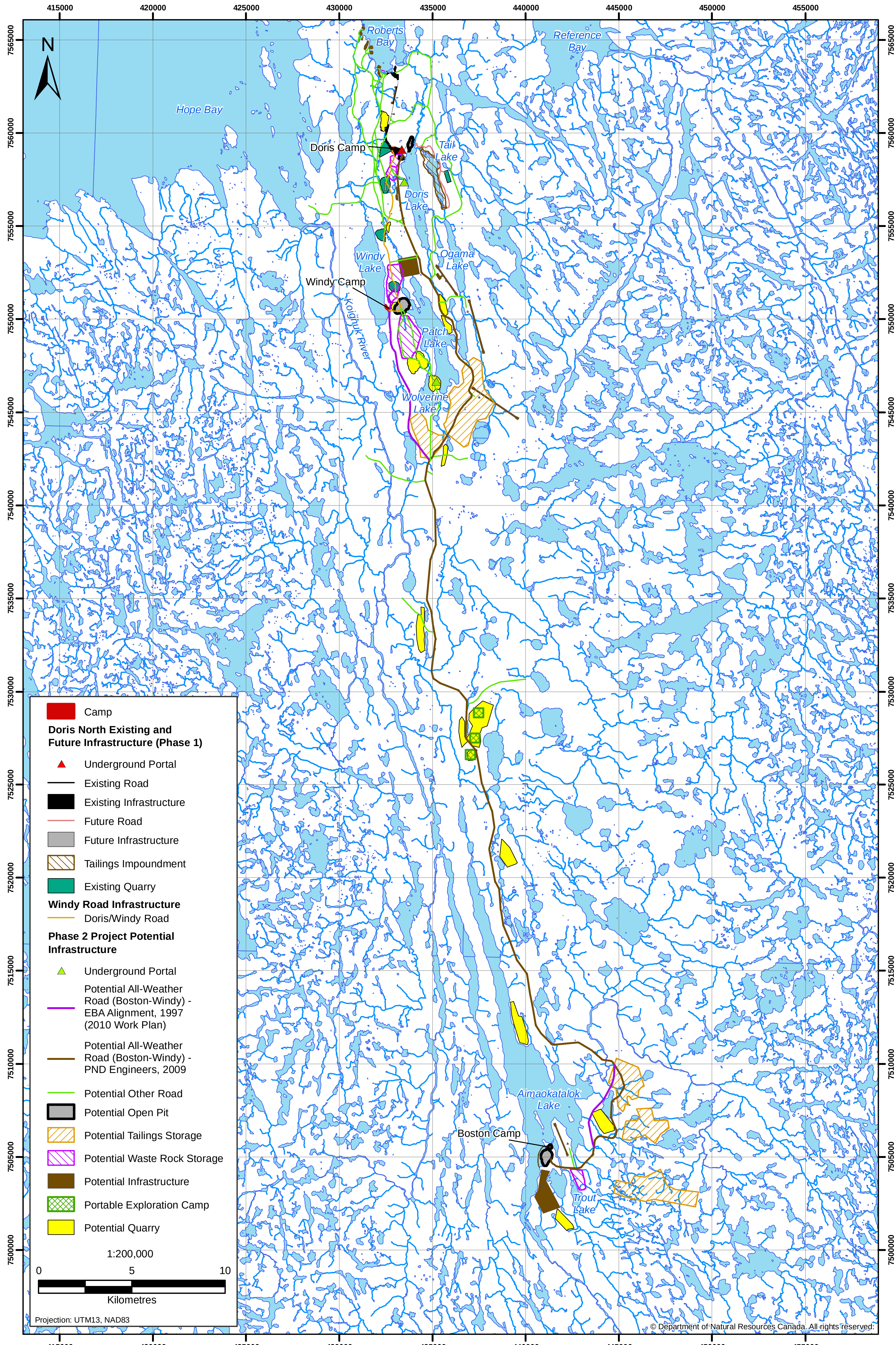

Figure 1-2

NEWMONT NORTH AMERICA

Site Layout Options Considered for Phase 2 Baseline Program, 2011

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Figure 1-2

- 2011 Aquatic Effects Monitoring Report, Doris North Project
- 2011 Air Quality Compliance Reports, Doris North Project

This report presents the results from the Hydrology portion of the 2011 Phase 2 environmental baseline program. The objectives of the 2011 hydrometric monitoring program were to:

- continue with the monitoring program in the Doris/Madrid area that covers areas additional to the Doris North hydrology compliance program; and
- collect additional hydrologic data in the Boston area in basins that could be influenced by the development of the Phase 2 Project.

The report is divided into the following four sections:

- Section 2: A brief description of the hydrologic setting of the watersheds within the project area;
- Section 3: A description of the methods used to collect and analyze the hydrometric data;
- Section 4: A summary of the hydrologic results for the Doris North and Boston areas; and
- Section 5: A comparison of the hydrologic differences and similarities between the Doris/ Madrid and Boston areas. This also includes a comparison of the information collected in 2011 to the available on-site historical data.

2. Hydrologic Setting

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2. Hydrologic Setting

2.1 ARCTIC HYDROLOGY

The Hope Bay Belt lies within the continuous permafrost zone of the Canadian Arctic within the Arctic Tundra biome. This region is composed of vegetated tundra slopes with lakes and wetland fens scattered throughout the landscape. Hydrologic processes in the region are dominated by the presence of permafrost, which has very low hydraulic conductivity and acts as a barrier to deeper groundwater recharge and thus tends to lead to increased surface runoff and decreases sub-surface flow. Rivers located within the region of continuous permafrost are classified as being Arctic-nival, which is characterized by low base and winter flows and where snowmelt is the major hydrologic event. Additional factors influencing Arctic hydrological processes include the thickness of the active layer, snow accumulation and melt, surface runoff, and runoff routed through lakes.

The hydrologic year for the region can be divided into four periods: snowmelt; outflow breakup; a summer period with no ice cover and high evaporation; and winter freeze-up. The winter freeze-up typically occurs in late-October to early-November for the Belt. In small watersheds, like many of those in the Belt, streams typically freeze to their bottom with zero flow during winter. Some larger rivers may maintain flow year round, likely due to either groundwater discharge from taliks or flow from upstream lakes, where turbulent flow maintains ice free zones at the lake outlets. Water is stored in the snowpack during winter and is released in the spring freshet.

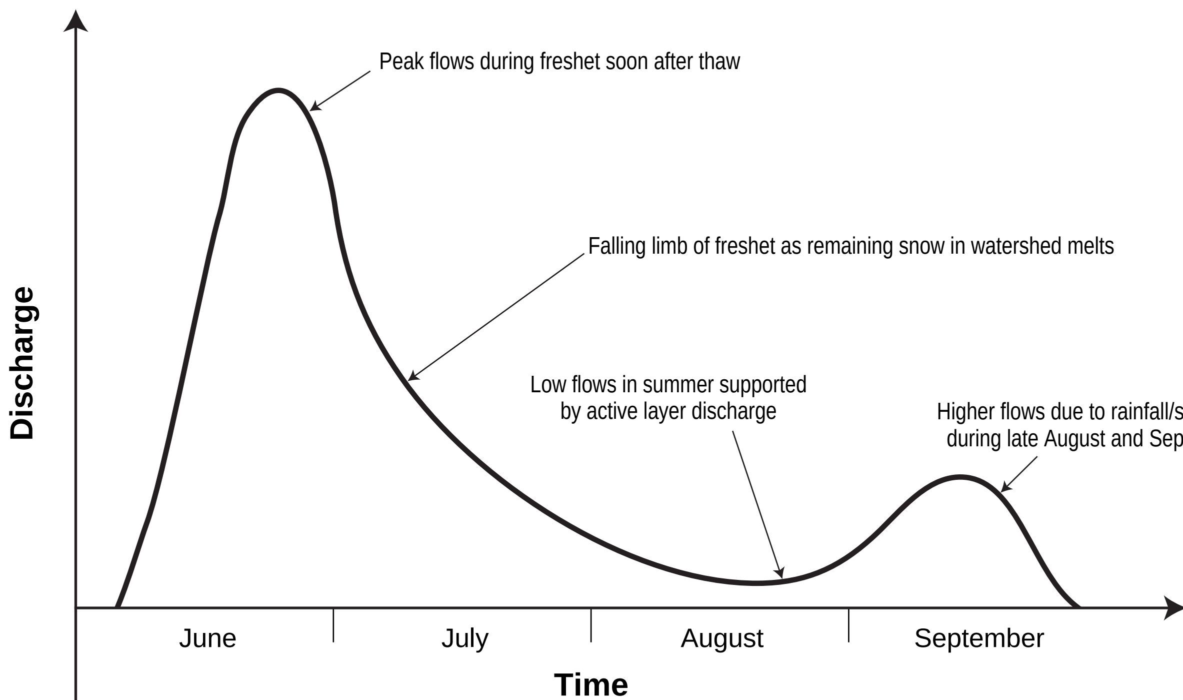
A conceptual hydrograph showing typical annual discharge patterns for small watersheds is shown in Figure 2.1-1. The hydrograph is characterized by a steep rising limb leading to a peak during the freshet period and a second rainfall-generated peak that can be observed in certain years in late August or early to mid-September. The shape of the hydrograph and the response of streams to both spring snowmelt and precipitation are strongly correlated to basin size. Smaller watersheds respond more rapidly to inputs than larger watersheds. The magnitude and timing of runoff events may vary with watershed size and precipitation.

In very small basins the freshet can be as short as a few days and will often occur immediately after ice break-up in the lakes. Flow in these basins may cease after freshet until the late summer rains begin. For rivers draining larger basins, the freshet peak may be delayed after ice break-up compared to smaller drainages as snowmelt from upper portions of the watershed is routed through the system.

Smaller watersheds can also have more dramatic responses to precipitation. In larger watersheds, the presence of lakes creates significant flow attenuation and diminishes the magnitude of peak flows. The attenuation of flows in lakes also reduces risks of flooding in the area due to lower downstream peak flows.

The overall shape of the annual flow hydrograph for Arctic watersheds is relatively easy to predict. However, predicting the volume of freshet or the size of the peak flow during freshet is much more difficult. This is due to a number of factors that influence freshet runoff, including:

- *Amount of snowpack available to be melted in spring*. Snowpack is dependent on the amount of snowfall during the previous winter and the amount of snow remaining in each watershed in May or June. Snow can be lost or redistributed due to sublimation, melting, or wind;



Adapted from Woo (1990)

Note: Approximate scale only

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Theoretical Typical Annual Flow Hydrograph for a Small Arctic Watershed

Figure 2.1-1

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- *Rate of temperature rise in spring*. This can greatly affect peak flow rates as a rapid increase in temperature after the snowpack has saturated can produce high melt rates. Also there can be differential melt rates on north and south facing slopes which may affect the size of the contributing area to the melt;
- *Timing of opening of stream channels linking lakes*. In the Belt, snowmelt from hillslopes surrounding lakes can occur before the stream channel draining the lake becomes ice free. In this case, meltwater can be stored in the lake and then released once the channel is open to flow; and
- *Soil moisture conditions and lake levels at the end of the previous summer*. If there was a dry summer during the previous year, lake levels could have been lowered and a soil moisture deficit could have developed within the hillslopes surrounding the lakes. As a result, a portion of the annual runoff will recharge the lakes and soil moisture and not be transmitted from the watershed as stream flow.

The amount of runoff during summer and fall is controlled by rainfall and evaporation. Open-water evaporation rates in summer often exceed total rainfall such that soil moisture deficits build up in the shallow active layer of the soil. Studies of hillslope processes in northern watersheds (e.g., Quinton and Marsh 1998) have shown that summer rainfall may produce little or no runoff from hillslopes in the permafrost zone. In this case, stream flow increases only due to rain falling directly onto lake surfaces or when there is high intensity or lower intensity/higher duration rainfall.

2.2 STUDY AREA

2.2.1 Climate

The average annual temperature for the Doris and Boston areas was -10.0 and -9.9°C during the 2010/2011 hydrologic year. According to Environment Canada, based on 64 years of data, this was the second warmest winter on record in the Arctic Tundra region. The warmest year was 2010 (Environment Canada 2011). Temperature data were ranked from the warmest to the coolest year. Spring temperatures in the region were a little cooler and ranked 37th with a 0.3°C departure from the long-term mean. Total annual rainfall at both the Doris and Boston meteorological stations was 126.0 mm and 109.3 mm respectively. In terms of precipitation, winter 2011 ranked 21st with a positive 13.6% departure from the long-term mean. Precipitation data was ranked from wettest to driest. During the spring of 2011, the recorded precipitation amount was 35% below the long term average and ranked 60th in the data set.

2.2.2 Physiography

The Hope Bay Project is located within the Slave Structural Province, a geological sub-province of the Canadian Shield. The region is underlain by the late Archean Hope Bay greenstone belt, which is mainly comprised of mafic metavolcanic and meta-sedimentary rocks that are bound by Archean granite intrusives and gneisses.

The project area has been subjected to multiple glaciations and was overridden by the northwestern sector of the Laurentide Ice Sheet. The present day landscape reflects the predominant glacial ice movement of the most recent glaciation (Late Wisconsinan) through visible rock striations, orientation of eskers, depressional grooves and drumlins. According to Dyke and Dredge (1987) the region where the Project is located became ice free about 8,800 years ago when the ice sheet retreated toward the southeast, leaving a blanket of basal till.

Following deglaciation, the sea level was approximately 200 m higher than it is today. The entire Project area was submerged and marine sediments were deposited on top of the glacial till. As the landscape emerged due to isostatic rebound, the land surface was reworked and redistributed by waves, currents, and sea ice. Some of the existing rock outcrops were exposed as the thin soils were washed off the uplands and deposited in the valley bottoms. Since emergence, the landscape has been exposed to natural slope processes, frost action and permafrost (Dyke and Dredge 1989). What remains today at the surface is a mix of glacial till, marine sediments, as well as surficial sediments derived from glaciofluvial, lacustrine, and alluvial deposits.

The Project area is characterized by extensive networks of lakes and low relief topography. The Doris/Madrid area is located near the coast. The Boston area is located approximately 60 km inland, south from the Doris/Madrid area. The drainage basins are generally long and narrow and predominantly oriented along a north-south axis (Plate 2.2-1). Drainage basins are relatively flat, with a large percentage of lake area and high ridges along basin boundaries formed by rock outcrops. The local topography ranges from sea level at Roberts Bay to 158 m at the summit of Doris mesa, 3 km inland (Plate 2.2-2).

Plate 2.2-1. Oblique aerial view facing north in the Doris/Madrid area. The majority of the lakes are elongated and oriented on a north-south axis. Wolverine and Patch lakes are in the foreground of the photograph. Hope Bay is located in the background. Photograph taken on June 7, 2010.

2.2.3 Watersheds

The 2011 Study Area included four main watersheds (Figure 2.2-1): Koignuk (2,937 km^2), Windy-Glenn (48 km^2), Doris-Roberts (194 km^2), and Aimaokatalok (1,224 km^2). The Aimaokatalok Watershed is nested within the larger Koignuk Watershed which drains north into Hope Bay. The Windy-Glenn Watershed is located east of the Koignuk River and flows north into Roberts Bay via Glenn Lake. The Doris-Roberts Watershed is located east of the Windy-Glenn Watershed, and the outlet stream from Doris Lake flows north into Roberts Bay via the channel that drains Little Roberts Lake.

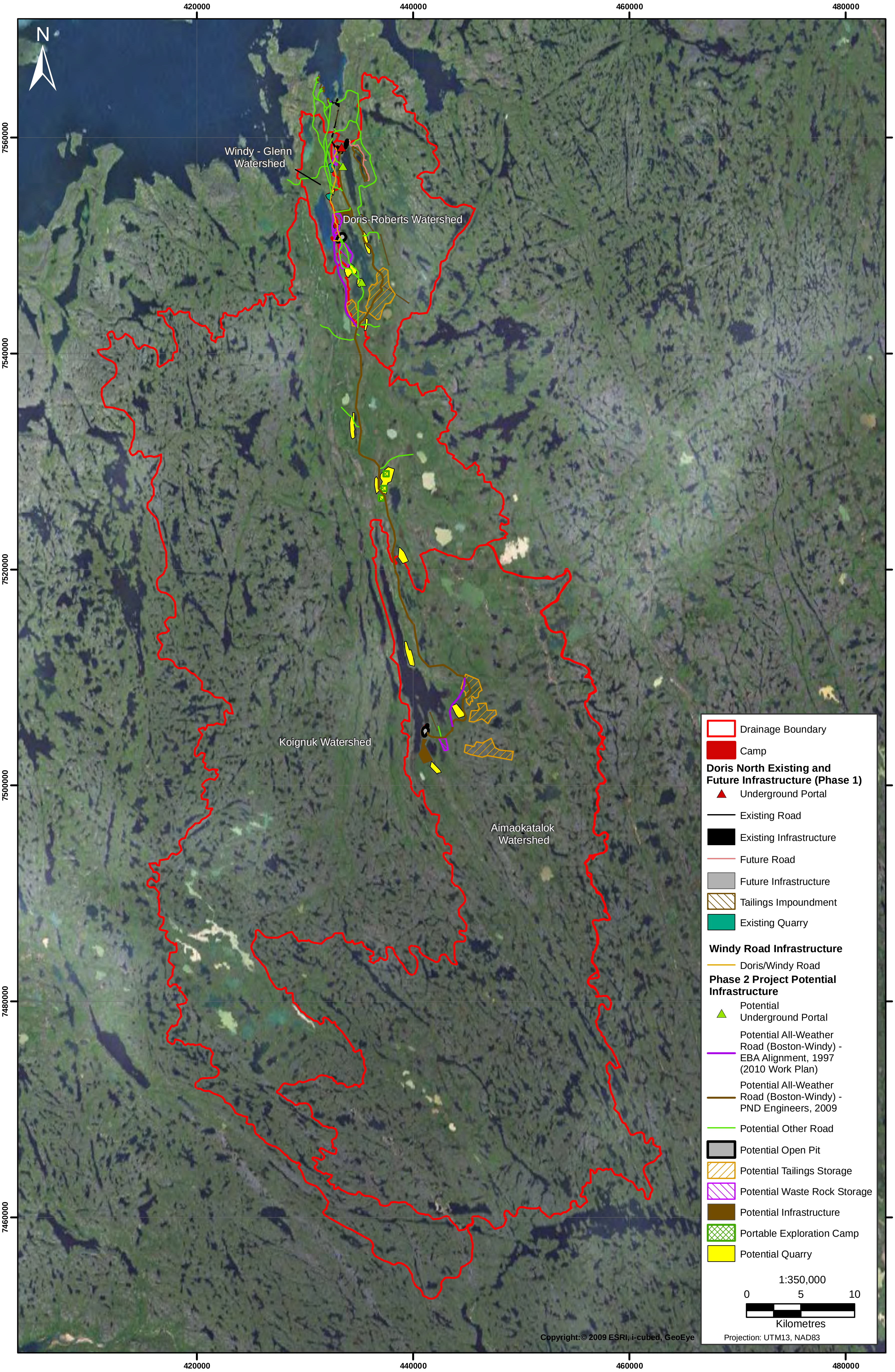

Figure 2.2-1

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Main Watersheds in the Study Area

Figure 2.2-1

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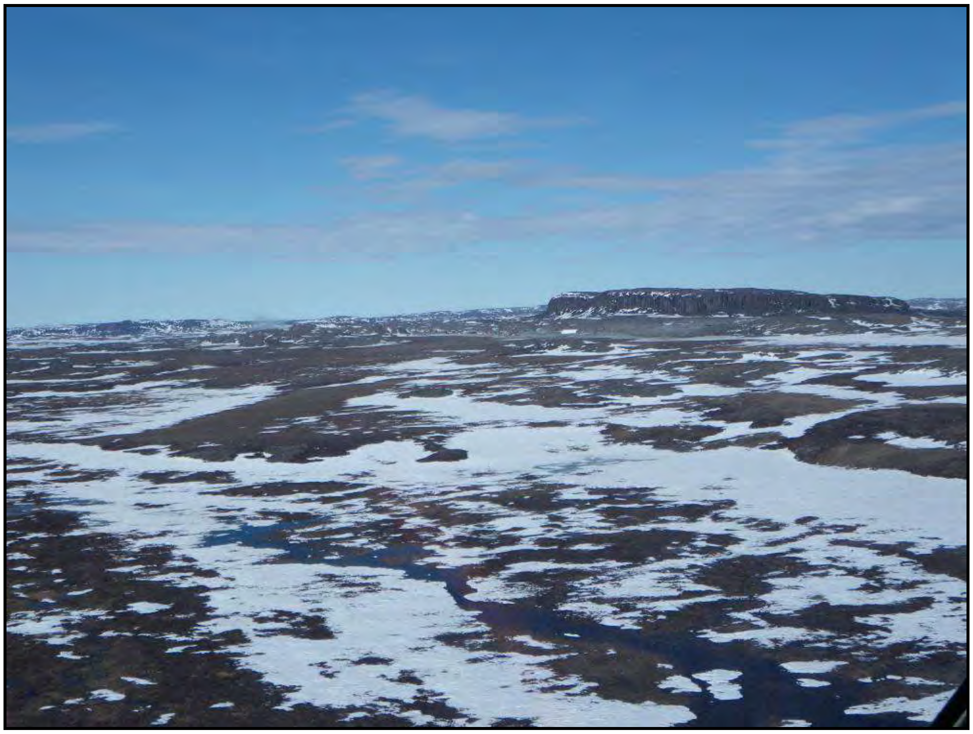

Plate 2.2-2. Oblique aerial view looking north in the Doris/Madrid area. In the distance note how Doris Mesa represents the highest terrain feature that dominates the surrounding landscape. Photograph taken on June 12, 2011.

2.3 AVAILABLE HYDROLOGIC DATA

2.3.1 Historical Site Data

Various hydrometric stations have been installed and operated throughout the Hope Bay Belt area since the mid-1990s. Multiple years of data are available for many of the major lake drainage outlets within the Doris/Madrid area. Fewer years of data are available for the Boston area. Hydrometric monitoring in the area began in 1993 at several sites where surface water flows and water levels were manually recorded. Automated monitoring began in 1996 and has continued to the present. However, the number of monitoring stations has changed from year to year over that period (Tables 2.3-1 and 2.3-2).

Table 2.3-1. Summary of Historic Hydrometric Stations in the Doris/Madrid Area

Monitoring Station	Geographic Location[a]		Drainage Area (km^2)	Years of Automated Data Collection
	Easting	Northing		
Doris Lake	433,513	7,558,451	94.6	2004-2011
Doris Lake Outflow (TL-2)	434,063	7,559,507	94.6	1996-1998, 2000, 2003-2011
Doris Lake Outflow (TL-3)	434,204	7,559,985	95.3	2011
Glenn Lake Outflow	430,616	7,561,906	31.6	1996-1998, 2000, 2006-2009
Koignuk River	429,739	7,554,336	2,937	2006-2011
Little Roberts Outflow	434,271	7,563,159	198.9	2003-2008
Ogama Inflow	436,617	7,550,891	64.6	1997

(continued)

Table 2.3-1. Summary of Historic Hydrometric Stations in the Doris/Madrid Area (completed)

Monitoring Station	Geographic Location[a]		Drainage Area (km²)	Years of Automated Data Collection
	Easting	Northing		
Ogama Lake and Outflow	435,648	7,555,130	72.1	1996-1998, 2006-2011
Patch Lake and Outflow	435,993	7,549,169	30	2006-2011
PO Lake	436,584	7,551,126	34.4	2007-2011
PO Lake Outflow	436,565	7,550,014	64.9	2007-2011
Roberts Lake and Outflow	435,289	7,562,800	97.9	2003-2011
Tail Lake	434,899	7,558,494	4.2	2004-2011
Tail Lake Outflow	434,273	7,559,147	4.2	2000, 2004-2010
Windy Lake and Outflow	431,507	7,555,043	14.1	2006-2011
Wolverine Lake and Outflow	435,222	7,545,888	1.97	2006-2011
Roberts Bay (tidal gauge)	432,612	7,563,336	n/a	2009-2011

[a] *UTM Zone 13W NAD 83.*

Table 2.3-2. Summary of Historic Hydrometric Stations in the Boston Area

Monitoring Station	Geographic Location[a]		Drainage Area (km²)	Years of Automated Data Collection
	Easting	Northing		
Aimaokatalak/Spyder River	441,634	7,499,360	769	2006-2008, 2010-2011
Aimaokatalak/Spyder Lake Outflow	438,847	7,509,056	1,224	2010,2011
Aimaokatalak/Spyder Lake	438,892	7,508,794	1,224	2006-2009, 2010[b]
Stickleback Outflow	441,934	7,504,127	2.6	1998, 2006-2008, 2011
Trout Outflow	442,699	7,503,688	31.9	2006-2008, 2011
Trout Inflow	442,599	7,502,024	27	2010
East Aimaokatalak/Spyder Lake Inflow	444,038	7,509,257	363	2010-2011
East Tailings Inflow	444,385	7,508,941	8	2010-2011

[a] *UTM Zone 13W NAD 83.*
[b] *Partial year only. Station malfunctioned in June 2010.*

2.3.2 Regional Data

Table 2.3-3 and Figure 2.3-1 present the locations of regional hydrometric stations operated by the Water Survey of Canada (WSC). Data from these stations were used to supplement the on-site data collected for 2011 in order to calculate annual runoff estimates for the Koignuk River. It is important to note that for those WSC stations still in operation, data were only available until the end of 2010.

Table 2.3-3. Regional Water Survey of Canada (WSC) Stations Relevant to the Study Area

Station Name	Station Number	Geographic Location		Drainage Area (km²)	Period of Record
Burnside River near the mouth	10QC001	66°43'30" N	108°48'42" W	16,800	1976-2011[a]
Tree River near the mouth	10QA001	67°38'6" N	111°54'9" W	5,810	1968-2011
Freshwater Creek near Cambridge Bay	10TF001	69°7'52" N	104°59'26" W	1,490	1970-2011

(continued)

Table 2.3-3. Regional Water Survey of Canada (WSC) Stations Relevant to the Study Area (completed)

Station Name	Station Number	Geographic Location		Drainage Area (km^2)	Period of Record
Ellice River near the mouth	10QD001	67°42'30" N	104°08'21" W	16,900	1971-2011
Back River below Beechy Lake	10RA001	65°11'14" N	106°5'9" W	19,600	1978-2011
Burnside River at outlet of Contwoyto Lake	10QC004	66°00'45" N	111°17'34" W	6056	1991-2011
Fairy Lake River near outlet of Napaktulik Lake	10PC005	66°15'7" N	113°59'7" W	6,442	1993-2011
Coppermine River above Copper Creek	10PC004	67°13'44" N	115°53'12" W	46,200	1987-2008
Kendall River near outlet of Dismal Lakes	10PC001	67°12'31" N	116°34'20" W	2,790	1969-2009
Gordon River near the mouth	10QC002	66°48'36" N	107°6'4" W	1,530	1977-1994

[a] *2011 data from the WSC real-time network are provisional. WSC has not yet completed necessary QA/QC on the data, and results may be revised once the process has been completed. Final datasets are typically available in the second quarter of the following year.*

PROJECT #1009-002-03 GIS # HB-10-008 November 24 2009

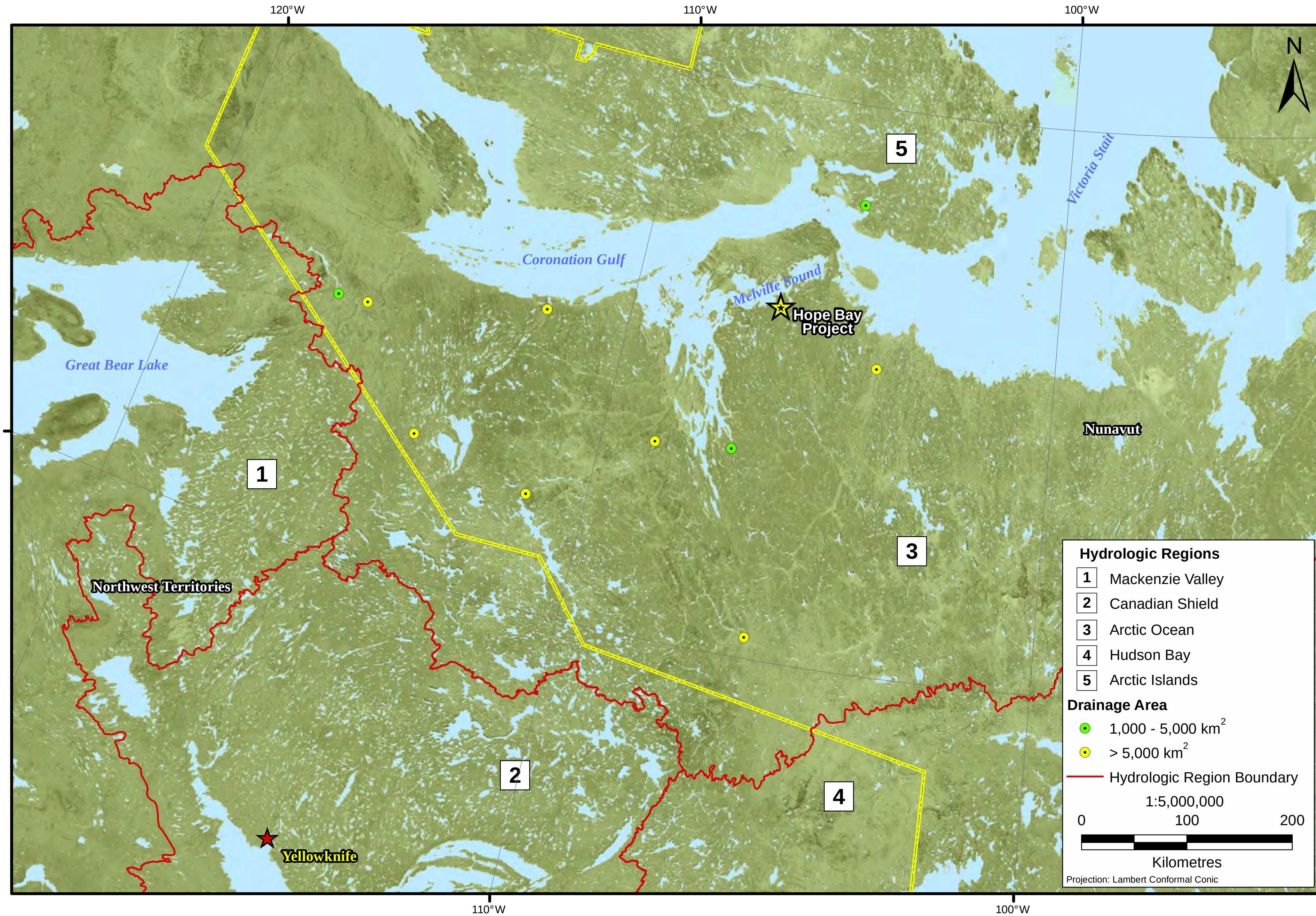

Figure 2.3-1

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WSC Hydrometric Stations near the Project Area with More than 5 Years of Hydrologic Data

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3. Methods

3. Methods

3.1 HYDROMETRIC MONITORING NETWORK

A network of 19 hydrometric stations monitoring surface water levels at different water bodies was operated during 2011 in the Doris/Madrid and Boston areas. Of the 19 stations, nine monitored stream surface water levels, nine monitored lake surface water levels, and one monitored ocean surface water levels (tidal gauge).

In the Doris/Madrid area, 11 hydrometric monitoring stations were remobilized in 2011, and one new station was installed (Table 3.1-1; Figure 3.1-1).

Table 3.1-1. 2011 Hydrometric Monitoring Stations of Streams and Lakes in the Doris/Madrid Area

Basin/Station	Geographic Location	Geographic Coordinates[a]		Drainage Area (km^2)	Period of Operation	Monitoring Type
		Easting (m)	Northing (m)			
Doris-Roberts Watershed						
TL-2 (Doris Creek, upstream location)	Doris Lake Outflow, downstream of new bridge	434,059	7,559,504	94.6	June 9 to October 17	stream water level
TL-3 (Doris Creek, downstream location)[b]	Doris Creek, downstream of Doris Falls	434,204	7,559,985	95.3	July 22 to September 25	stream water level
Doris Lake	Doris Lake	433,512	7,558,452	94.6	January 1 to September 24[c]	lake water level
Tail Lake	Tail Lake	434,899	7,558,452	4.2	January 1 to September 24[c]	lake water level
Ogama-Hydro	Ogama Lake outflow	435,501	7,555,173	75	June 21 to September 23	stream water level
Patch-Hydro	Patch Lake	436,062	7,549,169	32	June 21 to September 23	lake water level
PO-Hydro	PO Lake	436,549	7,550,584	68	June 7 to September 23	lake water level
Roberts-hydro	Roberts Lake	435,310	7,562,560	97.9	June 14 to October 4	lake water level
Wolverine-Hydro	Wolverine Lake	434,802	7,545,443	3	June 20 to September 26	lake water level
Windy-Glenn Watershed						
Windy-Hydro	Windy Lake	431,481	7,555,089	14.1	June 21 to September 22	lake water level
Koignuk Watershed						
Koignuk-Hydro	Koignuk River	429,731	7,554,332	2,937	June 17 to September 24	stream water level
Reference-B Watershed						
Reference B-Hydro	Reference Lake outflow	427,077	7,529,965	159	June 18 to September 26	lake water level

(continued)

Table 3.1-1. 2011 Hydrometric Monitoring Stations of Streams and Lakes in the Doris/Madrid Area (completed)

Basin/Station	Geographic Location	Geographic Coordinates[a]		Drainage Area (km^2)	Period of Operation	Monitoring Type
		Easting (m)	Northing (m)			
Roberts Bay						
Roberts Bay (tidal gauge)	Roberts Bay, approx. 90 m east of existing jetty	432,612	7,563,336	n/a	July 24 to September 28	Ocean water level

[a] NAD 83, Zone 13 W.
[b] New station.
[c] Station remained in operation through the 2011-2012 winter.
n/a - not applicable.

In the Boston area, five hydrometric monitoring stations were remobilized, and one new station was installed in 2011 (Table 3.1-2; Figure 3.1-2).

Table 3.1-2. 2011 Hydrometric Monitoring Stations of Streams and Lakes in the Boston Area

Basin/Station	Location	Geographic Coordinates[a]		Drainage Area (km^2)	Period of Operation	Monitoring Type
		Easting (m)	Northing (m)			
Aimao Out Hydro	Aimaokatalok Lake outflow	438,847	7,509,056	1,224	June 20 to September 20	lake water level
Aimao In Hydro	Aimaokatalok River	441,637	7,499,326	725	June 20 to September 19	stream water level
East Aimao Hydro	Eastern tributary of Aimaokatalok Lake	444,038	7,509,257	363	June 10 to September 19	stream water level
East Tailings Hydro	Eastern tributary of Aimaokatalok Lake draining potential tailings storage	444,385,	7,508,941	8	June 12 to September 19	stream water level
Trout Hydro	Trout Lake outflow	442,599	7,502,024	31.9	June 11 to September 20	stream water level
Stickleback Hydro[b]	Stickleback Lake outflow	441,973	7,504,235	2.6	June 19 to September 20	stream water level

[a] UTM NAD 83, Zone 13.
[b] new station.

In 2011 the monitoring period of the hydrometric stations varied. The majority of the stations commenced operation during freshet in June 2011. The exceptions were the tidal gauge at Roberts Bay (remobilized in late-July) and the existing stations located at Doris and Tail lakes, which operated through the 2010-2011 winter. At the end of the open water season, in late-September, the majority of the stations were demobilized in order to prevent damage caused by freezing conditions. The exceptions were the stations located at Doris and Tail lakes, which remained in operation as of the last site visit on September 24, 2011. Instrumentation at these lakes was placed at a water depth below 5 m to prevent freezing damage during the winter months.

3.2 HYDROMETRIC STATION SETUP

All the automated hydrometric stations consisted of a pressure transducer and a data logger combination. The instrumentation recorded water level data, or stage, at specific time intervals. The station setup varied among the different stations operating within the project area. The following is a description of the setups used in the 2011 monitoring program.

*PROJECT #*1009-002-03 *GIS #* HB-10-026 *February 01 2012*

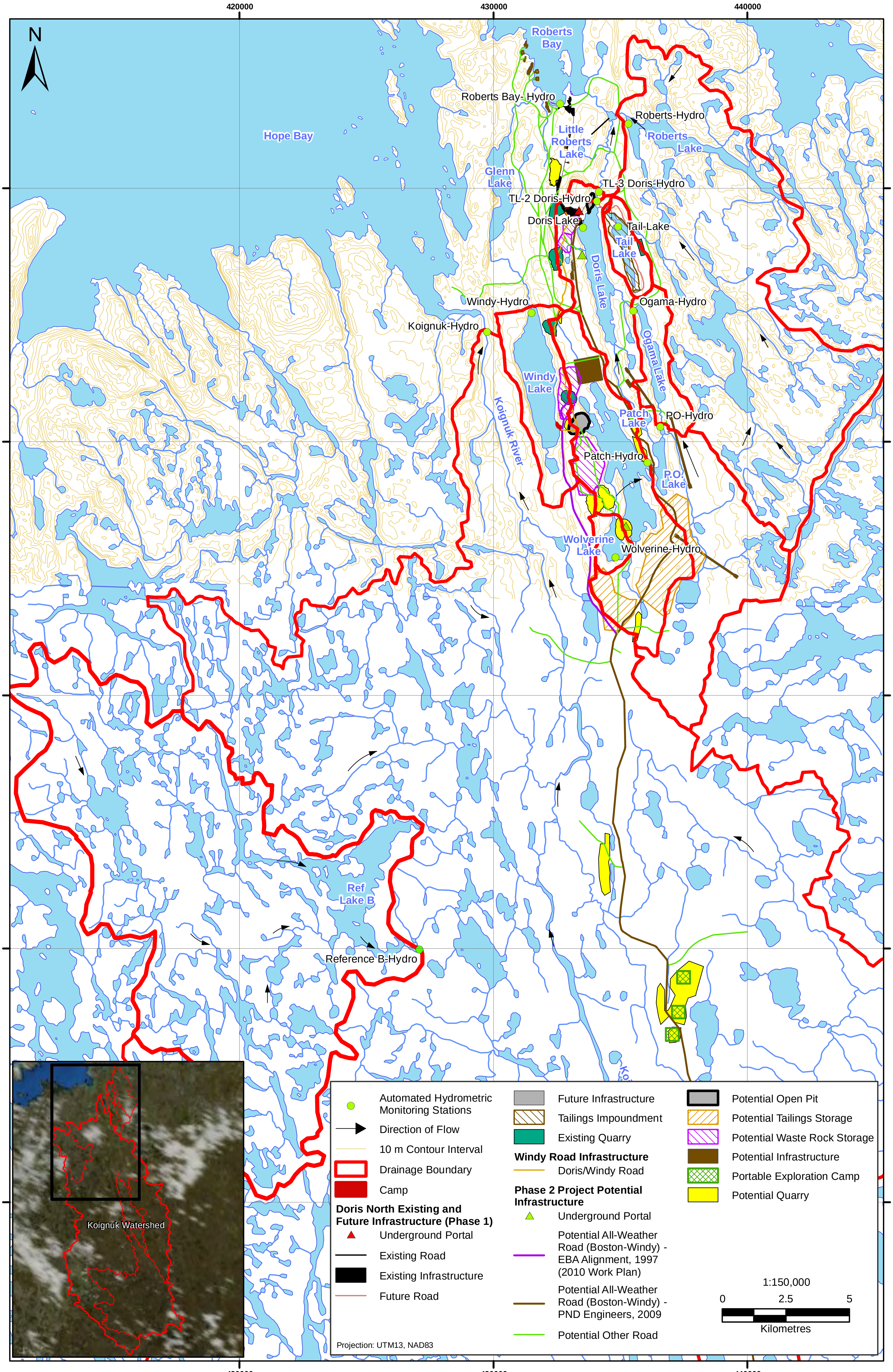

Figure 3.1-1

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Location of 2011 Hydrometric Monitoring Stations within the Doris/Madrid Area, Hope Bay Belt Project

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Figure 3.1-1