# Appendix V5-1E

Hope Bay Project: 2010 Hydrology Baseline Report

Hope Bay Mining Limited

# HOPE BAY BELT PROJECT
# 2010 Hydrology Baseline Report

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# HOPE BAY BELT PROJECT

# 2010 HYDROLOGY BASELINE REPORT

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**Prepared for:**

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# Executive Summary

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# Executive Summary

The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound. The property consists of a greenstone belt running in a north/south direction. The belt is approximately 80 km long, with 3 main gold deposit areas. The Doris and Madrid deposits are located in the north end of the belt and the Boston deposit is located in the south end of the belt.

The potential Phase 2 Project involves developing deposits in the Madrid and Boston areas and includes a proposed all-weather road connecting the north and south areas of the belt. Rescan Environmental Services Ltd. (Rescan) was contracted by Hope Bay Mining Ltd. (HBML) to carry out baseline studies to support the permitting of the Phase 2 Project in 2010.

This report presents the findings of the 2010 hydrology baseline study. The objective of the 2010 hydrology program was to collect additional hydrometric data to support permitting of the Phase 2 Project. This report presents the methods used to collect and analyze hydrometric data for 2010 as well as the results obtained for the basins located within the Doris/Madrid and the Boston areas. The report also includes a comparison of the 2010 results to on-site historical data and regional data.

A network of 18 hydrometric monitoring stations within the belt was operated during 2010. In the Doris/Madrid area nine hydrometric monitoring stations were remobilized, one new station was installed, and two existing stations were maintained. In the Boston area five new hydrometric monitoring stations were installed, and an existing hydrometric station at Aimaokatalok Lake was maintained.

The 2010 open water period extended from early-June until mid-November. In 2010, runoff estimates for drainage basins located within the belt were similar. The estimated mean annual runoff was 141 mm for basins in the Doris/Madrid area and 146 mm for basins in the Boston area.

Hydrologic conditions in 2010 were wetter than in 2009; the estimated annual runoff values were approximately 22% higher than in 2009. Compared to regional estimates, the annual runoff results obtained in 2010 are consistent with hydrologic wet conditions associated with a 1-in-20 year recurrence interval.

The timing of the annual peak flows was similar for the drainage basins located in the belt. Peak flows occurred during the spring freshet period in mid-June to mid-July, driven by snowmelt. The observed instantaneous peak flows for the drainage basins in the Doris/Madrid area ranged from 0.2 $m^3/s$ at Tail Outflow to 205 $m^3/s$ at the Koignuk River near its discharge point into Hope Bay. Observed peak flows for the drainage basins located within the Boston area ranged from 0.6 $m^3/s$ at East Tailings-Hydro to 66 $m^3/s$ at East Aimao-Hydro. Peak flows in 2010 were higher than in 2009. Peak flows in most of the drainage basins in the belt equalled or exceeded the magnitude of events associated with a 1-in-100 year recurrence interval.

Observed low flows for the drainage basins in the Doris/Madrid area occurred in early-to-late September and ranged from 0.02 $m^3/s$ at Tail-Hydro to 6.75 $m^3/s$ at Koignuk-Hydro. The observed low flows for the drainage basins in the Boston area occurred in mid-August to early-September and ranged 0.001 $m^3/s$ at East Tailings-Hydro to 3.05 $m^3/s$ at Aimao Out-Hydro.

In the Doris/Madrid area changes in lake water levels recorded from June 1st to October 3rd ranged from 0.10 m at Windy Lake to 0.68 m at Doris Lake, respectively. In the Boston area the change in the estimated lake water levels from June 6th to September 26th was 2.13 m.

Tide levels were measured by a hydrometric station installed near the existing jetty located in the southern part of Roberts Bay from July 21st to October 2nd. The tides in Roberts Bay were microtidal (<2 m tidal range) and semi-diurnal (two high tides and two low tides per day). Daily tide ranges were generally between 0.20 and 0.44 m (average: 0.34±0.07 m), with a maximum tidal range (the difference between high and low water in one tidal cycle) of 0.53 m on September 7, 2010 during the spring tide.

# Acknowledgements

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# Acknowledgements

This report was prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd. The 2010 hydrology fieldwork was conducted by Xavier Pinto (M.Sc.) and Craig Hatt (Dipl. Tech. Engineering). The report was prepared and written by Xavier Pinto and technically reviewed by R.W. (Bob) Askin (M.Sc., MCSCE, P.Geo., P.Eng.). The project was managed by Deborah Muggli (Ph.D., M.Sc., R.P.Bio.)

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# Glossary and Abbreviations

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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.

| | |
|---|---|
| **ADCP** | Acoustic Doppler current profiler. |
| **7-day low flow** | The minimum average 7-day flow that occurs over a specified period, such as a month, season or year. |
| **Annual runoff** | Annual runoff is a measure of the hydrologic response of a watershed. It is often presented as a depth, in mm, over an entire watershed allowing direct comparison with precipitation totals. |
| **Bankfull Stage/Discharge** | The stage or discharge of a watercourse in which the stream completely fills its channel and the elevation of the water surface coincides with the bank margins. |
| **EC** | Environment Canada |
| **Flood frequency** | The frequency that a flood of a specified magnitude occurs, inversely related to flood return period (see Return Period). |
| **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 graphical plot of water discharge versus time. |
| **NAD 83** | North American Datum 1983. A datum is a reference system for computing or correlating the results of a survey. The NAD83 datum is based on the spheroid (GRS80). |
| **Qn (Q2, Q20, Q100, Q200)** | The water discharge that is equalled or exceeded on average once every n years. |
| **Return Period** | The average interval at which an event occurs, calculated from the probability of its occurrence in a given year. |
| **Stage** | The depth of water in a water course or channel |
| **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. |
| **WSC** | Water Survey of Canada |
| **USGS** | United States Geological Survey |
| **UTM** | Universal Transverse Mercator. A mathematical transformation (map projection) of the earth's surface to create a flat map sheet. |

# 1. Introduction

# 1. Introduction

The Hope Bay Belt Property is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the south shore of Melville Sound (Figure 1-1). The nearest communities are Omingmaktok (75 km to the southwest of the property), Cambridge Bay, and Kingaok (Bathurst Inlet; 160 km to the southwest of the property).

The property consists of a greenstone belt running in a north/south direction, approximately 80 km long, with 3 main gold deposit areas. The Doris and Madrid deposits are located in the northern portion of the belt, and the Boston deposit is located in the southern end. The northern portion of the property consists of several watershed systems that drain into Roberts Bay, and a large river (Koignuk River) that drains into Hope Bay. Watersheds in the southern portion of the belt ultimately drain into the upper Koignuk, which drains into Hope Bay.

Hope Bay Mining Limited (HBML) is proceeding with the development of the Doris North Project. Required licences and permits are in place for the development of the Doris North Gold Mine, and construction of the project commenced in 2010.

HBML plans to develop additional deposits in the belt, and planning for this Phase 2 Project development has commenced. Baseline studies to support the permitting of the Phase 2 Project were carried out in 2009, and were continued in 2010. The environmental baseline program conducted in 2010 was intended to fill in information gaps in order to support the permitting process for the Phase 2 Project, which is anticipated to start in 2011. The site layout options considered for the 2010 Phase 2 environmental baseline program are shown in Figure 1-2.

Results from the 2010 Phase 2 Project environmental baseline program are being reported in a series of reports, as follows:

- 2010 Hydrology Baseline Report
- 2010 Freshwater Baseline Report
- 2010 Freshwater Fish and Fish Habitat Baseline Report
- 2010 Marine Baseline Report
- 2010 Marine Fish and Fish Habitat Baseline Report
- 2010 Terrain and Soils Baseline Report
- 2010 Country Foods Baseline Report
- 2010 Ecosystems and Vegetation Baseline Report
- 2010 Marine Wildlife Baseline Report

In addition, numerous reports are being produced as part of the Doris North Project compliance requirements, and many of these reports cover the geographical areas of the proposed Phase 2 Project. Examples of Doris North Project compliance reports generated in 2010 that are relevant to the proposed Phase 2 Project include:

- 2010 Meteorology Compliance Report, Doris North Project
- 2010 Hydrology Compliance Report, Doris North Project

PROJECT # 1009-002-29 ILLUSTRATION # a23708w-DO November 17, 2010


Figure 1-1

# Hope Bay Belt Project Location

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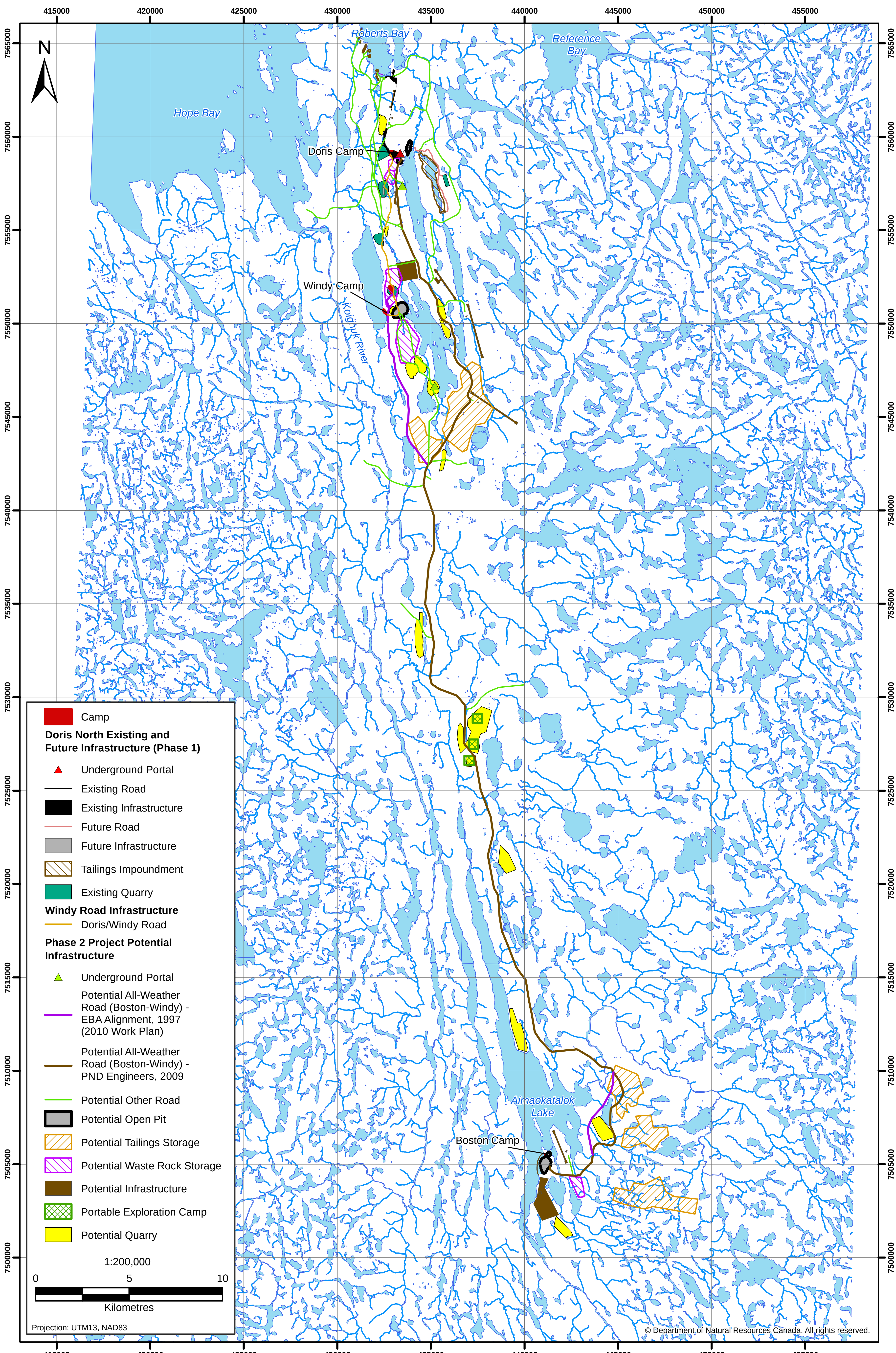


Figure 1-2

## Site Layout Options Considered for Phase 2 Baseline Program, 2010

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- 2010 Wildlife Monitoring and Mitigation Report, Doris North Project
- 2010 Wildlife DNA Study, Doris North Project
- 2010 Air Quality Compliance Reports, Doris North Project

Archaeology work was also conducted in 2010 and is being reported separately.

This report presents the results from the Hydrology portion of the 2010 Phase 2 environmental baseline program. The objectives of the 2010 hydrometric monitoring program were to:

- Continue with the monitoring program that was initiated in 2009 in the Doris/Madrid area; and
- Collect additional hydrometric data in the Boston area in areas 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 2010 to the available on-site historical data.

# 2. Hydrologic Setting

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## 2.1 ARCTIC HYDROLOGY

The Hope Bay Belt lies within the permafrost zone of the Canadian Arctic. This region is composed of vegetated tundra slopes with lakes and wetland fens scattered throughout the landscape. Hydrologic processes are dominated by snow accumulation and melt, surface runoff, and runoff routed through lakes. The annual flow hydrograph is defined by the long cold winters and the short summers. Most of the annual runoff occurs during spring freshet and is derived from the melting snow pack. Late August and September precipitation events can also produce moderate runoff. Following freshet, a low flow period typically develops through July and August. Due to the presence of permafrost, there is no groundwater contribution to the smaller streams. However, an interaction between local groundwater sources and larger rivers and lakes occurs through taliks or openings in the permafrost. As a result, baseflow in streams is low and supported only by flow through the shallow upper active layer of the soil profile, the only part of the soil profile that melts in the summer months.

The hydrologic year for the region is defined by freeze-up, which 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 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.

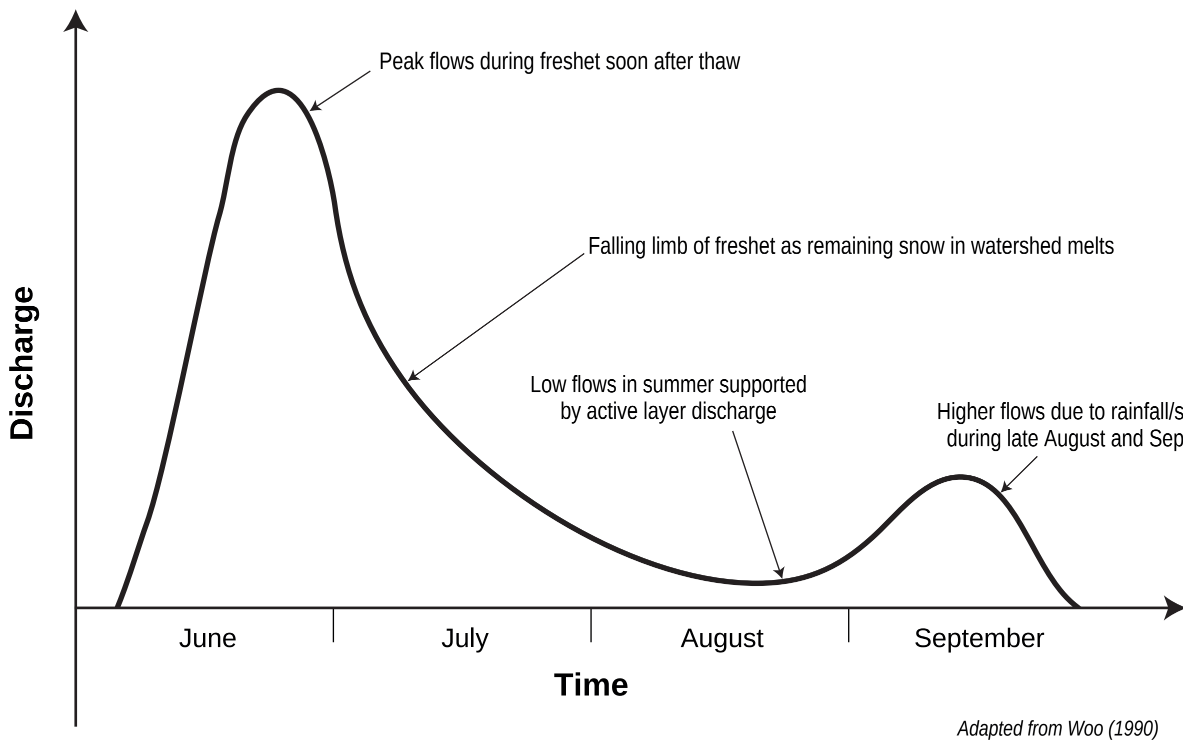
A conceptual hydrograph showing typical annual discharge patterns for small watersheds is shown in Figure 2.1-1. The hydrograph is characterized by a steep rising limb leading to a peak during the freshet period and a second rainfall-generated peak that can be observed in certain years in late August 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;




*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 WATERSHEDS

The Study 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. 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 (Plates 2.2-1 and 2.2-2).

The 2010 Study Area included four main drainages (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 of Doris Lake flows north into Roberts Bay of Melville Sound via Little Roberts Lake.

## 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 outflows 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 flow 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).

*Plate 2.2-1. Koignuk River facing upstream (south). Photograph taken on July 23, 2010.*

*Plate 2.2-2. Oblique aerial view facing north in the Doris/Madrid area. Doris Lake is on the right of the photograph with Doris mesa located near the northern end of the lake. Hope Bay is located in the background. Photograph taken on June 17, 2010.*