Appendix V5-1C

Doris Project Area 2008 Hydrology Baseline Update

March 2009

DORIS PROJECT AREA

2008 HYDROLOGY BASELINE UPDATE - DRAFT REPORT

Submitted to:
Hope Bay Mining Ltd.
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REPORT

Report Number: 08-1373-0026

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2 Copies: Hope Bay Mining Ltd., North Vancouver, BC
2 Copies: Golder Associates Ltd., Edmonton, AB

Golder Associates

EXECUTIVE SUMMARY

This report was commissioned to characterize the hydroclimatic and hydrological parameters at the Doris Project Area (the Project). The baseline is based on data collected from 2004 to 2008 as well as regional and site-specific data that were collected or reported in previous studies.

The report is intended to provide a basis for hydrological modeling and analysis that may take place during preparation of an environmental impact assessment. The model and derived parameters may be used to evaluate the effects of changes to hydrology at various phases of the Project, and to provide a design basis for water management infrastructure at the Project.

The baseline report characterizes hydroclimatic and hydrological parameters relevant to the Project, including the following:

- precipitation based on regional data and compared to site-specific data;
- lake evaporation based on regional and local data; and
- development of a time series runoff model for the Little Roberts Lake and Glenn Lake watersheds, including upstream waterbodies.

Available Site-Specific and Regional Data

Local data include snow depth and density, streamflow, water level, and meteorological data recorded during the years 2004 to 2008.

Regional temperature and precipitation data are available from several stations in Nunavut. The closest long-term station is Cambridge Bay A, located approximately 125 km north east of the Doris Project camp site. Climate data collection at Cambridge Bay A was initiated in 1929. Complete records are available from 1948 to 2008 with a data gap in 1993. The closest regional evaporation estimates are from a short-term stations operated by Indian and Northern Affairs Canada (INAC).

Baseline Climate Conditions

Air Temperature

Air temperature at the Project may fall below 0°C on any day of the year. The monthly mean air temperature is typically above 0°C for the months of June to September, and is below 0°C between October and May. July has been the warmest month and February has been the coldest month. The mean annual temperature for the period of record was -12.4°C.

Precipitation

Mean annual precipitation at the Project, based on the hydrological year from October 1 to September 30, was estimated to be 226.4 mm after accounting for rainfall and snowfall undercatch. Approximately 50% of precipitation occurs as rain (104.1 mm) and 50% occurs as snow (105.4 mm). The 24-hour extreme rainfall intensity with 10-year return period was estimated to be 1.2 mm/h, or 29.7 mm total depth. Corresponding values for the 100-year return period are 2.1 mm/h or 49.8 mm total depth.

Evaporation

Mean annual lake evaporation for small lakes at the Project is estimated to be 251 mm between June and September, based on the derived values for Doris Lake.

Wind Speed and Direction

The recorded prevail winds are from west and west-northwest. The wind blows from the west-northwest direction almost 20% of the time, and the least frequent wind direction is south-west with less than 2%. . The calm frequency is 10.9% of the time. The mean values for wind speed have the same characteristics and show that the west and west-northwest winds are having the highest mean speeds and tend to be the strongest.

Relative Humidity and Solar Radiation

The mean annual relative humidity at the Project was estimated to be 78.3%.

The mean monthly global solar radiation at the Project varied from 0.4 W/m^2 in May to 255.7 W/m^2 in December.

Hydrological Conditions

Water Yields

Derived mean annual water yields for lakes in the Little Roberts Lake and Glenn Lake watersheds vary from 72 mm (at Tail Lake) to 105 mm (at PO Lake). These are comparable to the long-term mean annual value of 85 mm at Freshwater Creek near Cambridge Bay.

Extreme Discharges

Flood peak and low flow discharges of various durations and frequencies were derived for lake outflows in the Little Roberts Lake and Glenn Lake watersheds and vary with watershed size, lake outflow geometry and upstream flow attenuation.

Conclusions

This ongoing climate and surface water hydrologic baseline provides a strong basis for environmental impact assessment and water management planning at the Project. The climate and hydrology characteristics described for the Project are based on long-term regional information as well as site-specific data that have been collected since 2004. The available data confirm that the Project fits within the established regional context of precipitation and runoff.

ACKNOWLEDGEMENTS

The authors would like to thank Chris Hanks (Director, Environment and Social Responsibility of Hope Bay Mining Ltd.) for offering us the opportunity to work on this project.

The following Golder Associates personnel participated in report preparation:

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1.0 INTRODUCTION

1.1 BACKGROUND

The Doris North Project was approved by the Nunavut Impact Review Board (NIRB), and a subsequent Project Certificate was issued to Miramar Mining Corporation in 2007. In December 2007, Miramar Hope Bay Ltd. and their operations at the Hope Bay Greenstone Belt, were purchased by Newmont Mining Corporation and reorganized as an affiliate known as Hope Bay Mining Ltd (HBML). As of September 2008, construction of the mine, mill, and tailings facility was placed on hold while HBML evaluated alternatives for development of a multi-mine project in the Hope Bay Greenstone Belt.

The Hope Bay Project Area consists of three component project areas: Doris North (Doris), Madrid, and Boston. The Doris and Madrid project areas are located in the northernmost part of the Hope Bay Belt and include several lake systems that drain into Roberts Bay. The Doris and Madrid project areas are located approximately 685 km northeast from Yellowknife and 125 km southwest from Cambridge Bay, approximately 5 km south of Melville Sound on the Arctic Ocean. The nearest mainland communities are Umingmaktok, located 75 km to the southwest, and Bathurst Inlet, located 160 km to the southwest (Figure 1.1).

The Boston Project Area is situated approximately 55 km south from the Doris and Madrid project areas and includes several lake and river systems that drain into Hope Bay.

1.2 OBJECTIVES

The 2008 Hydrology Baseline Update was commissioned to update the previous (AMEC 2003) climate and hydrology baseline for the Doris Project (the Project) Area. The update is based on new regional and site-specific data that were collected or reported since the interim Hydroclimatic Parameter Re-evaluation (Golder 2006a).

This report considers local data that are now available, and derives long-term hydrological characteristics based on comparison with regional data. The update is intended to characterize the long-term variation of key meteorological and hydrological parameters to provide a basis for impact assessment and water management design. The scope of the update includes waterbodies in the Little Roberts and Glenn lake watersheds, including local waterbodies that may be affected by the Madrid Project, but excluding the Koignuk River.

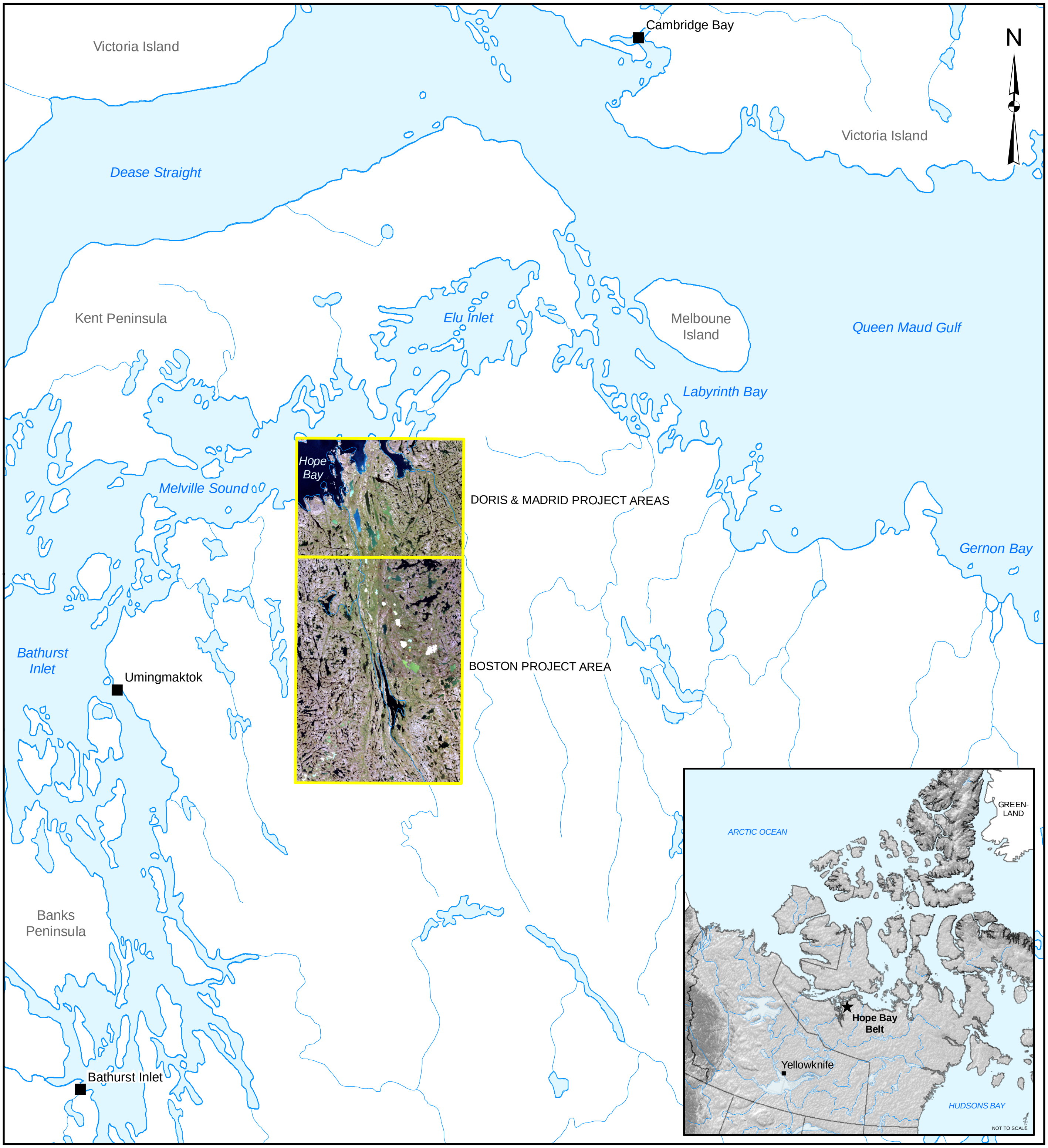
1.3 DATA SOURCES

Meteorology and hydrology baseline studies were carried out within the Boston Project Area from 1993 to 2000 and from 2006 to 2008. At the Doris Project Area, baseline studies were carried out from 1995 to 2008. Madrid Project Area baseline studies were conducted from 1995 to 2000 and 2006 to 2008. Climate and hydrology data collected from 1993 to 2002 were compiled and presented by Rescan (2002). Annual studies were subsequently conducted by Golder (RL&L/Golder 2003, Golder 2005, 2006b, 2007, 2008, 2009).

Data collected at the Project included:

- Meteorological data including air temperature, rainfall, wind speed and direction, relative humidity and solar radiation;
- spring snow course surveys; and
- water level and discharge measurements in local watersheds.

Additional regional data were compiled from other agencies, including Environment Canada and Indian and Northern Affairs Canada (INAC).



LEGEND

- ■ COMMUNITY
- WATERCOURSE
- WATERBODY
- STUDY AREA

40 0 40

SCALE 1:1325000 KILOMETRES

REFERENCE

Base data obtained from Government of Canada, Natural Resources Canada, Centre for Topographic Information (1:50 000). Landsat 7 imagery captured in 2007, obtained from CanImage.
Projection: UTM Zone 13 Datum: NAD 83

PROJECT

NEWMONT
The Gold Company

HOPE BAY MINING LTD.

TITLE

PROJECT LOCATION MAP

Golder Associates
Edmonton, Alberta

PROJECT NO. 08-1373-0026			SCALE AS SHOWN	REV. 1
DESIGN	JL	10 Mar. 2009	FIGURE: 1.1	
GIS	DC	20 Mar. 2009		
CHECK	DC	25 Mar. 2009		
REVIEW	NS	25 Mar. 2009		

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2.0 BASELINE HYDROCLIMATIC DATA

2.1 AVAILABLE DATA

Meteorological data are available locally at the Doris North climate station for the period of March 2004 to December 2008. Additional data are available from the Boston climate station, located 55 km to the south, which has a period of record from 1993 to 2008. The Boston data set is not continuous during that period due to various problems including power failures and the tower being blown over (AMEC 2003).

Long-term regional data are available from several Meteorological Service of Canada (MSC; a division of Environment Canada) stations located within 350 km of the Project (Environment Canada 2008a). These include Cambridge Bay Airport (period of record 1929 to 2008), Kugluktuk Airport (previously Coppermine; combined period of record 1930 to 2008) and Lupin Airport (previously Contwoyto; combined period of record 1959 to 2008).

Additional short-term regional data are available from INAC at Walker Bay, Nunavut. The station is located on the Kent Peninsula, approximately 70 km northwest of the Project, and is the closest station to the Project with available climate data. This station provides 12 years of record from 1996 to 2007.

Basic information on these stations is summarized in Table 2.1. Local and regional station locations are shown on Figure 2.1 and Figure 2.2 respectively.

Table 2.1: Climate Stations within 350 km of the Project

Station Name	Station ID	Period of Record	Elevation	Latitude (North)	Longitude (West)	Distance from Project
Doris North	CR10XDOR	2004 – 2008	36.0 m	68° 08.0’	106° 36.2’	0 km
Boston	CR10XBOS	1993 – 2008[a]	80.0 m	67° 39.0’	106° 22.6’	55 km S
Cambridge Bay A	2400600	1929 – 2008[b]	27.4 m	69° 06.6’	105° 08.4’	125 km NE
Kugluktuk A	2300902	1978 – 2008	22.6 m	67° 49.2’	115° 08.4’	350 km W
Coppermine	2300900	1930 – 1977	9.1 m	67° 49.8’	115° 07.2’	
Lupin A	23026HN	1982 – 2006	490.1 m	65° 45.6'	111° 15.0'	323 km SW
Contwoyto Lake	2300850	1959 – 1981	451.4 m	65° 28.8'	110° 22.2'	
Walker Bay (INAC)	n/a	1996 – 2007	40.0 m	68° 21.5'	108° 05.9'	70 km NW

(a) Incomplete precipitation records for most years.

(b) Incomplete records from 1929 to 1948 and 1993

3000 0 3000

SCALE 1:100000 METRES

LEGEND

- CAMP
- DORIS NORTH CLIMATE STATION
- HYDROMETRIC STATION
- MAJOR DRILLING SHOP
- CONTOUR (20 m INTERVAL)
- WATERCOURSE
- WATERBODY

REFERENCE

Base data obtained from Government of Canada, Natural Resources Canada, Centre for Topographic Information (1:50 000). Landsat 7 imagery captured in 2007, obtained from CanImage. Field data collected by Golder Associates Ltd., 2008.
Projection: UTM Zone 13 Datum: NAD 83

PROJECT

NEWMONT The Gold Company

HOPE BAY MINING LTD.

TITLE

CLIMATE AND HYDROMETRIC STATION LOCATIONS
DORIS PROJECT AREA

Golder Associates
Edmonton, Alberta

PROJECT NO. 08-1373-0026			SCALE AS SHOWN	REV. 0
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GIS	DC	20 Mar. 2009		
CHECK	DC	25 Mar. 2009		
REVIEW	NS	25 Mar. 2009		

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LEGEND

- ▲ CLIMATE STATIONS
- WATERCOURSE
- WATERBODY

75 0 75

SCALE 1:2500000 KILOMETRES

REFERENCE

Base data obtained from Government of Canada, Natural Resources Canada, Centre for Topographic Information (1:50 000).
Projection: UTM Zone 13 Datum: NAD 83

PROJECT

NEWMONT The Gold Company

HOPE BAY MINING LTD.

TITLE

REGIONAL CLIMATE STATION LOCATIONS

Golder Associates
Edmonton, Alberta

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CHECK	DC	25 Mar. 2009		
REVIEW	NS	25 Mar. 2009		

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2.2 AIR TEMPERATURE

2.2.1 Annual and Monthly Air Temperatures

Continuous air temperature data are available at the Doris North climate station from late February 2004 to December 2008. These temperatures were compared to concurrent records at the Environment Canada station at Cambridge Bay A (Station 2400600) and are presented in Figure 2.3. Figure 2.3 shows that daily temperatures in the Project are similar to those recorded at Cambridge Bay A. Temperatures recorded at that station were thus used to characterize long-term temperatures at the Project. Temperatures from Cambridge Bay A were also compared to concurrent records from the INAC Walker Bay station. The comparison, presented in Appendix A, shows a close correlation between the two stations.

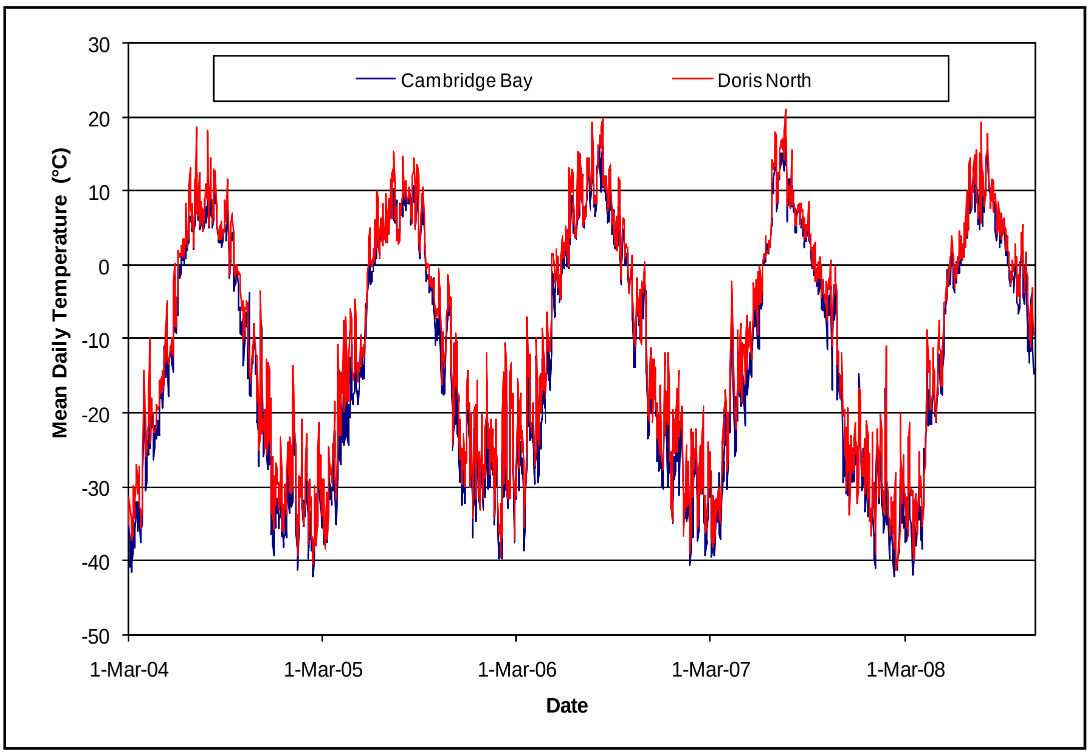

Figure 2.3: Mean Daily Air Temperatures at Doris North and Cambridge Bay A Climate Stations, March 2004 to December 2008

Continuous air temperature data are available at the Cambridge Bay A climate station for the period of 1929 to 2008. Most records are incomplete from 1929 to mid-January 1948 and also for 11 months in 1993. Long-term air temperatures at the Project were derived by applying a linear regression equation based on the concurrent records at the Cambridge Bay A and Doris North climate stations, to the period of record from 1948 to 2008 available at the Cambridge Bay A climate station. The linear regression between daily mean air temperature data from the Doris North and the Cambridge Bay A climate stations is shown in Figure 2.4.

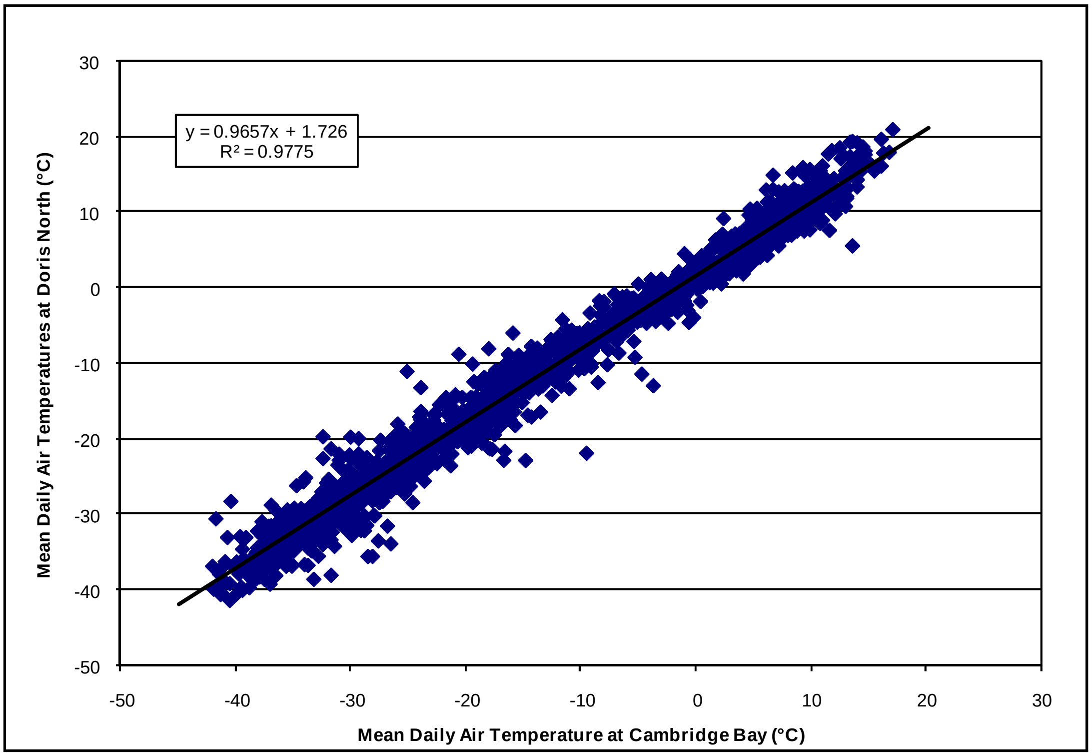

Figure 2.4: Correlation of Mean Daily Air Temperatures at Doris North and Cambridge Bay A Climate Stations, 2004 to 2008

Derived air temperature statistics at the Project for the period of 1948 to 2008 are presented on a monthly basis in Table 2.2 and on Figure 2.5. Monthly and annual temperature data for the Cambridge Bay A climate station for the period 1948 to 2008 are provided in Appendix B.

Air temperatures at the Project may fall below 0°C on any day of the year. The monthly mean air temperature is typically above 0°C for the months of June to September, and is below 0°C between October and May. July is the warmest month and February is the coldest month. The mean annual temperature over the period of record was -12.4°C.

The mean annual air temperature was -14.6°C at Cambridge Bay A over the period of 1948 to 2008. The mean annual air temperature was -11.5°C at the combined Lupin-Contwoyto station over the period 1959 to 2005 and was -10.9°C at the combined Kugluktuk-Coppermine station over the period 1933 to 2008. Long-term air temperature characteristics for these climate stations are provided in Appendix B.

Table 2.2: Derived Air Temperature Statistics at the Project (°C), 1948 to 2008

Month	Warmest and Coldest Day in the Month				Monthly Mean [(b)]
	Extremes		Means		
	Maximum	Minimum	Maximum	Minimum	
January [(a)]	-3.0	-46.0	-8.4	-44.9	-30.2
February	-4.6	-47.1	-11.0	-45.3	-30.8
March	-2.1	-43.9	-6.1	-41.4	-27.5
April	7.7	-39.6	0.4	-35.3	-19.1
May	12.8	-29.4	7.7	-22.7	-7.4
June	24.2	-15.5	17.5	-11.1	3.7
July	27.7	0.1	20.6	2.7	9.8
August	26.9	-6.9	19.2	-2.0	8.1
September	16.8	-14.9	11.2	-11.7	1.6
October	13.6	-30.1	5.7	-27.6	-9.1
November	0.2	-40.7	-1.1	-36.1	-20.7
December	-6.4	-43.4	-6.00	-42.3	-26.7
Annual	**27.7**	**-47.1**	**20.6**	**-45.3**	**-12.4**

(a) 1949 to 2008 data were used due to the incomplete record in January 1948

(b) 1993 data were omitted from the analysis due to the incomplete record

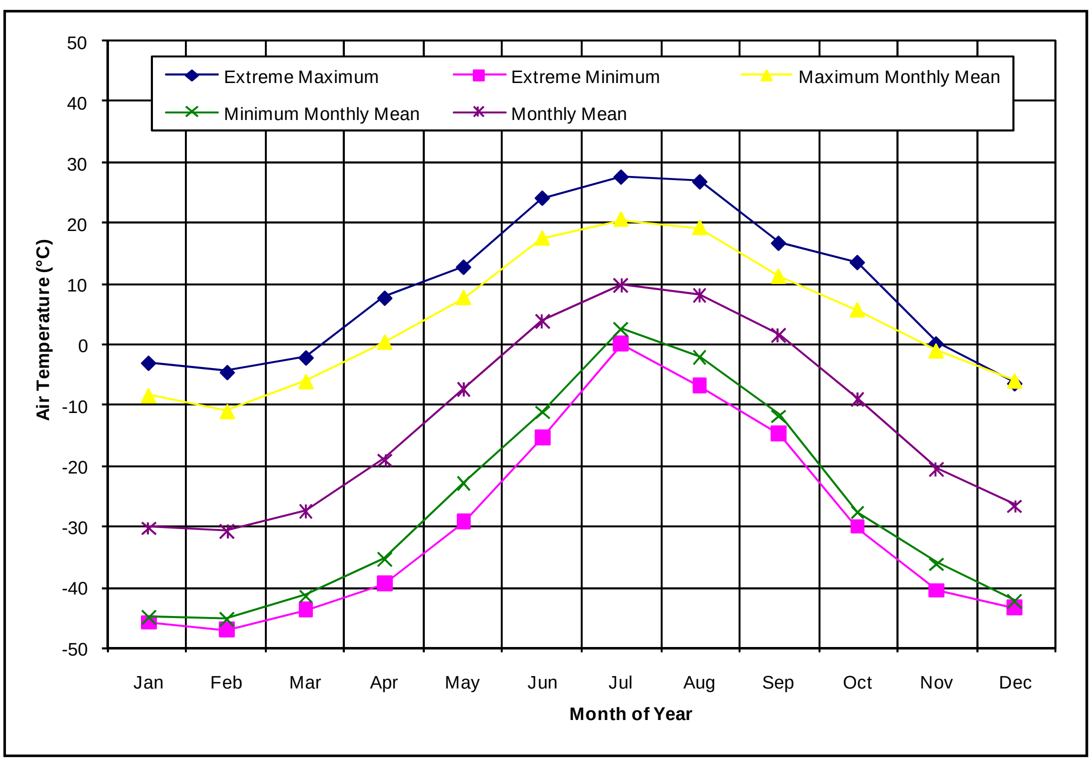

Figure 2.5: Derived Air Temperature Statistics at the Project, 1948 to 2008

Derived annual mean air temperatures at the Project are presented in Figure 2.6 for the period of 1948 to 2008. The 1993 value was omitted from the analysis due to incomplete data.

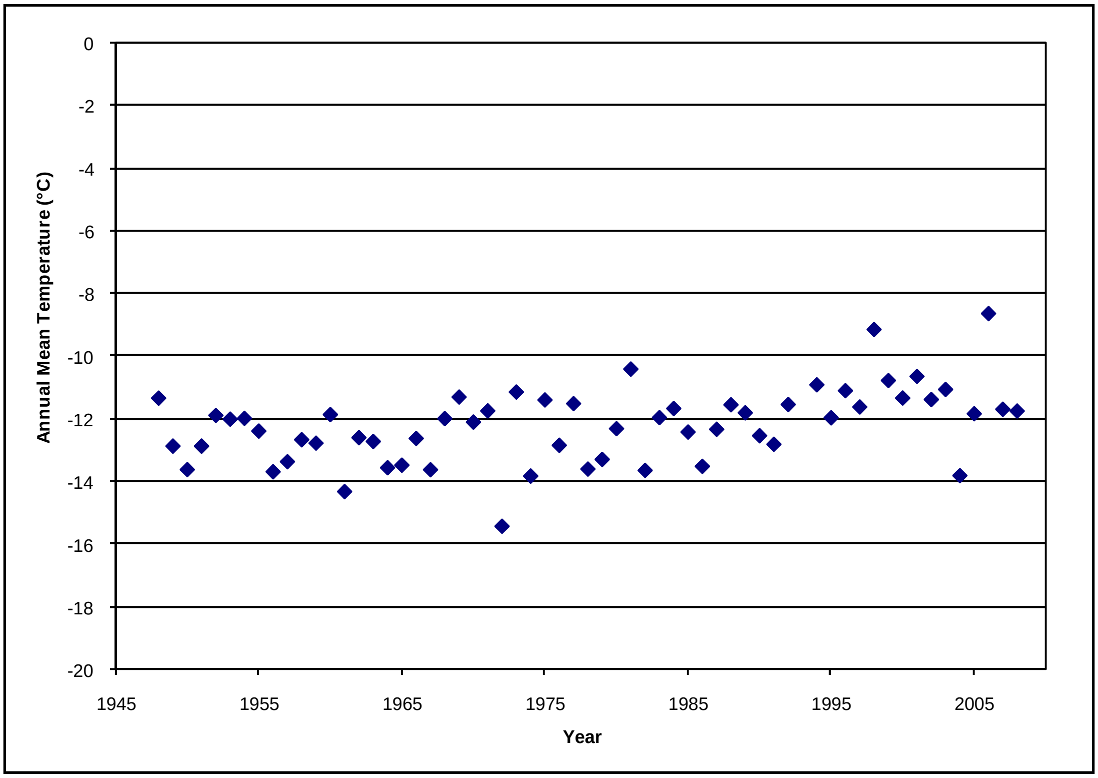

Figure 2.6: Derived Annual Mean Air Temperature at Doris North, 1948 to 2008

2.2.2 Discussion of Climate Change

The Draft Guidelines to Preparation of an EIS for the Sabina Silver Corporation's Hackett River Project (NIRB 2008) noted that "over the past 50 years, the western Arctic has experienced a warming trend" and, indeed, Figure 2.6 appears to show an upward trend in derived annual mean temperatures over the period 1948 to 2008. These values were based on data from the MSC climate station at Cambridge Bay A.

Observations of the Cambridge Bay A climate station and inspections of historical records (Environment Canada 2008b) provide the following information that is not available on the Environment Canada web site:

- the station was relocated three times in 1952, in 1960 and at some point between 1999 and 2002. These locations are presented in Figure 2.7;
- the first two locations (until 1960) were sited on land cover that is representative of the local area, with no exposure to buildings affecting the ventilation of the temperature sensor. These locations were across the bay, east from the town site;
- the third location (1960 to approximately 1999) was sited on land cover that is representative of the local area, but with exposure to several buildings and two roads. This location was approximately five kilometres west-southwest of the previous station, at the existing airport; and

1500 0 1500

SCALE 1:40000

METRES

LEGEND

- ▲ WEATHER STATION LOCATION
- ROAD
- WATERCOURSE
- AIRPORT
- WATERBODY

(*) Station was relocated between 1999 and 2002

REFERENCE

Base data obtained from Government of Canada, Natural Resources Canada, Centre for Topographic Information (1:50 000).
Projection: UTM Zone 13 Datum: NAD 83

PROJECT

NEWMONT
The Gold Company

HOPE BAY MINING LTD.

TITLE

ENVIRONMENT CANADA CLIMATE STATION
CAMBRIDGE BAY A (2400600)
HISTORICAL LOCATIONS

Golder Associates
Edmonton, Alberta

PROJECT NO. 08-1373-0026			SCALE AS SHOWN	REV. 1
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GIS	DC	20 Mar. 2009		
CHECK	DC	25 Mar. 2009		
REVIEW	NS	25 Mar. 2009		

- the existing station (approximately 1999 to present) is located on a bare gravel pad that may have a microsite effect on surface albedo. This location is approximately 200 m east-southeast of the previous location

Ideal site exposure for climate stations is described by Davey and Pielke (2005) as open sites allowing for ample ventilation of the temperature sensor, with homogeneous land cover representative of the region. It is further discussed that “the complex interaction of various field plots [such as gravel surface beneath the sensor] could have a marked influence on temperature readings at the site”.

Magee et al. (1999) suggest that man-made surface modifications on vegetation could result in temperature differences. The authors state that “evapotranspiration processes in plants help to cool an area; thus, a significant vegetation deficit could result in higher temperatures.”

A study was performed on the climate station located at the Resolute, Nunavut airport (Woo et al. 1999). This study reported that climate conditions at the airport were warmer with a lower snow albedo due to human settlement, when compared to adjacent rural sites.

Biases caused by microclimatic change around individual climate stations, including painting of the Stevenson screen housing the thermometer, instrument relocations, vegetation growth or removal, and construction of infrastructure, should be considered when making any judgments on climate change based on temperature data from this station.

The precise effects of local development on temperatures measured at northern climate stations can not be quantitatively defined. However, it appears that documented changes at the Cambridge Bay A climate station, including changes to ground cover and to snow albedo due to increases in human population and proximate activity, are likely to have introduced a warming bias over the period of record. Therefore, the observed temperature trend is likely greater than what the actual trend would have been in the absence of local human activity.

2.3 PRECIPITATION

Long-term precipitation data in the Project area are sparse. Continuous local data are available at the Doris North climate station for the period 2004 to 2008.

AMEC (2003) identified three MSC climate stations with long-term periods of record (Table 2.1). Data from these stations up to 2001 provided a basis for the derived Doris North precipitation values presented by AMEC (2003). An update of this information and analysis is provided in the following sections.

2.3.1 Environment Canada

Precipitation data recorded at the Cambridge Bay A climate station from 1982 to 2006 were compared with the concurrent records from the Kugluktuk A and the Lupin A climate stations, as shown on Figure 2.8. This period of record was selected because data are only available from 1982 to 2006 at the Lupin A climate station.

Figure 2.8 shows drier conditions recorded at Cambridge Bay A than at Kugluktuk A and Lupin A. Golder (2006b) reported that monthly and annual rainfall in the Project area are similar to those recorded at the MSC station at Cambridge Bay A and that station will be used to derive the precipitation at the Project. Rainfall data from Cambridge Bay A were also compared to concurrent records from the INAC Walker Bay climate station. The comparison, presented in Appendix A, shows a close correlation between the two stations.

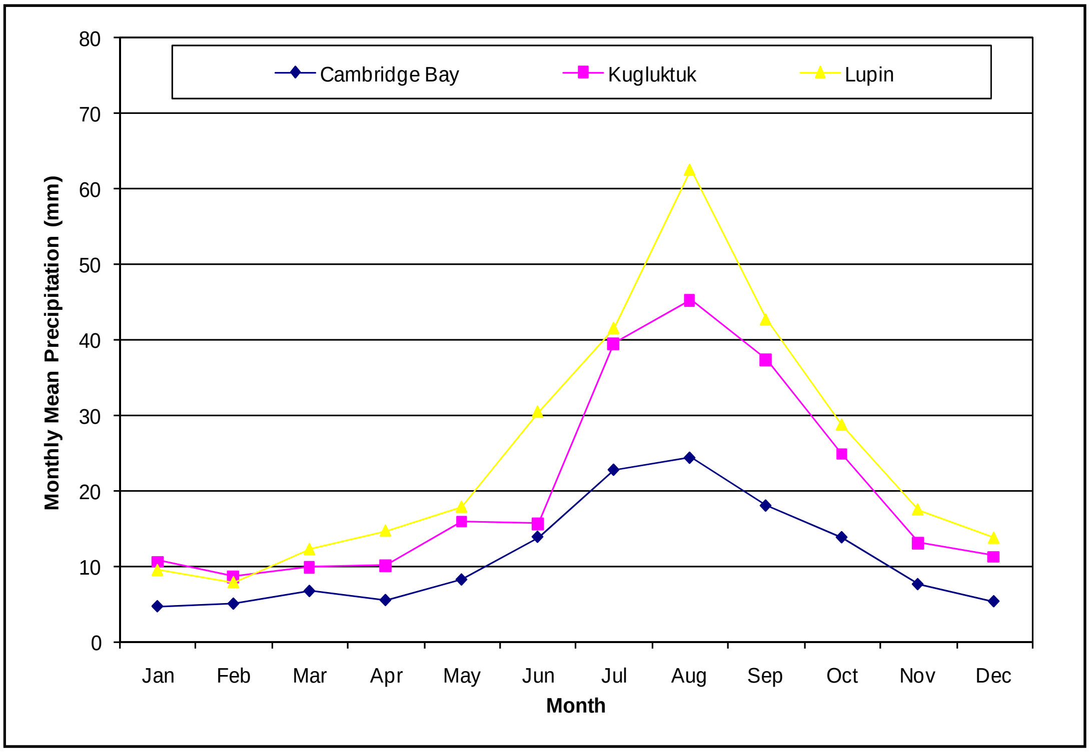

Figure 2.8: Comparison of Monthly Precipitation at Cambridge Bay A, Kugluktuk A and Lupin A MSC Climate Stations

Daily rainfall, snowfall and total precipitation data are available at the Cambridge Bay A climate station for the period 1929 to 2008. Most records are incomplete from 1929 to mid-January 1948 and for 11 months in 1993. Environment Canada, through the Adjusted Historical Canadian Climate Database (AHCCD), provides adjusted precipitation values for undercatch (refer to Section 2.3.4) for the period 1940 to 2007 (Environment Canada 2008c). As with the recorded data, most of the records are missing from 1940 to January 1948. Thus, only data from 1948 to 2007 were considered in the analysis. For the year 1993, most of the daily values are missing, but both AHCCD and the MSC provide monthly values, which were used in the analysis.

The MSC (Environment Canada 2008a) reports the precipitation as “the sum of the total rainfall and the water equivalent of the total snowfall observed during the day” and the rainfall as “the total rainfall, or amount of all liquid precipitation such as rain, drizzle, freezing rain, and hail, observed during the day”. The snowfall values in the report are presented in millimetres and are obtained by subtracting the rainfall values from the precipitation values.

Mean monthly and annual precipitation data recorded at the Cambridge Bay A climate station are provided in Table 2.3, and monthly and annual precipitation values for each year are provided in Appendix C.

The adjusted mean monthly and annual values provided by AHCCD are presented in Table 2.4. Appendix C contains the monthly and annual adjusted precipitation values for each year. Records are missing in January 1948, November 1994 and October 1995.

Table 2.3: Recorded Mean Monthly and Annual Precipitation, Snowfall and Rainfall at Cambridge Bay A, 1948 to 2008

Month	Total Precipitation (mm)	Snowfall (mm)	Rainfall (mm)
Jan	4.9	4.9	0.0
Feb	4.4	4.4	0.0
Mar	5.7	5.7	0.0
Apr	6.2	6.1	0.1
May	8.7	7.6	1.1
Jun	13.2	3.8	9.4
Jul	22.7	0.1	22.6
Aug	27.3	1.2	26.2
Sep	17.6	7.1	10.4
Oct	14.7	14.1	0.7
Nov	7.5	7.5	0.0
Dec	5.4	5.4	0.0
Annual	**138.3**	**68.0**	**70.3**

Note: mm= millimetres

Table 2.4: Adjusted Mean Monthly and Annual Precipitation, Snowfall and Rainfall at Cambridge Bay A, 1948 to 2008

Month	Total Precipitation (mm)	Snowfall (mm)	Rainfall (mm)
Jan	9.5	9.4	0.0
Feb	8.8	8.8	0.0
Mar	10.7	10.7	0.0
Apr	11.4	11.2	0.2
May	15.6	13.3	2.3
Jun	18.4	5.8	12.6
Jul	26.7	0.2	26.6
Aug	32.7	1.9	30.8
Sep	25.4	11.8	13.6
Oct	24.5	22.6	1.8
Nov	14.2	14.1	0.1
Dec	10.5	10.5	0.0
Annual	**209.3**	**120.6**	**88.1**

Note: mm= millimetres

A comparison between the recorded and the adjusted mean annual values based on the calendar year for Cambridge Bay A climate station is provided in Table 2.5, with the previous reported undercatch factors by AMEC (2003) and the updated derived undercatch factors.

Table 2.5: Adjusted Mean Annual Total Precipitation, Snowfall and Rainfall based on Calendar Year at Cambridge Bay A, 1948 to 2008

	Observed (mm)	Adjusted (mm)	Undercatch Factor	
			AHCCD (2008)	AMEC (2003)
Rainfall	70.3	88.1	1.29	1.21
Snowfall	68.0	120.6	1.79	1.91
Precipitation	138.3	209.3	1.52	1.66

Note: mm= millimetres

Using the undercatch factor derived based on AHCCD data, the missing adjusted monthly values for January 1948, November 1994 and October 1995 were estimated based on the reported data at the Cambridge Bay A climate station and further used in the analysis.

The adjusted monthly precipitation data at the Cambridge Bay A climate station were used to derive the mean values for a hydrological year (Table 2.6). The hydrological year is defined to include most, if not all, precipitation that contributes to the annual runoff. At the Project, most precipitation occurring after 1 October will fall as snow and accumulate over the winter to contribute to the next year's runoff. The hydrological year is thus defined to extend from 1 October of the previous year to 30 September of the current year.

Table 2.6: Adjusted Mean Total Precipitation, Snowfall and Rainfall based on Hydrological Year at Cambridge Bay A, 1948 to 2008

	Hydrological Year		
	Observed (mm)	Adjusted (mm)	Undercatch Factor
Summer Rainfall	80.7	104.1	1.31
Spring Snowfall	57.8	105.4	1.85
Precipitation	138.7	208.9	1.52

Note: mm= millimetres

Summer rainfall was considered to be the rainfall that occurs during the period from June to September. Spring snowfall represents the amount of precipitation (mostly snowfall) occurring from October of the previous year until June of the current year. Differences between the calendar year and the hydrological year values are due to the fact that precipitation that occurs after 1 October and before 1 June is included in the snowpack and added to the spring snowfall value. Annual precipitation data based on hydrological year, as well as annual summer rainfall and spring snowfall, are presented in Appendix C.

Based on the values presented in Table 2.6, the proportion of adjusted precipitation that falls as rainfall during the summer months and the spring snowfall is almost equal (49.8% for summer rainfall; 50.2% for spring snowfall).

2.3.2 Doris North Precipitation

Rainfall data were collected at the Doris North climate station for the period February 2004 to December 2008. Monthly and annual recorded rainfall values are presented in Table 2.7.

Table 2.7: Recorded Monthly and Annual Rainfall at Doris North Climate Station, 2004 to 2008

Month	Year (mm)				
	2004	2005	2006	2007	2008
Jan		0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0	0.0
Apr	0.0	0.0	0.0	0.3	0.0
May	1.0	0.0	2.0	0.5	0.3
Jun	6.4	18.0	10.9	2.3	25.1
Jul	11.9	27.2	22.1	8.9	38.6
Aug	15.5	31.2	9.4	59.4	39.4
Sep	15.5	3.0	3.6	5.6	26.9
Oct	0.0	0.0	2.0	1.5	2.8
Nov	0.0	0.0	0.0	0.0	0.0
Dec	0.0	0.0	0.0	0.0	0.0
Annual	**50.3**	**79.5**	**50.0**	**78.5**	**133.1**

Note: mm= millimetres

Concurrent data recorded at Cambridge Bay A and Doris North climate stations for the period of March 2004 to December 2008 show similar rainfall patterns, as shown on Figure 2.9.

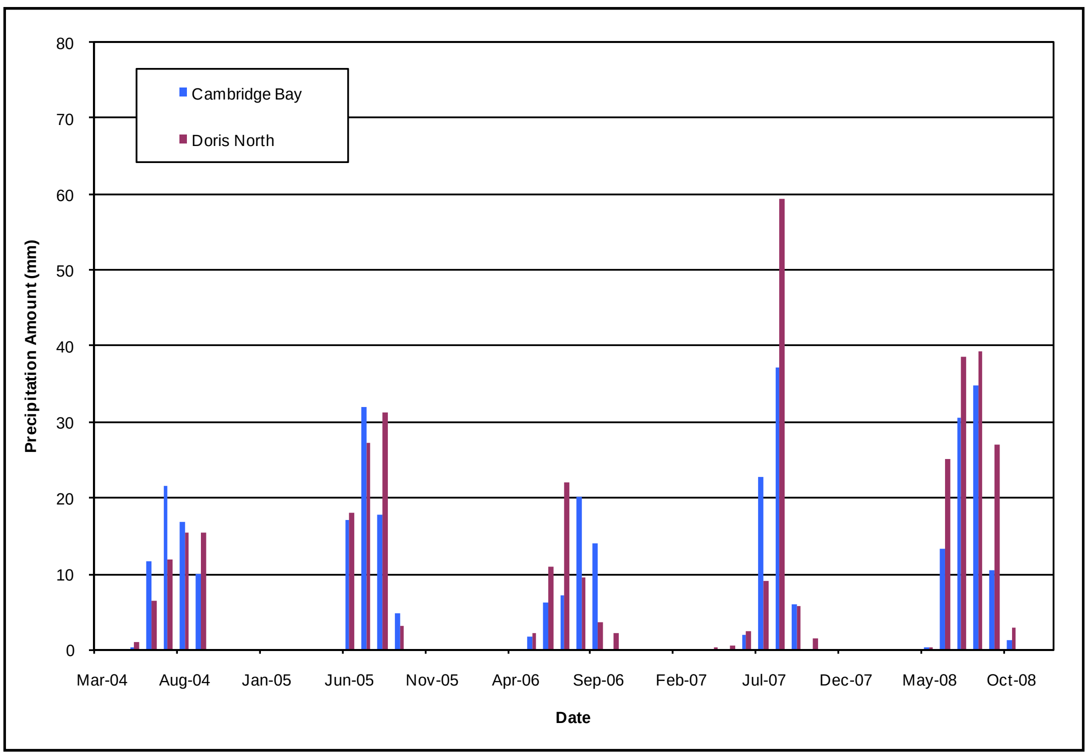

Figure 2.9: Recorded Rainfall Data at Cambridge Bay A and Doris North Climate Stations

A correlation factor of 1.11 was derived using a linear regression. The correlation is presented in Figure 2.10, and is based on concurrent monthly rainfall data, adjusted for undercatch, from the Cambridge Bay A and Doris North climate stations.

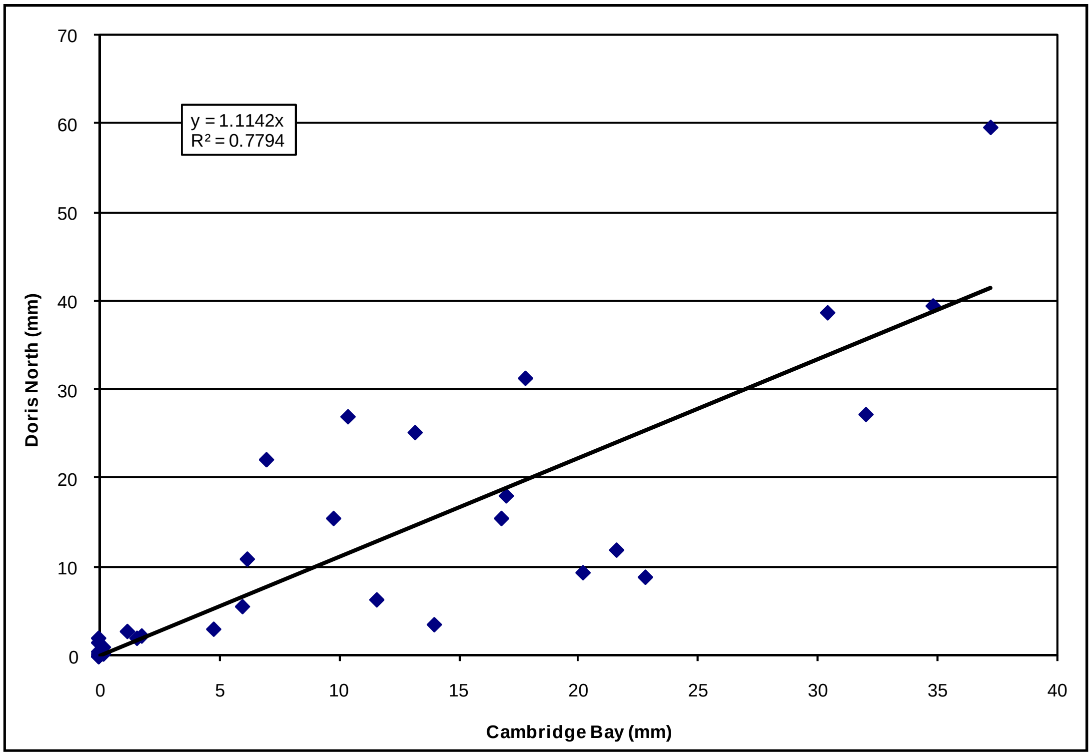

Figure 2.10: Recorded Monthly Rainfall at Cambridge Bay A and Doris North Climate Stations, 2004 to 2008

The derived monthly values for rainfall, snowfall and precipitation at the Project (Table 2.8) are based on the rainfall correlation factor, as no concurrent snowfall data are available at the two sites. Adjusted values for Cambridge Bay climate station for the period 1948 to 2008. Monthly and annual derived rainfall, snowfall and precipitation data for Doris North climate station for the period 1948 to 2008 are presented in Appendix C.

The driest calendar year on record occurred in 1954, with a total precipitation of 139.9 mm, or 60% of the mean. The wettest calendar year occurred in 1971, with a total recorded precipitation of 339.9 mm, or 146% of the mean. The mean annual value derived for the Project is 232.5 mm, including undercatch.

Derived annual precipitation values at Doris North are presented in Figure 2.11 for the period of 1948 to 2008. A frequency analysis of derived precipitation, snowfall and rainfall at Doris North is provided in Section 2.3.5.

Table 2.8: Derived Adjusted Mean Monthly and Annual Precipitation, Snowfall and Rainfall at the Project, 1948 to 2008

Month	Precipitation (mm)	Snowfall (mm)	Rainfall (mm)
Jan	10.4	10.4	0.0
Feb	9.7	9.7	0.0
Mar	11.9	11.9	0.0
Apr	12.6	12.4	0.2
May	17.0	14.5	2.5
Jun	20.9	6.8	14.2
Jul	29.7	0.2	29.5
Aug	37.0	2.1	34.9
Sep	28.3	13.2	15.2
Oct	27.7	25.7	1.9
Nov	15.6	15.5	0.1
Dec	11.5	11.5	0.0
Annual	**232.5**	**133.8**	**98.7**

Note: mm= millimetres

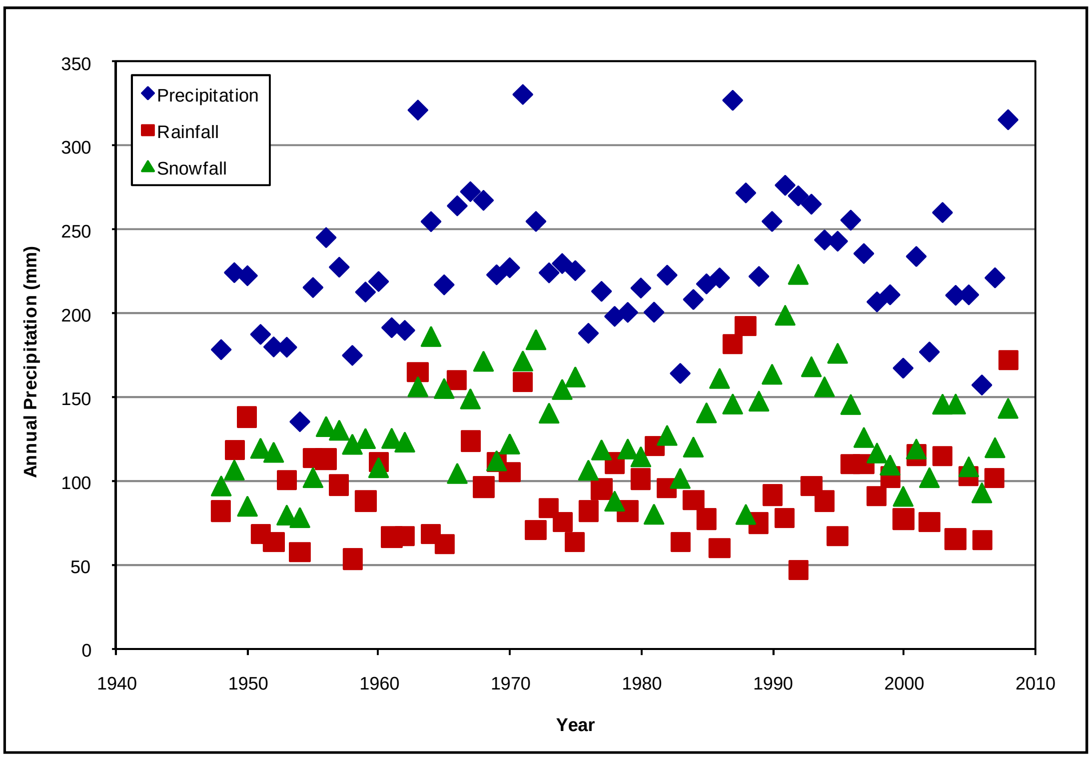

Figure 2.11: Derived Annual Precipitation at the Project, Calendar Years 1948 to 2008

2.3.3 Spring Snow Water Equivalent

Close to half of the region's water supply is derived from snow and thus the spring freshet plays a very important role in the water balance of regional waterbodies. The volume of spring snowmelt water depends on the quantity of snow accumulated and intercepted by vegetation, redistributed, and sublimated over the preceding winter.

Sublimation is the direct conversion of ice or snow to water vapour and can occur directly from static snowpack or during blowing snow events. The rates of sublimation depend on air humidity and wind speed (Essery et al. 1999; Déry and Yau 2002). Snow redistribution is done by wind and gravity.

Snow sublimation and redistribution can have an important effect on the amount of snow available for melt in the spring. In dry areas located above the treeline, wind redistribution and sublimation during blowing snow events can have a large effect on snow depths (Marsh et al. 1994; Pomeroy et al. 1997).

2.3.3.1 Environment Canada

Daily snowfall data were recorded at the Cambridge Bay A climate station from 1929 to 2008. As previously stated, most records are incomplete from 1929 to 1948 and in 1993. However, for 1993, monthly values are recorded in the AHCCD and thus used further in the analysis. The AHCCD (Environment Canada 2008c) has a homogeneous precipitation series from 1940 to 2007, where adjustments were applied on the daily level for rain and snow separately. However, between 1940 and 1948, most of the data are missing, so only the period from 1948 to September 2007 was considered for analysis. For snowfall, adjustments were done to account for trace events and density corrections.

The time period for each year used to derive the snowfall data for the spring snow water equivalent analysis was the hydrological year, which starts in October of the previous year and ends in September of the current year (Section 2.3.2). The observed and the adjusted annual snowfall values for the Cambridge Bay A climate station are presented in Appendix C.

The undercatch factor (Section 2.3.4) can be considered the ratio between the adjusted and the measured snowfall for each hydrological year. A mean value of 1.85 for the undercatch factor was calculated (Table 2.6). Using the adjusted snowfall values for the Cambridge Bay A climate station and the measured snow water equivalent (SWE) at Doris North for the period 2004 to 2008, the sublimation factor was derived (Table 2.9). This factor was highly variable between years and incorporates sublimation as well as differences in snowfall and snow redistribution.

The sublimation factor was applied to the adjusted snowfall values from Cambridge Bay A climate station to calculate the spring SWE for Doris North for the period 1948 to 2008 (Table 2.10). The calculated mean SWE value for the Project for the period 1948 to 2008 is 80.2 mm. A frequency analysis of derived spring SWE is provided in Section 2.3.5.

Table 2.9: Derived Sublimation Factor, 2004 to 2008

Period	Cambridge Bay Adjusted Snowfall (mm)	Doris North Measured SWE (mm)	Sublimation Factor
Spring 2004	112.0	56.1	0.50
Spring 2005	103.0	63.4	0.62
Spring 2006	96.2	79.0	0.82
Spring 2007	76.2	77.9	1.02
Spring 2008	105.8	93.1	0.88
		Mean	**0.77**

Note: mm= millimetres

Table 2.10: Cambridge Bay A and Doris North Snowfall Data, 1949 to 2008

Hydrological Year	Cambridge Bay A		Doris North
	Observed Snowfall (mm)	Adjusted Snowfall (mm)	Adjusted SWE (mm)
1949	49.2	78.7	60.4
1950	51.4	77.1	59.2
1951	48.8	76.7	58.9
1952	42.6	67.9	52.1
1953	67.5	99.6	76.5
1954	34.6	52.9	40.6
1955	50.1	82.4	63.3
1956	64.2	98.2	75.4
1957	53.1	83.2	63.9
1958	78.5	119.9	92.1
1959	63.4	96.6	74.2
1960	45.3	76.2	58.5
1961	44.6	76.1	58.4
1962	60.5	96.8	74.3
1963	80.7	128.3	98.5
1964	99.9	166.7	128.0
1965	90.1	159.7	122.6
1966	58.8	100.3	77.0
1967	59.0	105.7	81.2
1968	79.5	133.2	102.3
1969	54.6	109.9	84.4
1970	35.0	73.9	56.8
1971	53.0	117.2	90.0
1972	73.9	166.5	127.9
1973	42.9	99.6	76.5
1974	49.2	111.2	85.4
1975	77.2	141.5	108.7
1976	60.7	116.3	89.3
1977	59.4	108.3	83.2
1978	45.5	83.1	63.8
1979	48.6	84.4	64.8
1980	64.0	109.2	83.9
1981	32.2	65.0	49.9
1982	44.2	79.9	61.4
1983	44.4	82.7	63.5
1984	42.8	76.3	58.6
1985	76.2	135.4	104.0
1986	72.0	122.1	93.8
1987	48.7	107.2	82.3
1988	31.7	94.3	72.4
1989	46.6	106.4	81.7

Table 2.10: Cambridge Bay A and Doris North Snowfall Data, 1949 to 2008 (continued)

Hydrological Year	Cambridge Bay A		Doris North
	Observed Snowfall (mm)	Adjusted Snowfall (mm)	Adjusted SWE (mm)
1990	54.2	101.8	78.2
1991	62.0	144.8	111.2
1992	76.0	139.5	107.1
1993	106.3	218.1	167.5
1994	45.2	93.2	71.6
1995	88.8	153.8	126.4
1996	83.4	137.8	105.8
1997	52.4	86.6	66.5
1998	51.4	91.8	70.5
1999	80.5	127.7	98.1
2000	26.8	68.2	38.2
2001	57.6	108.7	83.5
2002	33.6	71.7	55.1
2003	63.2	122.2	93.8
2004	52.4	112.0	56.1
2005	56.2	103.0	63.4
2006	51.2	96.2	79.0
2007	41.0	76.2	77.9
2008	59.1	105.8	93.1
Mean	**57.8**	**105.4**	**80.7**

Note: mm= millimetres

2.3.3.2 Snow Survey Program 2004 to 2008

The 1993 to 2002 baseline program (Rescan 2002) reported SWE data, derived based on snow-on-ground data, but only intermittent data are available and was considered by previous reports (AMEC 2003) to be unreliable.

Late winter snow course survey observations were recorded at the Project from 2004 to 2008 to determine the SWE available at the start of the melting season. Snow depth and snow density measurements were performed over seven terrain type units. The terrain units and their characteristics are presented in Table 2.11, and the annual measured SWE values for each terrain unit are presented in Table 2.12.

Table 2.11: Snow Survey Terrain Units Characteristics

Terrain Unit	Characteristics
Open Lake	Open lake areas
Exposed Land	Areas with slope greater than 15 degrees
Low Land	Areas with slope lower than 3 degrees
North Aspect	North aspect areas with slope between 3 and 15 degrees
East Aspect	East aspect areas with slope between 3 and 15 degrees
South Aspect	South aspect areas with slope between 3 and 15 degrees
West Aspect	West aspect areas with slope between 3 and 15 degrees

Table 2.12: Measured Snow Water Equivalent (mm) for each Terrain Unit, 2004 to 2008

Terrain Unit	Year				
	2004	2005	2006	2007	2008
Open Lake	30.8	67.0	57.2	89.1	40.7
Exposed Land	45.6	67.8	63.8	76.0	86.8
Low Land	74.3	84.3	101.9	95.8	110.7
North Aspect	35.7	36.1	42.3	51.0	99.9
East Aspect	54.3	53.8	84.6	72.9	103.7
South Aspect	79.3	66.6	113.0	91.3	116.3
West Aspect	73.0	67.9	90.4	69.2	93.4

Note: mm= millimetres

The Little Roberts Lake and Glenn Lake watersheds were analyzed using digital elevation data with a 15.8 metre grid resolution from the Canadian Digital Elevation Data dataset provided by GeoBase. Using GIS software (ArcGIS) the proportion of the terrain unit distribution inside each watershed was computed (Table 2.13).

Table 2.13: Terrain Unit Percentage (%) for each Watershed in Project Area

Watershed	North Aspect	East Aspect	South Aspect	West Aspect	Low Land	Exposed Land	Open Lake
PO Outlet	1.96	5.21	2.11	11.35	67.45	0.57	11.34
PO Lake	2.85	12.93	3.67	12.44	41.13	3.93	23.06
Ogama Lake	3.35	12.20	3.61	21.51	34.58	2.26	22.49
Glenn Lake	4.59	8.35	5.45	17.45	47.51	3.93	12.74
Windy Lake	2.87	12.89	3.29	12.81	22.32	5.19	40.64
Little Roberts Lake	6.55	19.99	4.83	18.60	36.53	10.68	2.82
Doris Lake	4.49	19.26	4.69	11.20	32.62	3.58	24.16
Tail Lake	3.79	15.23	5.62	19.91	38.05	0.75	16.65
Roberts Lake	8.35	12.31	8.39	14.52	35.51	3.25	17.67
Wolverine Lake	2.71	21.46	3.49	7.19	27.86	1.80	35.49
Patch Lake	2.60	8.83	3.42	9.05	52.12	2.09	21.90

The SWE for each terrain type was used to derive the SWE for each watershed based on the proportion of that terrain type over the entire watershed. The results are presented in the Table 2.14.

Table 2.14: Derived Snow Water Equivalent (mm) for each Watershed, 2004 to 2008

Watershed	Year				
	2004	2005	2006	2007	2008
PO Outlet	64.9	66.4	85.2	73.1	100.2
PO Lake	59.2	66.8	81.9	78.1	90.5
Ogama Lake	57.5	65.5	81.0	77.8	89.7
Glenn Lake	61.4	64.9	83.2	74.8	97.1
Windy Lake	51.9	66.7	76.5	81.9	77.8
Little Roberts Lake	65.7	66.8	89.0	77.7	101.1
Doris Lake	58.2	67.7	81.3	79.8	89.4
Tail Lake	59.4	65.6	81.9	76.7	94.3
Roberts Lake	57.8	65.0	79.6	76.3	93.8
Wolverine Lake	55.0	69.0	78.7	82.2	82.6
Patch Lake	60.3	66.8	81.8	76.2	92.6

Note: mm= millimetres

2.3.4 Undercatch

Precipitation occurs as rainfall or as snowfall. In general, the accuracy of measurements for actual rainfall and snowfall amount is subject to limitations inherent in methods and equipment, most of which result in measured amounts being less than actual amounts. This phenomenon is termed “undercatch” and is applied mainly to snowfall, though rainfall is also affected to a lesser extent. The main factors that influence undercatch are as follows:

- wind turbulence at the gauge which tends to deflect some precipitation (especially snow) away from the gauge opening;
- wetting of gauge surfaces, which later evaporates and is not recorded as precipitation; and
- frequency of trace events, which add physical volume but have no recorded volume because they are too small to measure.

The cumulative effects of these factors are relatively larger in northern climates than southern climates due to the high incidence of wind during snowfall events and more frequent occurrences of trace events.

Mekis and Hogg (1999) discussed the issues involved, and the approach taken by Environment Canada in assessing undercatch and developing corrections. The corrected datasets for many climate stations throughout Canada, including MSC stations near the Project, are available in the AHCCD (Environment Canada 2008c). The corrected data sets are currently available to the end of 2007. Cambridge Bay A is the only MSC station with similar precipitation patterns as the Project (Section 2.3.2) and is recommended to represent the conditions at the Project.

Undercatch factors for the Cambridge Bay A climate station derived based on the AHCCD data were previously presented in Tables 2.5 and 2.6.

2.3.5 Extreme Precipitation

2.3.5.1 Annual Precipitation

Frequency analyses were conducted on the derived annual rainfall, snowfall and precipitation data at the Project for the period of 1948 to 2008 to characterize extreme values for various return periods. The Log Pearson 3 distribution was used for snowfall, and the Pearson 3 or Extreme Value distribution for rainfall and precipitation, according to the best-of-fit (Environment Canada 1994). Results of these analyses are presented in Table 2.15. Adjustment for undercatch was considered in the analysis.

Table 2.15: Frequency Analysis of Derived Annual Rainfall, Snowfall and Total Precipitation at the Project

Return Period (years)		Rainfall (mm)	Snowfall (mm)	Total Precipitation (mm)	SWE (mm)
Wet	200	236.7	242.8	358.5	171.9
	100	213.9	228.5	343.6	158.3
	50	191.9	213.9	327.9	144.7
	20	163.7	193.6	305.6	126.7
	10	142.8	177.3	287.0	112.8
	5	121.7	159.4	265.9	98.3
Median	2	91.7	130.0	229.3	76.6
Dry	5	71.4	106.1	197.3	61.1
	10	63.6	95.4	182.1	54.6
	20	58.3	87.4	170.4	50.1
	50	53.2	79.3	158.0	46.2
	100	50.4	74.2	150.2	44.1
	200	48.0	69.9	143.3	42.6

Note: mm= millimetres

Note that the 1:2 year values for Doris North (e.g. 91.7 mm for rainfall) represent statistical median values, and are not the same as the arithmetic means (e.g., 98.7 mm for rainfall) that were reported in Table 2.8.

It is also noted that the sum of rainfall and snowfall for a particular return period does not equal the precipitation amount as these values are independent (e.g., the 10 year wet rainfall and the 10 year dry snowfall event could occur in the same year, resulting in something close to the mean annual precipitation).

Because of the short data series, there is a low degree of confidence in derived values with return periods of 100 years and greater. Derived annual rainfall at Doris North for the period of 1948 to 2008 ranged from a low of 46.9 mm in 1992, to a high of 191.8 mm in 1988. Derived annual snowfall ranged from a low of 80.6 mm in 1954, to a high of 229.8 mm in 1992. Derived annual total precipitation ranged from a low of 139.9 mm in 1954, to a high of 339.9 mm in 1971.

2.3.5.2 Short Duration Rainfall Events

Intensity-duration-frequency (IDF) statistics derived by Environment Canada (2009) for the Cambridge Bay A climate station are presented in Table 2.16. The IDF statistics were derived from 17 years of data between 1970 and 1990. Because of the short data series, there is a low degree of confidence in derived values with return periods of 50 years and greater.

Table 2.16: Short Duration Rainfall Intensities at Cambridge Bay A (mm)

Duration	Return Period (years)					
	2	5	10	25	50	100
5 min	1.1	1.8	2.3	2.9	3.4	3.8
10 min	1.4	2.4	3.0	3.7	4.3	4.9
15 min	1.8	3.0	3.7	4.7	5.4	6.1
30 min	2.8	4.2	5.2	6.5	7.4	8.3
1 h	4.1	6.1	7.4	9.0	10.3	11.5
2 h	5.8	8.4	10.1	12.3	13.9	15.4
6 h	9.3	14.3	17.6	21.8	24.9	28.0
12 h	11.9	19.6	24.7	31.1	35.9	40.6
24 h	13.6	23.2	29.7	37.8	43.8	49.8

It is noted that while high intensity events are rare in the North, events greater than those presented in Table 2.16 have been recorded in the region. An extreme event took place in Kugluktuk on 21 July 2007, with a 24-hour rainfall of 118.3 mm (Hopkinson 2007). This eclipsed the previously recorded 24-hour maximum values of 63.5 mm (8 June 1948) and 57.2 mm (1 August 1973) recorded at Coppermine and 53.7 mm (12 August 1982) recorded at Kugluktuk A. The 48-hour rainfall for the 2007 event recorded 173.5 mm of rainfall. Environment Canada reports annual rainfall normals of 133.4 mm for Kugluktuk (normals refer to average measurements over a set amount of time at a specific location).

2.4 EVAPORATION

2.4.1 Indian and Northern Affairs Canada

Table 2.17 shows basic information on six stations that are operated on a seasonal basis by INAC. These stations are part of INAC's evaporation research program. Lake evaporation rates calculated using the Penman method are presented in Table 2.18.

Table 2.17: INAC Regional Climate Stations

Station Name	Station Location		Recorded Data		
	Latitude (North)	Longitude (West)	Data Type	Period of Record	Length of Record
Colomac	64° 26'	115° 04'	Lake evaporation	2000 to 2007	8
Discovery	63° 12'	113° 46'	Lake evaporation	2005 to 2007	3
Lupin	65° 45'	115° 15'	Lake evaporation	2004 to 2006	3
Nanisivik	73° 02'	84° 33'	Lake evaporation	1993 to 2002	10
Pocket Lake	62° 30'	114° 23'	Lake evaporation	1994 to 2007	14
Salmita	64° 03'	111° 10'	Lake evaporation	1994 to 2008	15
Silverbear	65° 37'	118° 07'	Lake evaporation	2005 to 2007	3

Table 2.18: Northern Lake Evaporation Rates Reported by INAC

Year	Station Name						
	Colomac (INAC 2007)	Discovery (INAC 2007)	Lupin (Gibson 1996; INAC 2009)	Nanisivik (INAC 2009)	Pocket Lake (INAC 2007)	Salmita (INAC 2009)	Silverbear (INAC 2007)
1983			260[a]				
1984			320[a]				
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992			300				
1993			220	120			
1994				90	461	336	
1995				95	445	261	
1996				88	414	283	
1997				94	376	243	
1998				104	433	348	
1999				91	402	295	
2000	322			88	435	278	
2001	255			90	386	296	
2002	221			77	361	232	
2003	338				427	327	
2004	239		172[b]		337	242	
2005	303	279	197[b]		372	235	177
2006	430	334	295[b]		431	340	297
2007	368	324			397	222	292
2008						250	
Average	**310**	**312**	**252**	**96**	**406**	**279**	**255**

(a) These estimates were based on the pan evaporation measurements at Lupin and a correction coefficient of 0.81

(b) Incomplete months

2.4.2 Environment Canada

Evaporation monitoring data in the north are noted as being extremely sparse. Prowse (1990) noted that only five evaporation pans operated in the Northwest Territories and Nunavut, and Environment Canada currently only reports pan evaporation normals for two sites in Northwest Territories and Nunavut, those being Yellowknife (62° 27' N, 114° 26' W) and Resolute (74° 43' N, 94° 59' W). Neither of these sites is close enough to the Project to provide any meaningful data.

2.4.3 Doris North Baseline Program 1993 – 2002

A pan evaporation gauge was operated at Windy Camp in 1995 and 1996, and at Boston Camp in 1997, 1998, and 2000 (Rescan 2002). However, due to data collection problems, the only year with reliable data was 1997 (AMEC 2003). The monthly lake evaporation values recommended by the baseline report (AMEC 2003), based on data from Boston Camp and regional stations, are presented in Table 2.19.

Table 2.19: Derived Mean Lake Evaporation (AMEC 2003)

Period	Days with Evaporation	Mean Lake Evaporation (mm)
June	15	35
July	31	95
August	31	77
September	30	13
Annual	**105**	**220**

Note: mm= millimetres

2.4.4 Doris North Baseline Program 2003 to 2008

No direct measurements of lake evaporation were performed during the baseline program from 2003 to 2008. However, data from the Doris North climate station were used as input to the WREVAP program (Morton et al. 1985) to estimate the monthly evaporation from Doris and Tail lakes. Evaporation from Doris Lake and Tail Lake were calculated separately, because lake evaporation is affected by the mean lake depth.

The WREVAP model requires accurate temperature, humidity and solar radiation data from a station with surroundings similar to the area of interest. The program is not recommended for use near “sharp environmental discontinuities, such as a high-latitude coastline… because of advection of heat and water vapour in the lower layers of the atmosphere.” However, the program documentation indicates “that the effects of such advections can decrease to near zero within 300 m, but this finding may not be generally applicable.” Doris Lake is approximately 4 km from the Roberts Bay coastline at its closest point, so it is assumed that the WREVAP model is applicable. Lake evaporation was calculated using the CRLE (Complementary Relationship Lake Evaporation) model component. Calculated evaporation estimates for the years 2004 to 2008 are presented in Table 2.20.

Calculated values for Tail Lake are approximately 5% to 12% greater due to the shallower depth of Tail Lake and its ability to warm up sooner in the summer.

Evaporation data are extremely sparse in the North, but it is generally accepted that annual values should decrease with increases in latitude, due to colder temperatures and a shorter ice-free season. Therefore, it is reasonable that the annual values at the Project should be lower than those reported for Colomac, Discovery, Pocket Lake, Salmita, and Silverbear, for concurrent years. Lupin was discarded from the analysis due to incomplete records for the period of 2004 to 2006 leading to underestimates of annual values.

Six years of data for Doris Lake (1997 and 2004 to 2008) provide a mean annual calculated lake evaporation value of 241 mm.

Table 2.20: Doris North Calculated Lake Evaporation, 2004 to 2008

	Lake Evaporation			Lake Evaporation	
Month	**Doris Lake CRLE (mm)**	**Tail Lake CRLE (mm)**	**Month**	**Doris Lake CRLE (mm)**	**Tail Lake CRLE (mm)**
June 2004	7	23	June 2007	9	28
July 2004	51	86	July 2007	66	119
August 2004	85	79	August 2007	109	104
September 2004	66	38	September 2007	75	40
2004 Annual Total	**209**	**226**	**2007 Annual Total**	**259**	**291**
June 2005	10	29	June 2008	11	31
July 2005	68	92	July 2008	73	106
August 2005	81	69	August 2008	95	84
September 2005	57	37	September 2008	72	42
2005 Annual Total	**216**	**227**	**2008 Annual Total**	**251**	**263**
June 2006	28	40			
July 2006	83	114			
August 2006	104	98			
September 2006	77	51			
2006 Annual Total	**292**	**303**			

Note: mm= millimetres

2.5 WIND SPEED AND DIRECTION

Hourly mean and maximum wind speed data as recorded at the Project are available from March 2004 to December 2008. Mean wind direction data, as well as its standard deviation, are also available on hourly basis for the same period of record.

At the Cambridge Bay A climate station, MSC provides hourly mean data for wind speed and wind direction, and daily maximum wind gust data if the maximum gust speed exceeds 29 km/h. Concurrent data were analyzed for mean wind speed values and a brief assessment is presented below.

At the Doris North climate station, the recorded prevailing winds are from west and west-northwest. The wind frequency rose presented in Figure 2.12 shows that the wind blows from the west-northwest direction almost 20% of the time. The calm frequency is 10.9% of the time. The least frequent wind direction is southwest, with a frequency of less than 2%. The mean values for wind speed show that the west and west-northwest winds have the highest mean speeds and tend to be the strongest. The values for wind speed frequency are presented in Table 2.21.

At the Cambridge Bay A climate station, the recorded prevailing winds show a different pattern from Doris North, with predominant directions from north, northwest and west. At this location, winds from the northeast direction have a higher frequency value than at Doris North. The combined wind frequency for west, north-west and north is more than 30% of the time (Figure 2.13). The calm frequency is 4.26% of the time. The values for wind speed frequency for Cambridge Bay are presented in Table 2.22.

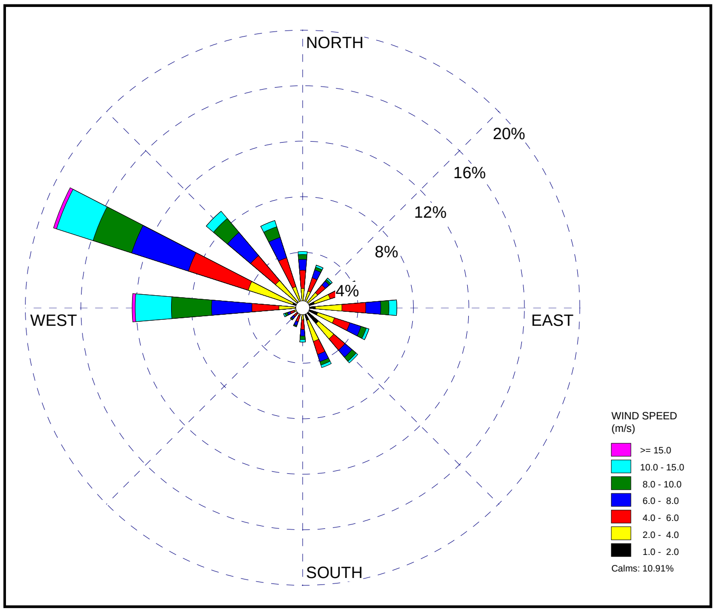

Figure 2.12: Doris North Mean Wind Speed and Direction - Frequency Rose

Table 2.21: Doris North Bay Wind Rose Speed and Direction Frequencies, 2004 to 2008

Direction		Wind Classes (m/s)							
Cardinal or Intermediate	**Sector Midpoint (°)**	**1.0 - 2.0**	**2.0 - 4.0**	**4.0 - 6.0**	**6.0 - 8.0**	**8.0 - 10.0**	**10.0 - 15.0**	**>= 15.0**	**Total (%)**
N	0.0	0.26	1.13	1.30	0.78	0.34	0.21	0.00	4.04
NNE	22.5	0.30	0.95	1.00	0.61	0.20	0.16	0.00	3.22
NE	45.0	0.48	0.94	0.73	0.36	0.15	0.13	0.00	2.80
ENE	67.5	0.90	1.18	0.92	0.56	0.36	0.27	0.04	4.22
E	90.0	0.92	1.91	1.72	1.08	0.59	0.56	0.00	6.78
ESE	112.5	1.13	1.27	1.17	0.84	0.39	0.21	0.00	5.01
SE	135.0	1.49	1.45	1.06	0.66	0.39	0.15	0.00	5.19
SSE	157.5	0.96	1.59	0.98	0.54	0.25	0.20	0.00	4.52
S	180.0	0.29	0.58	0.69	0.47	0.26	0.18	0.00	2.47
SSW	202.5	0.19	0.41	0.46	0.28	0.08	0.03	0.00	1.45
SW	225.0	0.19	0.34	0.32	0.20	0.09	0.02	0.00	1.17
WSW	247.5	0.27	0.38	0.28	0.22	0.18	0.10	0.00	1.44
W	270.0	0.52	1.18	1.94	2.90	2.90	2.60	0.22	12.27
WNW	292.5	0.75	3.37	4.52	4.29	2.92	2.76	0.23	18.83
NW	315.0	0.53	2.04	2.35	2.18	1.31	0.67	0.01	9.09
NNW	337.5	0.26	1.33	2.18	1.54	0.80	0.47	0.00	6.58
	Sub-Total	**9.43**	**20.06**	**21.62**	**17.52**	**11.21**	**8.73**	**0.52**	**88.71**
	Calms								**10.87**
	Missing/ Incomplete								**0.42**
	Total								**100.00**

Note: m/s= metres per second; %=percent

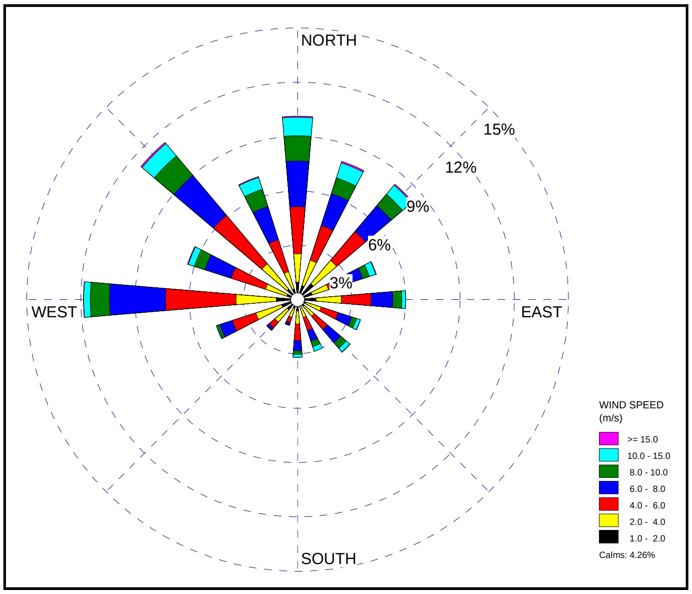

Figure 2.13: Cambridge Bay mean Wind Speed - Frequency Rose

Table 2.22: Cambridge Bay Wind Rose Speed and Direction Frequencies, 2004 to 2008

Direction		Wind Classes (m/s)							
Cardinal or Intermediate	**Sector Midpoint (°)**	**1.0 - 2.0**	**2.0 - 4.0**	**4.0 - 6.0**	**6.0 - 8.0**	**8.0 - 10.0**	**10.0 - 15.0**	**>= 15.0**	**Total (%)**
N	0.0	0.95	1.57	2.59	2.52	1.39	1.02	0.06	10.10
NNE	22.5	0.81	1.47	2.01	1.84	0.91	0.87	0.09	7.99
NE	45.0	1.14	1.68	2.08	1.87	0.82	0.66	0.08	8.33
ENE	67.5	0.86	0.94	1.09	0.89	0.39	0.37	0.03	4.57
E	90.0	1.02	1.39	1.65	1.20	0.50	0.21	0.00	5.98
ESE	112.5	0.49	0.88	0.99	0.78	0.29	0.21	0.01	3.66
SE	135.0	0.48	0.73	0.96	0.95	0.41	0.26	0.02	3.81
SSE	157.5	0.39	0.65	0.75	0.62	0.33	0.26	0.00	3.00
S	180.0	0.62	0.72	0.92	0.56	0.20	0.16	0.00	3.19
SSW	202.5	0.52	0.51	0.31	0.11	0.03	0.02	0.00	1.50
SW	225.0	0.73	0.90	0.42	0.13	0.02	0.03	0.00	2.23
WSW	247.5	0.92	1.50	1.37	0.72	0.14	0.05	0.02	4.72
W	270.0	1.17	2.22	3.90	3.10	1.06	0.36	0.02	11.83
WNW	292.5	0.62	1.24	1.99	1.52	0.61	0.35	0.04	6.38
NW	315.0	0.75	1.83	3.49	2.87	1.41	0.88	0.09	11.34
NNW	337.5	0.62	1.00	1.85	1.92	0.99	0.68	0.06	7.11
	Sub-Total	**12.09**	**19.25**	**26.37**	**21.57**	**9.50**	**6.41**	**0.53**	**95.73**
	Calms								**4.26**
	Missing/ Incomplete								**0.00**
	Total								**100.00**

Note: mm= metres per second; %= percentage

The different wind frequency pattern between the Doris North and Cambridge Bay A climate stations may be due to local topography around the Doris North climate station.

2.6 RELATIVE HUMIDITY AND SOLAR RADIATION

Table 2.23 provides a summary of maximum, minimum and mean monthly relative humidity data that were recorded at the Doris North climate station from late February 2004 to December 2008, and the mean values recorded at Cambridge Bay A climate station. Details of recorded data, summarized by month and year, are provided in Appendix D for both climate stations.

While Doris North is humid all year round, peaks typically occur during the months of September to November and lows during the summer in June, July and August.

Table 2.23: Relative Humidity Recorded at Doris North and Cambridge Bay, 2004 to 2008

Month	Doris North			Cambridge Bay A
	Relative Humidity [%]			
	Maximum	Minimum	Mean	Mean
Jan	95.7	59.2	75.0	61.6
Feb	93.4	46.6	72.3	64.8
Mar	95.7	41.5	72.2	65.4
Apr	98.1	40.8	79.4	72.4
May	99.7	30.0	82.8	86.5
Jun	98.9	24.1	76.5	84.8
Jul	98.6	22.4	72.7	78.6
Aug	98.1	25.5	78.1	82.5
Sep	99.1	33.4	82.8	86.9
Oct	99.5	52.0	87.9	86.2
Nov	97.0	63.0	81.5	71.2
Dec	93.9	60.3	76.9	63.9
Annual	**99.7**	**22.4**	**78.3**	**75.7**

Note: %= percent

The value of solar radiation is very much related to the length of the day in the north. The mean and the maximum monthly mean values of global solar radiation and the total radiation are presented in Table 2.24.

Table 2.24: Global Solar Radiation Recorded at Doris North, 2004 to 2008

Month	Monthly Radiation [W/m^2]		Total Radiation [MJ/m^2]	Month	Monthly Radiation [W/m^2]		Total Radiation [MJ/m^2]
	Mean	Maximum			Mean	Maximum	
Jan	2.4	2.7	6.5	Jul	218.4	274.0	576.8
Feb	25.6	41.1	50.5	Aug	138.0	184.6	364.1
Mar	90.7	106.8	239.3	Sep	69.2	87.1	177.1
Apr	184.5	200.8	471.2	Oct	28.5	29.3	75.1
May	255.7	274.1	674.1	Nov	5.1	5.9	13.0
Jun	247.0	263.8	630.5	Dec	0.4	0.4	0.9

Note: W/m^2= watts per squared metre; MJ/m^2= mega joules per squared metre

3.0 WATER YIELD AND RUNOFF

Runoff data relevant to the Doris North water balance include local monitoring data collected during the previous hydrology baseline studies by Rescan (2002), RL&L/Golder (2003) and Golder (2005, 2006b, 2007, 2008, 2009).

The typical hydrograph for the region displays the largest peak during the spring runoff, during the snowmelt period. Summer and autumn rainfall may produce secondary peaks that are generally lower than the spring peak flow.

3.1 ENVIRONMENT CANADA REGIONAL HYDROMETRIC STATIONS

Long-term Environment Canada hydrometric data are available from the regional stations listed in Table 3.1. Calculated mean annual water yields for these stations are presented in the table. Calculated annual water yields for each station are presented in Appendix F.

Table 3.1: Regional Environment Canada Hydrometric Stations

Station	Number	Period of Record[a]	Drainage Area (km^2)	Location	Period of Record (years)	Mean Annual Water Yield (mm)
Tree River near the Mouth	10QA001	1969 – 2007	5,810	67° 38' 06" N 111° 54' 08" W	29	194
Hood River near the Mouth	10QB001	1994 – 2002	14,100[c]	67° 21' 00" N 108° 56' 06" W	4	153
Burnside River near the Mouth	10QC001	1977 – 2007	16,800	66° 44' 00" N 108° 48' 08" W	25	252
Gordon River near the Mouth	10QC002	1977 – 1994	1,530	66° 48' 36" N 107° 06' 04" W	16	197
Ellice River near the Mouth	10QD001	1971[b] – 2007	16,900	67° 42' 42" N 104° 08' 27" W	19	172
Freshwater Creek near Cambridge Bay	10TF001	1970 – 2007	1,490	69° 07' 52" N 104° 59' 26" W	29	85

(a) At the time of this assessment, data were available for active stations through the end of 2007.

(b) Environment Canada has advised that data collected prior to 1984 should not be considered accurate and are not used in subsequent analyses.

(c) Reported by SRK Consulting (2003)

The available data show great variations in water yields throughout the region (Figure 3.1). However, in general, water yields are greater in the south and west and smaller in the north and east.

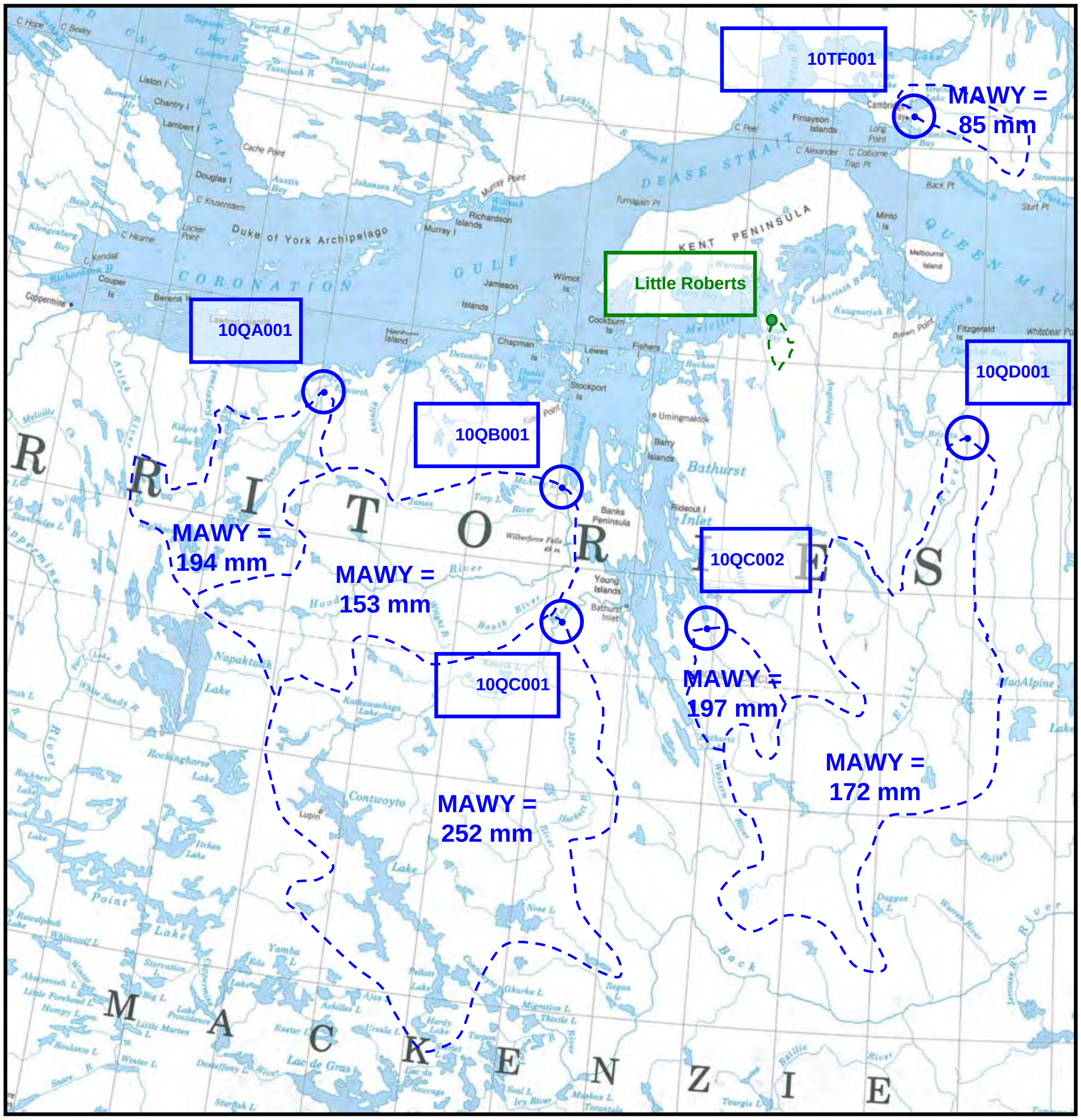

Figure 3.1: Locations of Regional Hydrometric Stations Relative to Little Roberts Lake Watershed

3.2 DORIS NORTH BASELINE PROGRAM

Hydrometric data were collected at Doris North starting in 1993 (AMEC 2003) and automated water level records were installed at some locations in 1996 and continued until 2008, although not all stations were operated for all years.

Year-round hydrometric monitoring allowed annual water yields to be calculated for the period 2004 to 2008 for four main hydrometric stations at the Project. Another seven stations were installed in 2006 and operated through 2008 to augment the hydrological monitoring program. Annual water yields were also calculated for the three stations with continuous data sets for these years.

Locations of the hydrometric stations at the Project are presented in Figure 3.2 and measured annual water yields are presented in Table 3.2. Detailed hydrometric data collected over the period 2004 to 2008 are provided in Appendix G.

Table 3.2: Annual Water Yields at the Project, 2004 to 2008

Station	Drainage Area (km^2)	Annual Water Yield (mm)				
		2004	2005	2006	2007	2008
Doris Lake Outflow	93.1	62	83	73	80	153
Tail Lake Outflow	4.4	42	84	53	82	152
Roberts Lake Outflow	97.8	61	100	72	72	170
Little Roberts Lake Outflow	198.9	64	90	68	83	158
Patch Lake	35.5	-	-	40	-	150
Ogama Lake	71.9	-	-	78	97	136
Glenn Lake	31.6	-	-	63	-	132

Note: mm= millimetres; km^2= square kilometres