIA South Dam	X		
TIA West Dam	X		
Expansion to water treatment plant	X		
Operation - use of existing approved and permitted infrastructure			
Accommodations	X	X	
Accommodations facilities (sewage treatment facilities, potable water treatment, fire suppression)	X	X	
Mill	X		
Ore stockpile	X		
Site roads use and maintenance	X		
Water discharge to the receiving environment	X		
Water management system	X		
Water use from Doris Lake	X		
Water use from Windy Lake		X	
Operation - proposed Madrid-Boston infrastructure			
Accommodations (expanded)	X	X	
TIA road use and maintenance	X		
TIA storage	X		
Reclamation and Closure - use of existing approved and permitted infrastructure			
Site surface and mining infrastructure	X		
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Accommodations (expanded)	X	X	
TIA roads (perimeter and South Dam)	X		
TIA	X		
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring	X		
Madrid North			
Construction - use of existing approved and permitted infrastructure			
Site roads	X	X	
Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)	X	X	

Project Component/Activity	Surface Hydrology: Alteration of Doris Watershed Streamflows	Surface Hydrology: Alteration of Windy Watershed Streamflows	Surface Hydrology: Alteration of Aimaokatalok Watershed Streamflows
Underground mine (drilling, blasting, excavation, ventilation)	X	X	
Waste rock pile	X	X	
Water management system	X	X	
Construction - proposed Madrid-Boston infrastructure			
Expansion of site pad (waste rock stockpile)	X	X	
Water discharge to the receiving environment	X	X	
Water management system (including expanded CWP)	X	X	
Operation - use of existing approved and permitted infrastructure			
Doris - Madrid road use and maintenance	X	X	
Madrid North access road use and maintenance	X	X	
Ore stockpile	X	X	
Site roads use and maintenance	X	X	
Waste rock pile	X	X	
Water Management System	X	X	
Operation - proposed Madrid-Boston infrastructure			
Water discharge to the receiving environment	X	X	
Water management system (including CWP)	X	X	
Domestic water trucked from existing water intake location	X	X	
Mine water trucked to Doris mixing box	X	X	
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Inter-site roads	X	X	
Site surface and mining infrastructure	X	X	
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring	X	X	
Madrid South			
Construction - use of existing approved and permitted infrastructure			
Site roads	X	X	
Water management system	X	X	
Construction - proposed Madrid-Boston infrastructure			
Water discharge to the receiving environment	X	X	
Water management system (including expanded CWP)	X	X	
Operation - use of existing approved and permitted infrastructure			
Doris - Madrid road use and maintenance	X	X	
Ore stockpile	X	X	
Site roads use and maintenance	X	X	

Project Component/Activity	Surface Hydrology: Alteration of Doris Watershed Streamflows	Surface Hydrology: Alteration of Windy Watershed Streamflows	Surface Hydrology: Alteration of Aimaokatalok Watershed Streamflows
Underground mine (drilling, blasting, excavation, ventilation)	X	X	
Waste rock pile	X	X	
Water management system - Type B licence	X	X	
Operation - proposed Madrid-Boston infrastructure			
Water discharge to the receiving environment	X	X	
Water management system (including CWP)	X	X	
Domestic water trucked from existing water intake location	X	X	
Mine water trucked to Doris mixing box	X	X	
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Inter-site roads	X	X	
Site surface and mining infrastructure	X	X	
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring	X	X	
Madrid-Boston All-Weather Road			
Construction - use of existing approved and permitted infrastructure			
Madrid-Boston winter road	X	X	X
Construction - proposed Madrid-Boston infrastructure			
All weather road (grading, backfill, excavation, drainage)	X	X	X
Water crossings	X	X	X
Operation - use of existing approved and permitted infrastructure			
Madrid-Boston winter road	X	X	X
Operation - proposed Madrid-Boston infrastructure			
All weather road use and maintenance	X	X	X
Water crossings	X	X	X
Reclamation and Closure - use of existing approved and permitted infrastructure			
Madrid-Boston winter road	X	X	X
Construction accommodations	X	X	X
Reclamation and Closure - proposed Madrid-Boston infrastructure			
All-weather road, quarries and associated infrastructure	X	X	X
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring	X	X	X
Boston			
Construction - use of existing approved and permitted infrastructure			
Accommodations			X
Construction - proposed Madrid-Boston infrastructure			

Project Component/Activity	Surface Hydrology: Alteration of Doris Watershed Streamflows	Surface Hydrology: Alteration of Windy Watershed Streamflows	Surface Hydrology: Alteration of Aimaokatalok Watershed Streamflows
Accommodations(sewage treatment facilities, potable water treatment, fire suppression)			X
Ore stockpile			X
Overburden pile			X
Site roads			X
Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility)			X
Underground mine (drilling, blasting, excavation, ventilation)			X
Waste rock pad and pile			X
Water discharge to the environment			X
Water management system			X
Water use from Aimaokatalok Lake			X
Dry-stack TMA			X
TMA roads			X
TMA water management system			X
Operation - proposed Madrid-Boston infrastructure			
Camp (sewage treatment facilities, potable water treatment, fire suppression)			X
Ore stockpile			X
Overburden pile			X
Site roads and maintenance			X
Underground mine (drilling, blasting, excavation, ventilation)			X
Waste rock pile			X
Water discharge to the environment			X
Water use from Aimaokatalok Lake			X
Water management system			X
Dry-stack TMA			X
TMA roads use and maintenance			X
TMA water management system			X
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Site surface and mining infrastructure			X
TMA and associated infrastructure			X
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring			X
Boston Airstrip			
Construction - proposed Madrid-Boston infrastructure			
Access road			X

	Surface Hydrology		
Project Component/Activity	**Alteration of Doris Watershed Streamflows**	**Alteration of Windy Watershed Streamflows**	**Alteration of Aimaokatalok Watershed Streamflows**
Airstrip and lighting			X
Operation - proposed Madrid-Boston infrastructure			
Access road use and maintenance			X
Reclamation and Closure - proposed Madrid-Boston infrastructure			
Site surface infrastructure			X
Post Closure - proposed Madrid-Boston infrastructure			
Post closure monitoring			X

Notes:
X= interaction
Blank = no interaction

1.5.3 Mitigation and Adaptive Management

1.5.3.1 Mitigation by Project Design

Mitigation measures, considered in the design of the project to minimize or eliminate potential effects of the Madrid-Boston Project on surface hydrology, include:

- Mine areas are constructed to minimize contact water. Facilities are designed with consideration of footprint minimization and are located, where possible, in areas of reduced runoff. Where necessary, runoff is diverted upstream of mine areas to further reduce the amount of contact water created.
- Contact water pond storage capacity, freshet flows, and expected storm event volumes are determined based on site-specific conditions. The sizing and design of these facilities is such that they can hold water during unusual storm events and contain freshet flows for prescribed periods.
- The TIA has been designed with substantial additional capacity to store both natural and Project-related inputs in exceedance of routinely expected volumes. The TIA will routinely be operated at a water level that provides availability of contingency capacity.
- Existing infrastructure associated with the Doris Project will be used to minimize the footprint of the Madrid-Boston Project.
- Climate change projections for key climatic and hydrologic design details have been considered.
- Routes of roads and pipelines have been minimized, and routing has been made as far as is practical from stream channel crossings and wet, boggy areas where fish habitat may be disturbed.
- Erosion potential will be reduced by working during periods of low runoff (e.g., winter) as much as possible.
- Water will be recycled and reused where possible.

The design of the Madrid-Boston Project also included adherence to regulatory requirements and guidelines relevant to the mitigation of potential effects on surface hydrology. These regulatory requirements included the following:

- Culvert maintenance will be conducted following the guidance provided in *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016), which adheres to the *Fisheries Act (1985)*.
- In-water work will be conducted during approved timing windows presented in *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat* (DFO 2013a).
- Water withdrawal will follow permit conditions.

1.5.3.2 Best Management Practices

Avoidance is an effective mitigation measure to reduce the potential effects on surface hydrology. Best management practices are described in relevant management plans provided in Volume 1, Annex V1-7. Management plans directly relevant to surface hydrology include:

- Doris Project Domestic Wastewater Treatment Management Plan (Package P4-4);
- Hope Bay Project Boston Sewage Treatment Operations and Maintenance Management Plan (P4-5);
- Hope Bay Project Groundwater Management Plan (P4-6);
- Hope Bay Project Doris-Madrid Water Management Plan (P4-7);
- Hope Bay Project Boston Water Management Plan (P4-8);
- Hope Bay Project Doris-Madrid Tailings Impoundment Area Operations, Maintenance, and Surveillance Manual (P4-9);
- Water and Ore/Waste Rock Management Plan (P4-11);
- Hope Bay Project Aquatic Effects Monitoring Plan (P4-18);
- Hope Bay Project Boston Conceptual Closure and Reclamation Plan (P4-19); and
- Hope Bay Project Doris-Madrid Interim Closure and Reclamation Plan (P4-21).

Mitigation and management measures relevant to surface hydrology include the following:

- Water collected in the contact water ponds will be routinely discharged to the TIA or tundra (where permitted and in compliance with discharge requirements), to retain maximum pond holding capacity and reduce the possibility of unintentional releases.
- Ponds will be routinely monitored and water will be pumped out of them as soon as the volume they contain is large enough for continuous pumping.
- Where possible, groundwater will be utilized during underground drilling to reduce fresh water and salt consumption, and to minimize groundwater discharge volumes.
- Sediment control measures, such as use of silt fences, will be implemented for works in or near waterbodies and watercourses.
- Erosion control measures, such as capping of soils exposed during construction activities with rock, will be implemented where necessary.
- Seepage and runoff from waste rock and ore stockpiles will be directed to contact water ponds.

- o Non-contact water will be diverted around infrastructure, as much as feasible, and directed to the existing drainage networks.
- o Groundwater will be collected in mine sumps and may be stored temporarily in the mine, and either pumped to the MOMB located in the mill building and discharged to Roberts Bay or transferred to the TIA. Discharge to Roberts Bay or the TIA may occur year round.
- o Exploration drilling water will be recycled to minimize the quantity of freshwater used, and to reduce salt use.
- o Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016);
- o During temporary closure the following will take place to protect freshwater water quantity:
  - Waste rock and ore piles and tailings facilities as well as dams, roads and pipelines will be inspected and maintained.
  - Surface water management and sediment and erosion control will continue as needed.
- o During Closure the TIA North Dam will be breached to restore natural drainage.
- o During Closure a low infiltration cover will be placed over the dry stack tailings in the Boston TMA. Once the cover is in place, the contact water pond berm will be breached to restore natural drainage. The remainder of the berms will stay in place in order to preserve the permafrost. The closure plan for the Boston TMA will be refined through the operations period through monitoring of water quality in the contact water ponds and updating water quality predictions.

1.5.3.3 Proposed Monitoring Plans and Adaptive Management

Water monitoring programs, described in Packages P4-7 and P4-8, will be undertaken to:

- o Comply with monitoring requirements outlined in applicable water licences and project certificates;
- o Ensure water being discharged to the environment meets the appropriate discharge limits;
- o Ensure points of discharge to tundra are not negatively affected by pooling water or erosion; and
- o Ensure tracking of water movement and volumes.

Routine visual inspections of all water management structures will be completed to determine whether the facilities are operating as designed and to assess maintenance requirements. Facility inspections are carried out following significant rain events and throughout freshet (P4-7 and P4-8). In addition, daily inspection of all pads and dykes located throughout the bulk sample infrastructure will be completed.

Adaptive management will be determined on a case-by-case basis. Management activities may include modifications to existing mitigation and management measures or installation of additional control measures.

1.5.4 Characterization of Potential Effects

Project residual effects are the effects that are remaining after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, the effect is eliminated from further analyses.

If the proposed mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and significance determination. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project-environment interactions between Project activities and components and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

Results of the water balance model (P5-4) include streamflow predictions at 13 assessment nodes during different phases of the Project (Appendix V5-1P), as well as lake elevation and volume predictions at nine lakes during different phases of the Project (Appendices V5-1Q and V5-1R). While streamflow predictions (Appendix V5-1P) are directly used in this section to assess streamflow alterations, lake elevation and volume predictions (Appendices V5-1Q and V5-1R) inform other effects assessment sections (e.g., fish habitat effect assessment in Volume 5, Chapter 6).

Streamflow prediction of the water balance model show that none of the three potential effects identified in Section 1.5.2 will be fully eliminated after implementation of mitigation measures (Section 1.5.3). Therefore, the following three potential effects are identified as residual effects and carried forward for additional characterization:

- *Alteration of streamflow in Doris Watershed;*
- *Alteration of streamflow in Windy Watershed;* and
- *Alteration of streamflow in Aimaokatalok Watershed.*

Assessment of the Madrid-Boston Project potential effects in isolation of existing and permitted projects would include comparison of project-affected flows during the Construction, Operation, Closure, and Post-closure phases of the Madrid-Boston Project, with flows before Construction of the Madrid-Boston Project (hereafter refer to as Year 0). It is noted that streamflows in Year 0 are not pre-development natural flows since these flows include the predicted effects of the Doris Project.

In contrast, assessment of the Madrid-Boston Project potential effects in combination with existing and permitted projects included comparison of project-affected flows during the Construction, Operation, Closure, and Post-closure phases of the Madrid-Boston Project (Appendix V5-1P), with baseline flow projections without any development (Appendix V5-1M).

Assessment of the Madrid-Boston Project in combination with existing and permitted projects results in higher streamflow effects than those of the Madrid-Boston Project in isolation of existing and permitted projects (Table 1.5-2). Therefore, for the purpose of surface hydrology effects assessment, characterization of potential effects and the significance determination are based on the Madrid-Boston Project in combination with existing and permitted projects relative to baseline flow projections. These effects, summarized in Appendix V5-1S and described in the following sections, are referred to as effects of the Hope Bay Project hereafter. This effect assessment provides conservative estimates for the Madrid-Boston Project in isolation of existing and permitted projects. This is consistent with the natural flow regime paradigm (Poff et al. 2010) and best practices for hydrologic effects assessments.

The water balance model (P5-4) also includes a sensitivity case for higher than expected groundwater inflows into underground mines. Results of this sensitivity case are summarized in Appendix V5-1T.

Table 1.5-2. Comparison of Project Effects on Surface Hydrology between the Madrid-Boston Project in Isolation of, and Hope Bay Project (Madrid-Boston Project in Combination with, Existing and Approved Projects)

	Annual Flow Predictions			Change in Annual Flow (averaged over life of Project)	
Surface Hydrology Assessment Node	Baseline Flows (averaged over life of Project) (m^3/s)	Flow in Year 01 (m^3/s)	Hope Bay Project-Affected Flows (averaged over life of Project) (m^3/s)	Madrid-Boston Project in Isolation of Existing and Approved Projects Flow Change (% Year 0 flow)	Hope Bay Project Flow Change (% of baseline)
Doris Watershed					
Wolverine Lake Outflow	0.0043	0.0043	0.0039	**-10.0%**	**-9.2%**
Patch Lake Outflow	0.075	0.074	0.068	**-7.1%**	**-8.6%**
PO Lake Outflow	0.090	0.089	0.084	**-5.6%**	**-7.1%**
Ogama Lake Outflow	0.242	0.237	0.235	**-0.8%**	**-2.6%**
Doris Lake Outflow	0.294	0.250	0.254	**1.5%**	**-13.7%**
Little Roberts Outflow	1.003	0.906	0.922	**1.8%**	**-8.0%**
Windy Watershed					
Windy Lake Outflow	0.026	0.024	0.025	**2.4%**	**-5.4%**
Glenn Lake Outflow	0.090	0.087	0.089	**2.0%**	**-1.6%**
Aimaokatalok Watershed					
Trout Lake Outflow	0.118	0.115	0.118	**2.4%**	**0.0%**
Stickleback Lake Outflow	0.0039	0.0038	0.0036	**-3.0%**	**-6.1%**
Aimaokatalok Outflow	4.532	4.421	4.527	**2.4%**	**-0.1%**
Koignuk River 1	5.177	5.051	5.172	**2.4%**	**-0.1%**
Koignuk River 2	7.701	7.515	7.696	**2.4%**	**-0.1%**

[1] *Year 0 is one year before Construction of Madrid-Boston Project commences.*

Streamflow Alteration in Doris Watershed

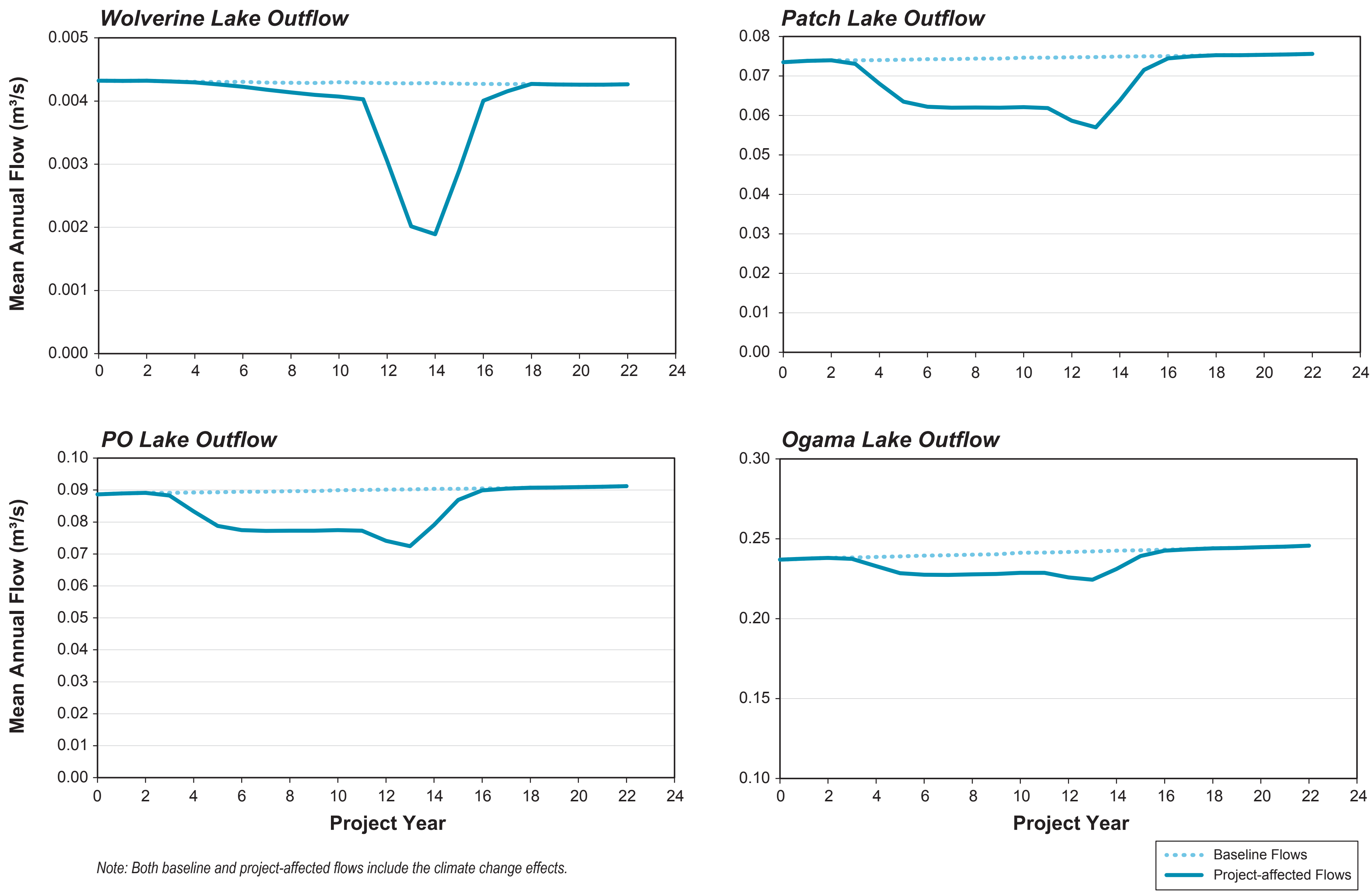
Effects of the Hope Bay Project on annual flow in Doris Watershed assessment nodes, including average annual effects as well as maximum annual effects during the life of the Madrid-Boston Project, under the average, dry, and wet climate conditions, are shown in Table 1.5-3. Figure 1.5-1 shows the inter-annual variation of annual effects.

Maximum flow reductions in all Doris Watershed nodes occur in the last years of Operation (Figures 1.5-1a and 1.5-1b). For example, annual Doris Lake Outflow is, on average, reduced by 13.7% during the life of Madrid-Boston Project, while the maximum annual flow reduction is 31.9% in two years during late Operation (Table 1.5-3 and Figure 1.5-1b). Percent flow reductions during dry (and wet) years are higher (and lower) than normal years (Table 1.5-3).

Average annual streamflow at Little Roberts Lake Outflow (i.e., the LSA Outflow) is reduced 8% from baseline. This is less than 10% flow reduction, which is generally assumed to be the natural variability of riverine systems (DFO 2013b). Exceedance curves for flow reductions at Doris Lake and Little Roberts lakes are provided (Figure 1.5-2) to support the assessment of effects of alteration in streamflow on freshwater fish VECs (Volume 5, Chapter 6).

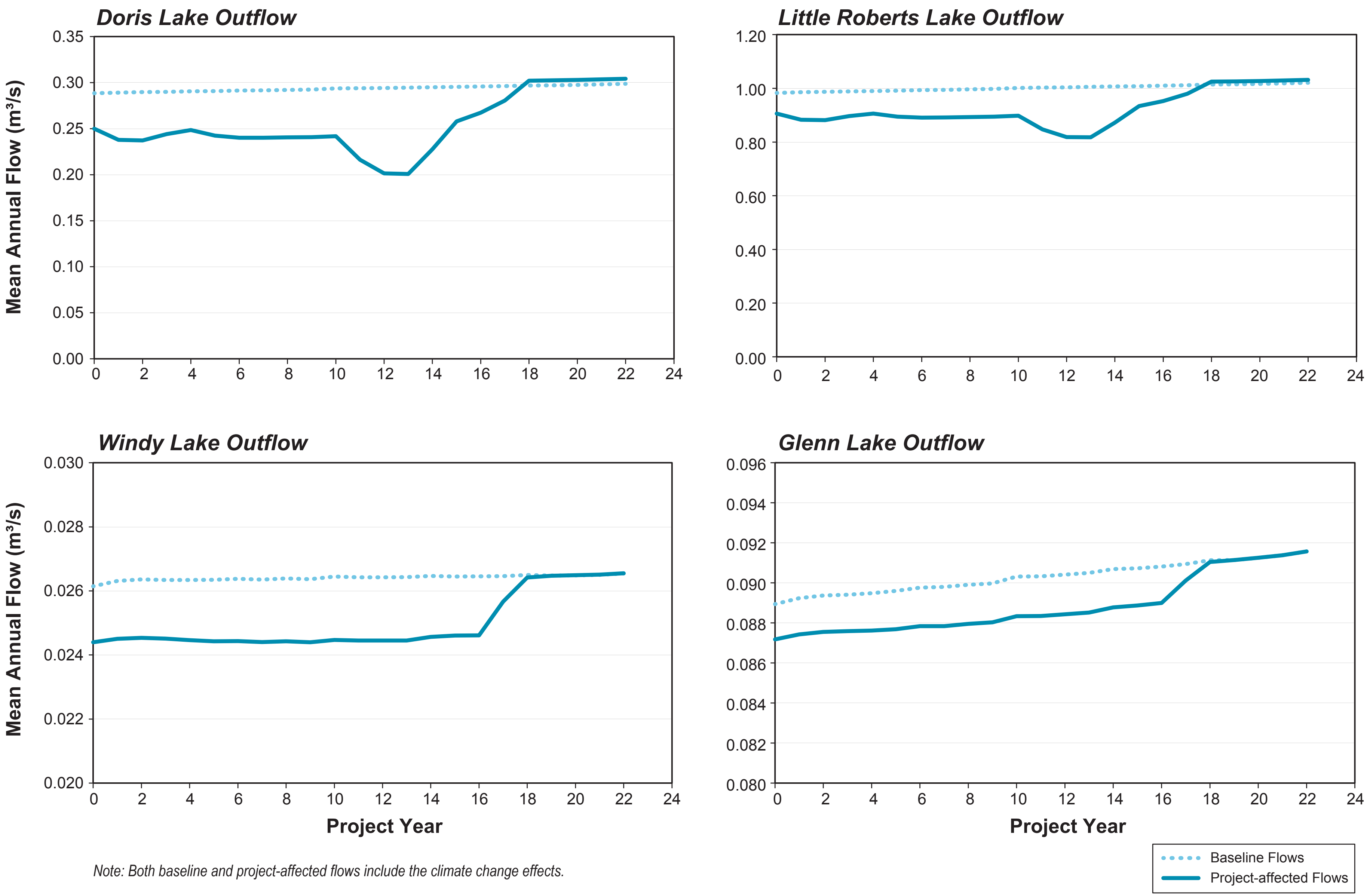
Effects of the Hope Bay Project on monthly flow in Doris Watershed assessment nodes, during project years with maximum flow reduction compared to baseline conditions, are shown in Table 1.5-6 to 1.5-11.

Figure 1.5-1a
Baseline and Project-affected Annual Flows



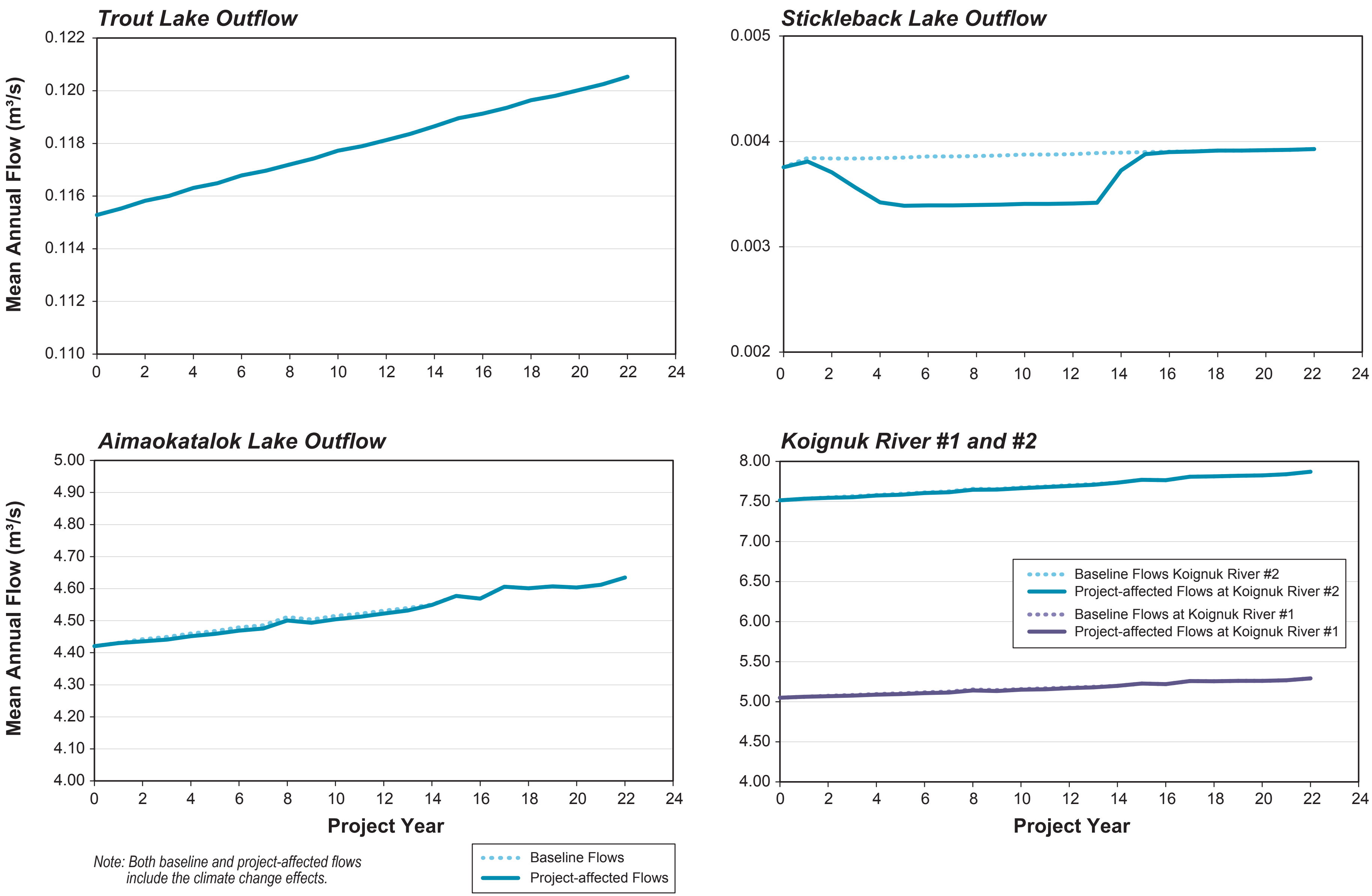
Note: Both baseline and project-affected flows include the climate change effects.

Figure 1.5-1b
Baseline and Project-affected Annual Flows



Note: Both baseline and project-affected flows include the climate change effects.

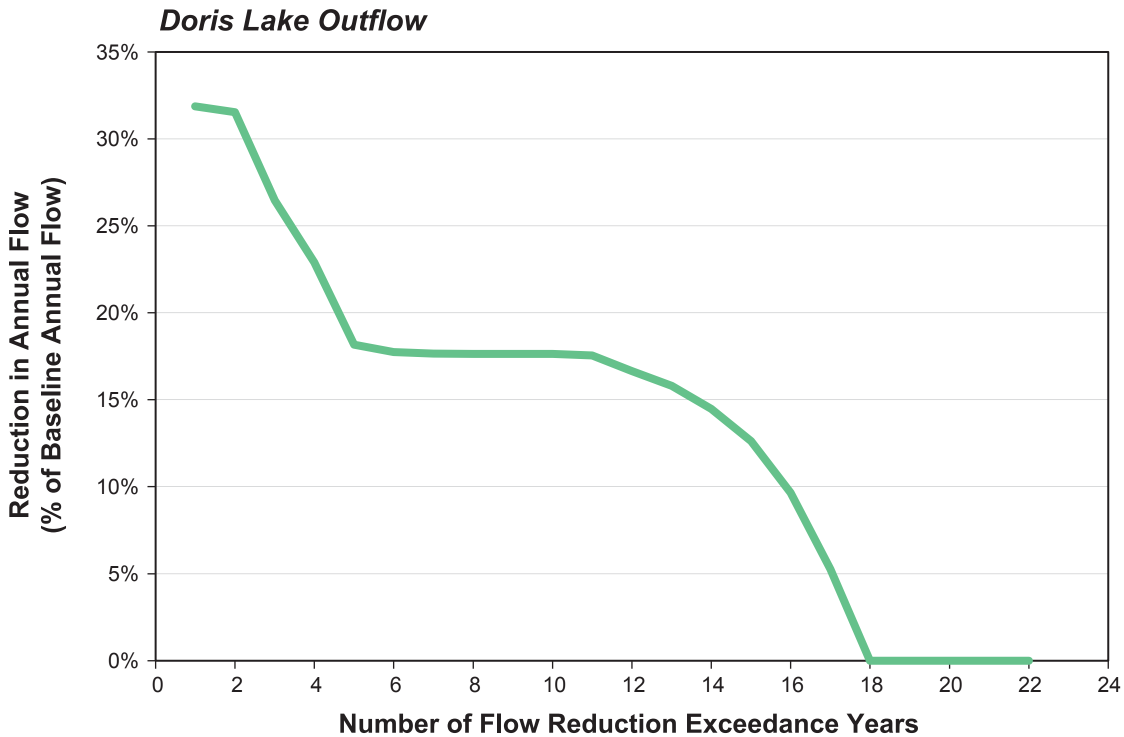
Figure 1.5-1c
Baseline and Project-affected Annual Flows



Note: Both baseline and project-affected flows include the climate change effects.

Figure 1.5-2

Exceedance Curve for Annual Flow Reduction at Doris Lake Outflow and Little Roberts Lake Outflow



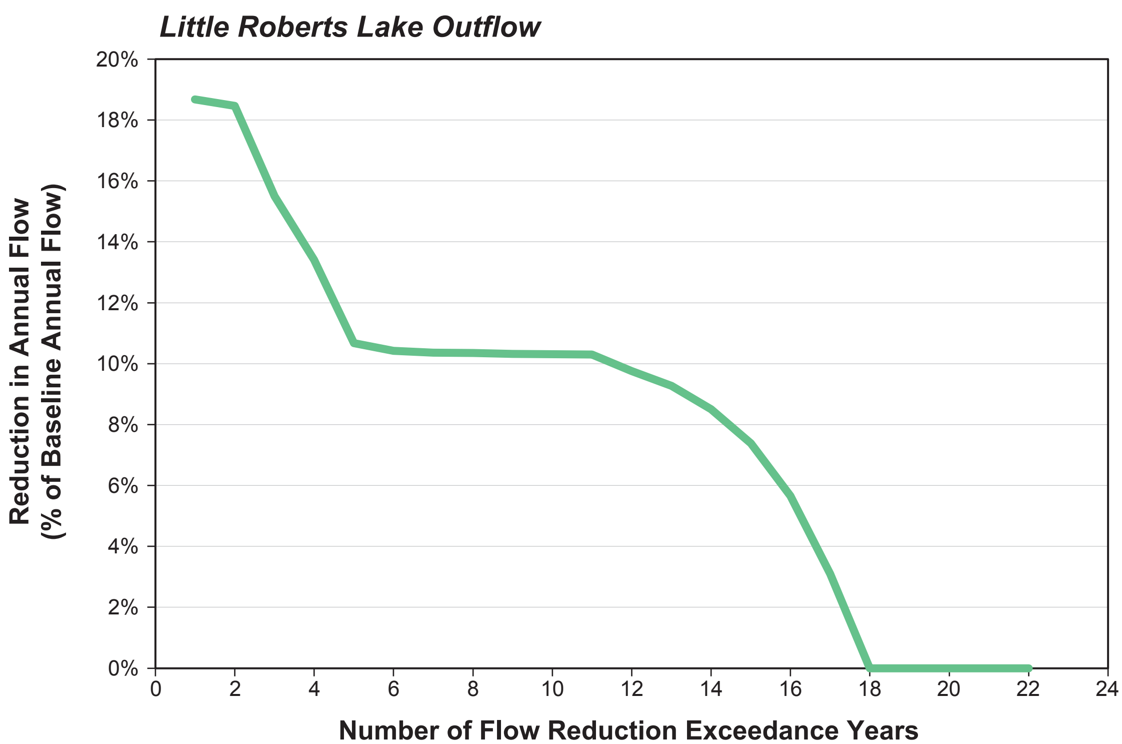


Table 1.5-3. Baseline and Project-affected Annual Flows at Doris Watershed Assessment Nodes during the Life of Project (Average of Years 1 to 22)

Surface Hydrology Assessment Node	Climate Condition	Average Annual Flows during All Project Phases: Baseline flows[1] (m^3/s)	Project-affected Flows[2] (m^3/s)	(% of annual baseline flow)	Maximum Change in Annual Flow (all project phases) (% of annual baseline flow)
Wolverine Lake Outflow	Average	0.0043	0.0039	**-9.2%**	-55.9%
	Dry[3]	0.0000	0.0000	**n/a**	n/a
	Wet[4]	0.0155	0.0148	**-4.8%**	-29.1%
Patch Lake Outflow	Average	0.075	0.068	**-8.6%**	-23.8%
	Dry[3]	0.041	0.036	**-12.4%**	-32.9%
	Wet[4]	0.138	0.130	**-5.8%**	-16.3%
PO Lake Outflow	Average	0.090	0.084	**-7.1%**	-19.7%
	Dry[3]	0.050	0.045	**-10.0%**	-27.0%
	Wet[4]	0.169	0.161	**-4.7%**	-13.3%
Ogama Lake Outflow	Average	0.242	0.235	**-2.6%**	-7.3%
	Dry[3]	0.108	0.103	**-4.9%**	-12.8%
	Wet[4]	0.495	0.486	**-1.8%**	-4.8%
Doris Lake Outflow	Average	0.294	0.254	**-13.7%**	-31.9%
	Dry[3]	0.128	0.110	**-14.4%**	-38.9%
	Wet[4]	0.605	0.533	**-11.9%**	-29.0%
Little Roberts Outflow	Average	1.003	0.922	**-8.0%**	-18.7%
	Dry[3]	0.370	0.339	**-8.3%**	-19.8%
	Wet[4]	2.038	1.904	**-6.6%**	-15.1%

[1] *Average of simulated baseline flows during the life of Project (i.e., Years 1 to 22) including climate change effects*
[2] *Average of predicted project-affected flows during the life of Project (i.e., Years 1 to 22) including climate change effects*
[3] *1-in-20-Year Dry Condition*
[4] *1-in-20-Year Wet Condition*

Streamflow Alteration in Windy Watershed

Effects of the Hope Bay Project on annual flow in Windy Watershed assessment nodes, including average annual effects as well as maximum annual effects during the life of the Madrid-Boston Project, under the average, dry, and wet climate conditions, are shown in Table 1.5-4. Average annual flow reduction in Windy Watershed nodes under average climate conditions are less than 10% (Table 1.5-4). Percent flow reductions during dry (and wet) years are higher (and lower) than normal years (Table 1.5-4).

Effects of the Hope Bay Project on monthly flow in Windy Watershed assessment nodes, during project years with maximum flow reduction compared to baseline conditions, are shown in Table 1.5-12 to 1.5-13.

Streamflow Alteration in Aimaokatalok Watershed

Effects of the Hope Bay Project on annual flow in Aimaokatalok Watershed assessment nodes, including average annual effects as well as maximum annual effects during the life of the Madrid-Boston Project, under the average, dry, and wet climate conditions, are shown in Table 1.5-5. Average annual flow reduction in Aimaokatalok Watershed nodes under average, dry, and wet climate conditions are less than 10% (Table 1.5-5).

Table 1.5-4. Baseline and Project-affected Annual Flows at Windy Watershed Assessment Nodes during the Life of Project (Average of Years 1 to 22)

Surface Hydrology Assessment Node	Climate Condition	Average Annual Flows during All Project Phases: Baseline flows[1] (m^3/s)	Project-affected flows[2] (m^3/s)	(% of annual baseline flow)	Maximum Change in Annual Flow (all project phases) (% of annual baseline flow)
Windy Lake Outflow	Average	0.026	0.025	**-5.4%**	-7.5%
	Dry[3]	0.010	0.009	**-10.2%**	-14.4%
	Wet[4]	0.057	0.055	**-3.1%**	-4.7%
Glenn Lake Outflow	Average	0.090	0.089	**-1.6%**	-2.2%
	Dry[3]	0.015	0.014	**-7.2%**	-15.7%
	Wet[4]	0.208	0.206	**-0.9%**	-1.3%

[1] Average of simulated baseline flows during the life of Project (i.e., Years 1 to 22) including climate change effects
[2] Average of predicted project-affected flows during the life of Project (i.e., Years 1 to 22) including climate change effects
[3] 1-in-20-Year Dry Condition
[4] 1-in-20-Year Wet Condition

Table 1.5-5. Baseline and Project-affected Annual Flows at Aimaokatalok Watershed Assessment Nodes during the Life of Project (Average of Years 1 to 22)

Surface Hydrology Assessment Node	Climate Condition	Average Annual Flows during All Project Phases: Baseline flows[1] (m^3/s)	Project-affected flows[2] (m^3/s)	(% of annual baseline flow)	Maximum change in annual flow (all project phases) (% of annual baseline flow)
Trout Lake Outflow	Average	0.118	0.118	**0.0%**	0.0%
	Dry[3]	0.017	0.017	**0.0%**	0.0%
	Wet[4]	0.264	0.264	**0.0%**	0.0%
Stickleback Lake Outflow	Average	0.0039	0.0036	**-6.1%**	-12.1%
	Dry[3]	0.0011	0.0010	**-10.9%**	-23.5%
	Wet[4]	0.0090	0.0086	**-4.1%**	-8.8%
Aimaokatalok Outflow	Average	4.532	4.527	**-0.1%**	-0.2%
	Dry[3]	1.644	1.641	**-0.2%**	-0.3%
	Wet[4]	9.202	9.195	**-0.1%**	-0.2%
Koignuk River 1	Average	5.177	5.172	**-0.1%**	-0.2%
	Dry[3]	1.796	1.794	**-0.1%**	-0.3%
	Wet[4]	10.464	10.457	**-0.1%**	-0.2%
Koignuk River 2	Average	7.701	7.696	**-0.1%**	-0.1%
	Dry[3]	2.357	2.354	**-0.1%**	-0.2%
	Wet[4]	15.632	15.626	**0.0%**	-0.1%

[1] Average of simulated baseline flows during the life of Project (i.e., Years 1 to 22) including climate change effects.
[2] Average of predicted project-affected flows during the life of Project (i.e., Years 1 to 22) including climate change effects
[3] 1-in-20-Year Dry Condition
[4] 1-in-20-Year Wet Condition

Effects of the Hope Bay Project on monthly flow in Aimaokatalok Watershed assessment nodes, during project years with maximum flow reduction compared to baseline conditions, are shown in Table 1.5-14 to 1.5-18.

Table 1.5-6. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Wolverine Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.053	0	0	0	0	0	0	**0.004**
Baseline 22[b]		22	0	0	0	0	0	0.052	0	0	0	0	0	0	**0.004**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.053	0	0	0	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.052	0	0	0	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.2%	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	**-0.2%**
Operation[f]	Flow (m^3/s)	14	0	0	0	0	0	0.023	0	0	0	0	0	0	**0.002**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-55.9%	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	**-55.9%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.035	0	0	0	0	0	0	**0.003**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-31.9%	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	**-31.9%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.052	0	0	0	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	**0**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-7. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Patch Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.427	0.230	0.122	0.104	0	0	0	**0.074**
Baseline 22[b]		22	0	0	0	0	0	0.463	0.225	0.118	0.103	0	0	0	**0.076**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.427	0.230	0.122	0.104	0	0	0	**0.074**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	n/a[e]	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.394	0.214	0.113	0.096	0	0	0	**0.068**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-9.2%	-6.6%	-7.2%	-8.1%	n/a[e]	n/a[e]	n/a[e]	**-8.1%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.322	0.181	0.097	0.084	0	0	0	**0.057**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-28.4%	-19.9%	-18.9%	-18.4%	n/a[e]	n/a[e]	n/a[e]	**-23.8%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.424	0.218	0.116	0.101	0	0	0	**0.072**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-6.3%	-3.5%	-2.5%	-1.8%	n/a[e]	n/a[e]	n/a[e]	**-4.6%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.457	0.226	0.119	0.103	0	0	0	**0.075**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	-0.0%	-0.0%	0.0%	n/a[e]	n/a[e]	n/a[e]	**-0.0%**

Notes:

[a] *Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0*

[b] *Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change*

[c] *Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences*

[d] *Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.*

[e] *When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.*

[f] *For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.*

Table 1.5-8. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on PO Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.552	0.250	0.138	0.125	0	0	0	**0.089**
Baseline 22[b]		22	0	0	0	0	0	0.593	0.245	0.135	0.124	0	0	0	**0.091**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.552	0.250	0.138	0.125	0	0	0	**0.089**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	n/a[e]	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.521	0.235	0.129	0.117	0	0	0	**0.083**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-6.8%	-6.2%	-6.4%	-6.7%	n/a[e]	n/a[e]	n/a[e]	**-6.6%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.454	0.200	0.112	0.105	0	0	0	**0.072**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-21.5%	-19.0%	-17.1%	-15.6%	n/a[e]	n/a[e]	n/a[e]	**-19.7%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.552	0.238	0.132	0.122	0	0	0	**0.087**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-4.9%	-3.5%	-2.3%	-1.6%	n/a[e]	n/a[e]	n/a[e]	**-3.9%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.586	0.246	0.135	0.124	0	0	0	**0.091**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	-0.0%	-0.0%	0.0%	n/a[e]	n/a[e]	n/a[e]	**-0.0%**

Notes:
[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0
[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change
[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences
[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.
[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.
[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-9. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Ogama Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	1.776	0.476	0.314	0.291	0.000	0	0	**0.237**
Baseline 22[b]		22	0	0	0	0	0.001	1.873	0.476	0.316	0.296	0.001	0	0	**0.246**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	1.776	0.476	0.314	0.291	0.000	0	0	**0.237**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	1.758	0.460	0.305	0.284	0.001	0	0	**0.233**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.9%	-3.5%	-3.0%	-2.9%	-11.8%	n/a[e]	n/a[e]	**-2.4%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0.000	1.721	0.422	0.288	0.273	0.001	0	0	**0.224**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-6.2%	-11.1%	-8.3%	-6.9%	-23.8%	n/a[e]	n/a[e]	**-7.3%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.001	1.815	0.465	0.311	0.292	0.001	0	0	**0.239**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.5%	-2.1%	-1.2%	-0.8%	-2.3%	n/a[e]	n/a[e]	**-1.5%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.001	1.855	0.476	0.315	0.295	0.001	0	0	**0.244**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.0%	0	-0.0%	0	0.0%	n/a[e]	n/a[e]	**-0.0%**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-10. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Doris Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	1.943	0.638	0.344	0.345	0.196	0.005	0	**0.288**
Baseline 22[b]		22	0	0	0	0	0.003	2.050	0.625	0.342	0.349	0.202	0.024	0	**0.299**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	1.666	0.587	0.305	0.294	0.151	0.003	0	**0.250**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-14.2%	-8.1%	-11.2%	-14.8%	-23.0%	n/a[e]	n/a[e]	**-13.4%**
Construction[f]	Flow (m^3/s)	2	0	0	0	0	0	1.527	0.578	0.301	0.292	0.150	0.003	0	**0.237**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-22.0%	-9.5%	-12.5%	-15.6%	-23.6%	n/a[e]	n/a[e]	**-18.2%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	1.204	0.509	0.281	0.283	0.130	0.006	0	**0.201**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-39.9%	-19.2%	-18.0%	-18.4%	-34.8%	n/a[e]	n/a[e]	**-31.9%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	1.709	0.582	0.316	0.312	0.169	0.016	0	**0.258**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-15.1%	-7.4%	-7.7%	-10.0%	-15.6%	n/a[e]	n/a[e]	**-12.6%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.005	2.056	0.638	0.362	0.358	0.196	0.021	0	**0.302**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	1.3%	1.8%	5.7%	2.9%	-2.1%	n/a[e]	n/a[e]	**1.8%**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-11. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Little Roberts Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	7.091	1.802	1.159	1.166	0.612	0.011	0	**0.983**
Baseline 22[b]		22	0	0	0	0	0.065	7.377	1.798	1.175	1.193	0.638	0.048	0	**1.021**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	6.539	1.700	1.082	1.064	0.522	0.007	0	**0.906**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-7.8%	-5.7%	-6.7%	-8.8%	-14.7%	n/a[e]	n/a[e]	**-7.8%**
Construction[f]	Flow (m^3/s)	2	0	0	0	0	0	6.269	1.683	1.075	1.061	0.523	0.007	0	**0.882**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-12.1%	-6.7%	-7.4%	-9.2%	-15.1%	n/a[e]	n/a[e]	**-10.7%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0.038	5.652	1.556	1.044	1.053	0.489	0.012	0	**0.818**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-22.1%	-13.4%	-10.6%	-10.8%	-22.1%	n/a[e]	n/a[e]	**-18.7%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.039	6.674	1.705	1.116	1.114	0.567	0.031	0	**0.934**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-8.3%	-5.1%	-4.5%	-5.9%	-9.9%	n/a[e]	n/a[e]	**-7.4%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.049	7.388	1.821	1.211	1.208	0.626	0.042	0	**1.025**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0.7%	1.3%	3.3%	1.7%	-1.4%	n/a[e]	n/a[e]	**1.1%**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-12. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Windy Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.183	0.079	0.027	0.025	0	0	0	**0.026**
Baseline 22[b]		22	0	0	0	0	0	0.197	0.075	0.025	0.023	0	0	0	**0.027**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.171	0.074	0.025	0.023	0	0	0	**0.024**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-6.7%	-5.8%	-8.0%	-8.1%	n/a[e]	n/a[e]	n/a[e]	**-6.7%**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.173	0.074	0.025	0.023	0	0	0	**0.024**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-7.1%	-6.2%	-8.6%	-8.8%	n/a[e]	n/a[e]	n/a[e]	**-7.1%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.178	0.072	0.023	0.022	0	0	0	**0.024**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-7.4%	-6.5%	-9.2%	-9.4%	n/a[e]	n/a[e]	n/a[e]	**-7.5%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.180	0.072	0.023	0.022	0	0	0	**0.025**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-6.9%	-6.1%	-8.6%	-8.8%	n/a[e]	n/a[e]	n/a[e]	**-7.0%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.194	0.076	0.025	0.023	0	0	0	**0.026**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.3%	-0.2%	-0.2%	-0.2%	n/a[e]	n/a[e]	n/a[e]	**-0.3%**

Notes:
[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0
[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change
[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences
[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.
[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.
[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-13. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Glenn Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.728	0.111	0.075	0.115	0.045	0	0	**0.089**
Baseline 22[b]		22	0	0	0	0	0	0.762	0.107	0.073	0.116	0.048	0	0	**0.092**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.716	0.107	0.073	0.113	0.045	0	0	**0.087**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.7%	-4.1%	-3.0%	-1.8%	0	n/a[e]	n/a[e]	**-2.0%**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.721	0.106	0.073	0.113	0.046	0	0	**0.088**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.8%	-4.3%	-3.2%	-1.9%	0	n/a[e]	n/a[e]	**-2.1%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.734	0.104	0.071	0.113	0.047	0	0	**0.089**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.9%	-4.5%	-3.3%	-1.9%	0	n/a[e]	n/a[e]	**-2.2%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.738	0.104	0.071	0.113	0.047	0	0	**0.089**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-1.8%	-4.2%	-3.1%	-1.8%	0	n/a[e]	n/a[e]	**-2.0%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.755	0.108	0.073	0.116	0.048	0	0	**0.091**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.2%	-0.1%	-0.0%	0	n/a[e]	n/a[e]	**-0.1%**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-14. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Trout Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.939	0.127	0.117	0.135	0.074	0	0	**0.115**
Baseline 22[b]		22	0	0	0	0	0.005	0.975	0.133	0.122	0.141	0.079	0	0	**0.121**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.939	0.127	0.117	0.135	0.074	0	0	**0.115**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.947	0.128	0.118	0.136	0.075	0	0	**0.116**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.963	0.130	0.120	0.138	0.077	0	0	**0.118**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.005	0.963	0.131	0.121	0.139	0.078	0	0	**0.119**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.005	0.968	0.132	0.121	0.140	0.078	0	0	**0.120**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**

Notes:

[a] *Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0*

[b] *Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change*

[c] *Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences*

[d] *Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.*

[e] *When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.*

[f] *For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.*

Table 1.5-15. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Stickleback Lake Outflow during different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	0.030	0.011	0.002	0.002	0	0	0	**0.004**
Baseline 22[b]		22	0	0	0	0	0	0.034	0.010	0.002	0.002	0	0	0	**0.004**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	0.030	0.011	0.002	0.002	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	n/a[e]	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	0.029	0.010	0.002	0.001	0	0	0	**0.003**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-9.7%	-10.6%	-20.6%	-22.7%	n/a[e]	n/a[e]	n/a[e]	**-10.9%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	0.029	0.009	0.001	0.001	0	0	0	**0.003**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-10.9%	-11.7%	-22.9%	-25.0%	n/a[e]	n/a[e]	n/a[e]	**-12.1%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0	0.033	0.010	0.002	0.002	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.6%	-0.4%	-0.6%	-0.5%	n/a[e]	n/a[e]	n/a[e]	**-0.5%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0	0.033	0.010	0.002	0.002	0	0	0	**0.004**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.0%	0	0	0	n/a[e]	n/a[e]	n/a[e]	**-0.0%**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-16. Effects of Hope Bay Projecton Surface Hydrology - Maximum Monthly Effects on Aimaokatalok Lake Outflow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	32.751	8.531	4.805	4.680	2.056	0.451	0	**4.421**
Baseline 22[b]		22	0	0	0	0	0.041	33.735	8.348	4.958	4.880	2.253	1.653	0	**4.635**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	32.751	8.531	4.805	4.680	2.056	0.451	0	**4.421**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	33.256	8.337	4.809	4.703	2.092	0.453	0	**4.451**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.2%	-0.1%	-0.3%	-0.3%	-0.5%	n/a[e]	n/a[e]	**-0.2%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	33.800	8.330	4.880	4.788	2.162	0.662	0	**4.532**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.1%	-0.2%	-0.2%	-0.4%	n/a[e]	n/a[e]	**-0.2%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.135	33.916	8.333	4.906	4.819	2.201	0.859	0	**4.577**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**-0.0%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.070	33.700	8.337	4.928	4.842	2.224	1.363	0	**4.601**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**

Notes:

[a] Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0

[b] Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change

[c] Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences

[d] Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.

[e] When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.

[f] For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.

Table 1.5-17. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Koignuk River 1 Flow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	37.863	9.267	5.462	5.405	2.437	0.451	0	**5.051**
Baseline 22[b]		22	0	0	0	0	0.102	39.005	9.117	5.645	5.637	2.659	1.653	0	**5.293**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	37.863	9.267	5.462	5.405	2.437	0.451	0	**5.051**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	38.414	9.076	5.473	5.436	2.481	0.453	0	**5.088**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.2%	-0.2%	-0.2%	-0.4%	n/a[e]	n/a[e]	**-0.2%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	39.043	9.088	5.556	5.532	2.557	0.662	0	**5.179**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.1%	-0.2%	-0.2%	-0.4%	n/a[e]	n/a[e]	**-0.1%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.195	39.120	9.095	5.585	5.563	2.602	0.859	0	**5.228**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**-0.0%**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.130	38.927	9.102	5.612	5.594	2.627	1.363	0	**5.255**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**

Notes:

[a] *Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0*

[b] *Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change*

[c] *Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences*

[d] *Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.*

[e] *When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.*

[f] *For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.*

Table 1.5-18. Effects of Hope Bay Project on Surface Hydrology - Maximum Monthly Effects on Koignuk River 2 Flow during Different Phases of the Project under Average Climate Conditions

Project Phase		Project Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline 0[a]		0	0	0	0	0	0	57.832	12.142	8.035	8.241	3.928	0.451	0	**7.515**
Baseline 22[b]		22	0	0	0	0	0.338	59.645	12.123	8.333	8.596	4.245	1.653	0	**7.871**
Existing and Permitted Projects[c]	Flow (m^3/s)	0	0	0	0	0	0	57.832	12.142	8.035	8.241	3.928	0.451	0	**7.515**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Construction[f]	Flow (m^3/s)	4	0	0	0	0	0	58.565	11.977	8.068	8.295	3.999	0.453	0	**7.575**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	n/a[e]	n/a[e]	**-0.1%**
Operation[f]	Flow (m^3/s)	13	0	0	0	0	0	59.529	12.041	8.195	8.441	4.103	0.662	0	**7.708**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	n/a[e]	n/a[e]	**-0.1%**
Closure[f]	Flow (m^3/s)	15	0	0	0	0	0.428	59.491	12.059	8.236	8.484	4.167	0.859	0	**7.772**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**
Post-closure[f]	Flow (m^3/s)	18	0	0	0	0	0.365	59.414	12.082	8.277	8.534	4.200	1.363	0	**7.814**
	Change (%)[d]		n/a[e]	n/a[e]	n/a[e]	n/a[e]	n/a[e]	0	0	0	0	0	n/a[e]	n/a[e]	**0**

Notes:

[a] *Baseline flow (natural flows if no infrastructure had been developed) in Project Year 0*

[b] *Baseline flow (natural flows if no infrastructure had been developed) at the end of mine life (i.e., Year 22), including the effects of climate change*

[c] *Flows in Project Year 0 with existing and permitted projects, before Construction of Madrid-Boston infrastructure commences*

[d] *Percent of baseline flow. Climate change effects are considered in both baseline and project-affected flows. For example, project-affected flows in Year 10 are compared with baseline flows in Year 10.*

[e] *When baseline flow is zero (i.e., in winter) or monthly-averaged flow is misleading because flow is zero during part of the month (e.g., May and November), percent changes are described as n/a.*

[f] *For each phase of the Project, the year with maximum difference from baseline conditions is shown on the table.*

1.5.5 Characterization of Residual Effects

1.5.5.1 Definitions for Characterization of Residual Effects

In order to determine the significance of Project residual effect, each potential negative residual effect is characterized by a number of attributes consistent with those defined in of the EIS guidelines (Section 7.14, Significance Determination for the Hope Bay Project; NIRB 2012a) and the effects assessment methodology (Volume 2, Chapter 4). A definition for each attribute and the contribution that it has on significance determination is provided in Table 1.5-19.

Table 1.5-19. Attributes to Evaluate Significance of Potential Residual Effects

Attribute	Definition and Rationale	Impact on Significance Determination
Direction	The ultimate long-term trend of a potential residual effect - positive, neutral, or negative.	Positive, neutral, and negative potential effects on the surface hydrology VEC are assessed, but only negative residual effects are characterized and assessed for significance.
Magnitude	The degree of change in a measurable parameter or variable relative to existing conditions. This attribute may also consider complexity - the number of interactions (Project phases and activities) contributing to a specific effect.	The higher the magnitude, the higher the potential significance.
Duration	The length of time over which the residual effect occurs.	The longer the length of time of an interaction, the higher the potential significance.
Frequency	The number of times during the Project or a Project phase that an interaction or environmental/ socio-economic effect can be expected to occur.	Greater the number times of occurrence (higher the frequency), the higher the potential significance.
Geographic Extent	The geographic area over which the interaction will occur.	The larger the geographical area, the higher the potential significance.
Reversibility	The likelihood an effect will be reversed once the Project activity or component is ceased or has been removed. This includes active management for recovery or restoration.	The lower the likelihood a residual effect will be reversed, the higher the potential significance.

For the determination of significance, each attribute is characterized. The characterizations and criteria for the characterizations are provided in Table 1.5-20. Each of the criteria contributes to the determination of significance.

Due to inherent data and modelling uncertainty in hydrologic studies, it is reasonable to account for at least a 5% error in hydrologic estimates. Therefore, it was assumed that any streamflow change less than 5% of the baseline flows could be an artifact of data and/or modelling uncertainty, and hence, was considered as a negligible change (Table 1.5-20). A variation of 10% from baseline conditions was assumed to be within the natural variability of the riverine system and, therefore, streamflow effects of less than 10% are *low* magnitude. This is in agreement with recommendations from the Science Advisory Secretariat, Fisheries and Oceans Canada (DFO 2013b), and with recent EIS studies in the region (e.g., Back River and Mary River). The relative values of *high* and *low* magnitude effects (i.e., 50% and 10%) were aligned with recent EIS studies in the region (e.g., Back River and Mary River).

Table 1.5-20. Criteria for Residual Effects for Environmental Attributes

Attribute	Characterization	Criteria[1]
Direction	Positive	Beneficial
	Variable	Both beneficial and undesirable
	Negative	Undesirable
Magnitude	Negligible	The change in streamflow is not detectable (i.e., less than 5% of the baseline flow)
	Low	The change in streamflow is less than 10% of the baseline flow[1]
	Moderate	The change in streamflow is between 10% and 50% of the baseline flow
	High	The change in streamflow is greater than 50% of the baseline flow
Duration	Short	Up to 4 years (Construction phase)
	Medium	Greater than 4 years and up to 17 years (4 years Construction phase, 10 years Operation phase, 3 years Reclamation and Closure phase)
	Long	Beyond the life of the Project
Frequency	Infrequent	Occurring only occasionally
	Intermittent	Occurring during specific points or under specific conditions during the Project
	Continuous	Continuously occurring throughout the Project life
Geographic Extent	Project Development Area (PDA)	Confined to the PDA
	Local Study Area (LSA)	Beyond the PDA and within the LSA
	Regional Study Area (RSA)	Beyond the LSA and within the RSA
	Beyond Regional	Beyond the RSA
Reversibility	Reversible	Effect reverses within an acceptable time frame with no intervention
	Reversible with effort	Active intervention (effort) is required to bring the effect to an acceptable level
	Irreversible	Effect will not be reversed

[1] *Established by fish habitat requirements (DFO 2013b)*

1.5.5.2 Determining the Significance of Residual Effects

Section 7.14 of the EIS guidelines provided guidance, attributes, and criteria for the determination of significance for residual effects (NIRB 2012a). Also, the Canadian Environmental Assessment Agency's *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects (CEA Agency 1992)* guided the evaluation of significance for identified residual effects. The significance of residual effects is based on comparing the predicted state of the environment with and without the Project, including a judgment as to the importance of the changes identified.

<u>Probability of Occurrence or Certainty</u>

Prior to the determination of the significance for negative residual effects, the probability of the occurrence or certainty of the effect is evaluated. For each negative residual effect, the probability of occurrence is categorized as unlikely, moderate or likely. Table 1.5-21 presents the definitions applied to these categories.

Table 1.5-21. Definition of Probability of Occurrence and Confidence for Assessment of Residual Effects

Attribute	Characterization	Criteria
Probability of occurrence or certainty	Unlikely	Some potential exists for the effect to occur; however, current conditions and knowledge of environmental trends indicate the effect is unlikely to occur.
	Moderate	Current conditions and environmental trends indicate there is a moderate probability for the effect to occur.
	Likely	Current conditions and environmental trends indicate the effect is likely to occur.
Confidence	High	Baseline data are comprehensive; predictions are based on quantitative predictive model; effect relationship is well understood.
	Medium	Baseline data are comprehensive; predictions are based on qualitative logic models; effect relationship is generally understood, however, there are assumptions based on other similar systems to fill knowledge gaps.
	Low	Baseline data are limited; predictions are based on qualitative data; effect relationship is poorly understood.

Determination of Significance

Significance of a residual effect on surface hydrology depends on the magnitude and other attributes of the effect. If the magnitude is *negligible* or *low*, the effect will be characterized as **not significant**, because streamflow alteration will be within the natural variation. If the magnitude is *high* and the effect is beyond the LSA, the effect will be characterized as **significant**, because such an effect would mean substantial change in hydrologic regime beyond the LSA.

If the magnitude is *moderate,* significance determination will depend on other attributes, and will become more subjective. Key attributes to consider are reversibility, duration, and geographic extent. A key consideration that can further qualify a *moderate* magnitude effect is its pathway to other VECs. For example, a *moderate* magnitude streamflow reduction that has a potential for fish habitat loss can be characterized differently depending on whether the application of fisheries offsetting has the potential to mitigate effects on the freshwater fish VECs of fish habitat and fish community.

Confidence

The knowledge or analysis that supports the prediction of a potential residual effect, in particular with respect to limitations in overall understanding of the environment and/or the ability to foresee future events or conditions, determines the confidence in the determination of significance. In general, the lower the confidence, the more conservative the approach to prediction of significance must be. The level of confidence in the prediction of a significant or non-significant potential residual effect qualifies the determination, based on the quality of the data and analysis and their extrapolation to the predicted residual effects. *Low* is assigned where there is a low degree of confidence in the inputs, *medium* when there is moderate confidence and *high* when there is a high degree of confidence in the inputs. Where rigorous baseline data were collected and scientific analysis performed, the degree of confidence will generally be *high*. Table 1.5-21 provides descriptions of the confidence criteria.

The water balance model used industry standard modelling software to support the assessment process, including the investigation of dry and wet climate sensitivities. Therefore, there is *high* confidence in the results of this residual effects assessment for predicted effects on surface hydrology.

Residual effects identified in the Project-related effects assessment are carried forward to assess the potential for cumulative interactions with the residual effects of other projects or human activities and to assess the potential for transboundary impacts should the effects linked directly to the activities of the Project inside the Nunavut Settlement Area (NSA), which occurs across provincial, territorial, international boundaries or may occur outside of the NSA.

1.5.5.3 Characterization of Residual Effect for Surface Hydrology VEC

Streamflow Alteration in Doris Watershed

Residual effects on streamflow are anticipated during the Construction and Operation phases, with maximum effects during the last two years of Operation. Streamflows are predicted to be 10 to 50% lower than baseline flows within the LSA (Table 1.5-3). Therefore, magnitude of the residual effect is *moderate*. At the boundary of the LSA (i.e., at Little Roberts Lake Outflow), average annual streamflow over the life of the Madrid-Boston Project is predicted to be 9% lower than baseline flows (Table 1.5-3). Therefore, magnitude of the residual effect at the LSA boundary is *low*.

The *negative* effects beyond natural variability are expected to be *local*, *medium-term* in duration, and *continuous* as water withdrawal from lakes and water loss to taliks are continuous. Surface hydrology has the capacity to recover and the effects are expected to be fully *reversible*. The probability of occurrence is estimated to be *likely*, and confidence was *high* because of the quantitative input from the baseline environmental data and water balance model, and the confidence in the mitigation and management strategies. Therefore, the residual effect of the Project is concluded to be **Not Significant** on surface hydrology.

Streamflow reduction in Doris Watershed has the potential to affect fish habitat in Doris Lake Outflow and Little Roberts Outflow. This potential effect is assessed in Volume 5, Chapter 6.

As previously mentioned (Section 1.5-4) this characterization was based on the Hope Bay Project (the Madrid Boston Project in combination with existing and permitted projects), but is conservatively also used for the Madrid Boston Project in isolation of existing and permitted projects.

Streamflow Alteration in Windy Watershed

Residual effects on streamflow are anticipated during the Construction and Operation phases. Streamflow reductions compared to baseline are predicted to be less than 10% under average climate conditions (Table 1.5-4). Therefore, magnitude of the residual effect is *low*.

The *negative* effects are expected to be *local*, *medium-term* in duration, and *continuous* as water withdrawal from lakes and water loss to talik are continuous. Surface hydrology has the capacity to recover and the effects are expected to be fully *reversible*. The probability of occurrence is estimated to be *likely*, and confidence was *high* because of the quantitative input from the baseline environmental data and water balance model, and the confidence in the mitigation and management strategies.

Based on the abovementioned attributes, the residual effect of the Project is concluded to be **Not Significant** on surface hydrology.

As previously mentioned (Section 1.5-4) this characterization was based on the Hope Bay Project (the Madrid Boston Project in combination with existing and permitted projects), but is conservatively also used for the Madrid Boston Project in isolation of existing and permitted projects.

Streamflow Alteration in Aimaokatalok Watershed

Residual effects on streamflow are anticipated during the Construction and Operation phases. Streamflow reductions compared to baseline are predicted to be less than 10% (Table 1.5-5). Therefore, magnitude of the residual effect is *low*.

The *negative* effects are expected to be *local*, *medium-term* in duration, and *continuous* as water withdrawal is continuous. Surface hydrology has the capacity to recover and the effects are expected to be fully *reversible*. The probability of occurrence is estimated to be *likely*, and confidence was *high* because of the quantitative input from the baseline environmental data and water balance model, and the confidence in the mitigation and management strategies.

Based on the abovementioned attributes, the residual effect of the Project is concluded to be **Not Significant** on surface hydrology.

As previously mentioned (Section 1.5-4) this characterization was based on the Hope Bay Project (the Madrid Boston Project in combination with existing and permitted projects; Table 1.5-22), but is conservatively also used for the Madrid Boston Project in isolation of existing and permitted projects (Table 1.5-23).

1.6 CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when the potential residual effects of the Project affect (i.e., overlap and interact with) the same surface hydrology VEC that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities.

1.6.1 Methodology Overview

1.6.1.1 Approach to Cumulative Effects Assessment

The general methodology for cumulative effects assessment (CEA) is described in Volume 2, Chapter 4, and focuses on the following activities:

1. Identify the potential for Project-related (Madrid-Boston Project) residual effects to interact with residual effects from the Existing and Approved Projects within the Hope Bay Greenstone Belt (i.e., the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, and the Boston Advanced Exploration Project) and other human activities and projects within specified assessment boundaries. Key potential residual effects associated with past, existing, and reasonably foreseeable future projects were identified using publicly available information or, where data was unavailable, professional judgment was used (based on previous experience in similar geographical locations) to approximate expected environmental conditions.
2. Identify and predict potential cumulative effects that may occur and implement additional mitigation measures to minimize the potential for cumulative effects.
3. Identify cumulative residual effects after the implementation of mitigation measures.
4. Determine the significance of any cumulative residual effects.

Table 1.5-22. Summary of Residual Effects and Overall Significance Rating for Surface Hydrology - Hope Bay Project

	Attribute Characteristic						Overall Significance Rating		
Residual Effect	**Direction** *(positive, variable, negative)*	**Magnitude** *(negligible, low, moderate, high)*	**Duration** *(short, medium, long)*	**Frequency** *(infrequent, intermittent, continuous)*	**Geographic Extent** *(PDA, LSA, RSA, beyond regional)*	**Reversibility** *(reversible, reversible with effort, irreversible)*	**Probability** *(unlikely, moderate, likely)*	**Significance** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Alteration Streamflow in Doris Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High
Alteration Streamflow in Windy Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High
Alteration Streamflow in Aimaokatalok Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High

Table 1.5-23. Summary of Residual Effects and Overall Significance Rating for Surface Hydrology - Madrid-Boston Project

Residual Effect	**Attribute Characteristic**						**Overall Significance Rating**		
	Direction *(positive, variable, negative)*	**Magnitude** *(negligible, low, moderate, high)*	**Duration** *(short, medium, long)*	**Frequency** *(infrequent, intermittent, continuous)*	**Geographic Extent** *(PDA, LSA, RSA, beyond regional)*	**Reversibility** *(reversible, reversible with effort, irreversible)*	**Probability** *(unlikely, moderate, likely)*	**Significance** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Alteration Streamflow in Doris Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High
Alteration Streamflow in Windy Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High
Alteration Streamflow in Aimaokatalok Watershed	Negative	Low	Medium	Continuous	LSA	Reversible	Likely	Not significant	High

1.6.1.2 Assessment Boundaries

The CEA considers the spatial and temporal extent of Project-related residual effects on the surface hydrology VEC combined with the anticipated residual effects from other projects and activities to assist with analyzing the potential for a cumulative effect to occur.

Spatial Boundaries

The spatial boundary for the CEA was the assessment Regional Study Area (RSA; Figure 1.4-1). This study area contains the LSA and was determined to cover the extent of direct and indirect effects of the Project on the freshwater environment.

Temporal Boundaries

The temporal boundaries of the CEA were defined by the timelines for Past, Existing, and Reasonably Foreseeable Projects as described in the CEA methodology (Volume 2, Chapter 4). These timelines were compared to the Project timeline (Section 1.4.3).

1.6.2 Potential Interactions of Residual Effects with Other Projects

The water balance model (P5-4) collectively characterized the potential effects of all components and activities related to the Madrid-Boston Project, as well as those related to the Existing and Approved Projects within the Hope Bay Greenstone Belt (i.e., the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, and the Boston Advanced Exploration Project). Therefore, characterization of residual effect for surface hydrology VEC (Section 1.5.5.3) accounts for effects of all these components and activities.

The mining industry is the main source of industrial activity in Nunavut, which is being explored for uranium, diamonds, gold and precious metals, base metals, iron, coal, and gemstones. In addition to major mining development projects, other land use activities are also present in the territory and, as required under Section 7.11 of the Project EIS guidelines, were considered for potential interactions with the Project (see Volume 2, Chapter 4 for more details).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Hope Bay Project lie within the freshwater assessment RSA. Therefore, no additional cumulative effects to the surface hydrology VEC were predicted.

A description of each cumulative residual effect is provided, parcelling out the contributions of the Madrid-Boston Project, the Doris Project, the Existing and Approved Exploration Projects at Hope Bay, and other projects and activities to the total cumulative effect (Table 1.6-1).

Table 1.6-1. Contributions of Projects and Activities to Cumulative Residual Effects on Surface Hydrology

Project or Activity	Description of Contribution to Cumulative Residual Effect
Madrid-Boston Project	Collectively Assessed in Section 1.5.5.3[1]
Doris Project	Collectively Assessed in Section 1.5.5.3[1]
Existing and Approved Exploration Projects within the Hope Bay Greenstone Belt	Collectively Assessed in Section 1.5.5.3[1]
Past Projects or Activities	No interactions
Existing Projects or Activities	No interaction

Project or Activity	Description of Contribution to Cumulative Residual Effect
Reasonably Foreseeable Future Project or Activity	No interactions
Description of Total Cumulative Residual Effect	Collectively Assessed in Section 1.5.5.3[1]

[1] The water balance model (P5-4) collectively characterized the potential effects of all components and activities related to the Madrid-Boston Project, as well as those related to the Existing and Approved Projects within the Hope Bay Greenstone Belt. These collective effects are assessed in Section 1.5.5.3.

1.7 TRANSBOUNDARY EFFECTS

The Project EIS guidelines define transboundary effects as those effects linked directly to the activities of the Project inside the NSA, which occur across provincial, territorial, international boundaries or may occur outside of the NSA (NIRB 2012a). Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

The watersheds that have potential interaction with a Project component(s) or physical activity drain into Roberts Bay and Hope Bay; these watersheds lie entirely within Nunavut, and therefore no potential for transboundary effects was identified.

1.8 IMPACT STATEMENT

The surface hydrology VEC was identified because surface water flow is a key component of the biophysical environment. It is linked to other components of the aquatic ecosystem including surface water quality, fish, fish habitat, and aquatic resources. The Inuit identify rivers and lakes as important sources of drinking water and fish habitat. Surface water is also protected by the *Canada Water Act* (1985).

Baseline studies included monitoring streamflow during the open-water season using hydrometric stations. A water balance model was developed to simulate both baseline and project-affected flows; the water balance model accounted for climate change with predicted increases to temperature and precipitation.

The Project has the potential to interact with surface hydrology through a number of activities including water withdrawal from lakes, construction and use of underground mines, and modification of natural drainages. These activities have the potential to alter streamflow in Doris, Windy, and Aimaokatalok watersheds.

Mitigation measures include use of existing infrastructure, minimization of Project footprint, recycle and reuse of contact water, adherence to regulatory requirements and permit conditions, sufficient contact water storage capacity, implementation of erosion control plans, water management inspections, and use of groundwater to minimize freshwater use.

Residual effects on surface hydrology, after implementation of mitigation measures, are:

- Alteration of streamflow in Doris Watershed
- Alteration of streamflow in Windy Watershed
- Alteration of streamflow in Aimaokatalok Watershed

Water balance modelling results showed that the alteration of average annual streamflow at the LSA boundary of Doris, Windy, and Aimaokatalok watersheds would be within the natural variation of streamflow. Therefore, effects of the Project on surface hydrology would be **Not Significant**.

No cumulative effects are predicted to occur because the surface hydrology residual effects are not predicted to overlap spatially with any other past, existing, or reasonably foreseeable project. Similarly, no transboundary effects are identified.

1.9 REFERENCES

1985. *Canada Water Act*, RSC. C-11

1985. *Fisheries Act*, RSC. F-14

AMEC. *2003 Meteorology and Hydrology Baseline*. Prepared for Miramar Hope Bay Ltd by AMEC Earth & Environmental Limited, Burnaby, BC.

Banci, V. and R. Spicker. 2016. Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project Naonaiyaotit Traditional Knowledge Project (NTKP). Kitikmeot Inuit Association: Kugluktuk, NU.

CEA Agency. 1992. *Reference Guide: Determining Whether A Project is Likely to Cause Significant Adverse Environmental Effects*. http://www.CEAa-acee.gc.ca/default.asp?lang=En&n=D213D286-1&offset=&toc=hide (accessed May 2016).

Church, M. 1974. Hydrology and permafrost with reference to northern North America. *Proc. Workshop Seminar on Permafrost Hydrology,* Can. Nat. Comm., IHD, Ottawa, pp. 7 – 20

DFO. 2013a. *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat*. http://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/nu-eng.html (accessed December 1, 2016).

DFO. 2013b. *Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*, Science Advisory Report 2013/017, May 2013

DFO. 2016. *Measures to Avoid Causing Harm to Fish and Fish Habitat*. http://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures/measures-mesures-eng.html (accessed December 1, 2016).

Golder and Associates. 2009. *Doris Study Area 2008 Hydrology Baseline Update - Draft Report*. Report Number: 08-1373-0026

ERM 2015. *Doris North Project: 2014 Hydrology Compliance Monitoring Program*. Memorandum to TMAC Resources Inc.

ERM 2016. *Doris North Project: 2015 Hydrology Compliance Monitoring Program*. Memorandum to TMAC Resources Inc.

ERM Rescan. 2014. *Doris North Project: 2013 Hydrology Compliance Monitoring Report*. Prepared for TMAC Resources Inc. by ERM Rescan: Yellowknife, NT.

Herschy, R. W. 2009. *Streamflow measurement*. Third ed. New York, NY: Taylor & Francis.

International Organization for Standardization. 2010. *Hydrometry — Measurement of liquid flow in open channels — Part 2: Determination of the stage-discharge relationship*. ISO 1100-2:2010(E).

Kane, D.L., Gieck, R.E., Hinzman, L.D. 1997. Snowmelt Modeling at Small Alaskan Arctic Watershed. *Journal of Hydrologic Engineering*. Vol. 2, No. 4, 204-210.

Kennedy, E.J. 1984. Discharge Ratings at Gaging stations: *U.S. Geological Survey Techniques of Water-Resources Investigations*, book 3, chap. A10, 59 p.

NIRB. 2012a. *Guidelines for the Preparation of an Environmental Impact Statement for Hope Bay Mining Ltd.'s Phase 2 Hope Bay Belt Projec*t (NIRB File No. 12MN001). Nunavut Impact Review Board: Cambridge Bay, Nunavut.

NIRB. 2012b. *Public Scoping Meetings Summary Report for the NIRB's Review of Hope Bay Mining's Ltd.'s "Phase 2 Hope Bay Belt Project* NIRB File No.: 12MN001. Nunavut Impact Review Board: Cambridge Bay, Nunavut

Poff N.L. et al. 2010. The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* 55:147-170.

Rantz et al. 1982. *Measurement and Computation of Streamflow: Volume 1*. Measurement of Stage and Discharge, USGS.

Rescan. 2002. *1993 - 2002 Data Compilation Report for Meteorology and Hydrology*. Prepared for Hope Bay Joint Venture by Rescan Environmental Services: Vancouver, BC.

Rescan. 2009. *Hope Bay Belt Project: 2009 Hydrology Baseline Report*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010. *Doris North Project: Hydrology Compliance Report 2010*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011a. *Hope Bay Belt Project: 2010 Hydrology Baseline Report*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011b. *Doris North Project: Hydrology Compliance Report 2011*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012a. *Hope Bay Belt Project: 2011 Hydrology Baseline Report*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2012b. *Doris North Project: Hydrology Compliance Report 2012*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

TMAC. 2017. *Madrid-Boston Final Environmental Impact Statement*. Submitted to Nunavut Impact Review Board (NIRB) December 2017.

USGS. 2005. *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers*. U.S. Geological Survey Scientific Investigations Report 2005-5183.

Water Survey of Canada 2004. *Procedures for Conducting ADCP Discharge Measurements*. Version 1.0, 2004. Environment Canada.