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Appendix B-1
Meteorology & Climate Effects Assessment

Author: Rescan Environmental Services Ltd.
Date: November 2007

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Meteorology and Climate Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

BIPR	Bathurst Inlet Port and Road
DEIS	Draft Environmental Impact Statement
DIAND	Department of Indian Affairs and Northern Development
GHG	greenhouse gas
GMT	Greenwich Mean Time
masl	metres above sea level
MSC	Meteorological Services of Canada
the Project	the Bathurst Inlet Port and Road Project
the proponent	Bathurst Inlet Port and Road Project Joint Venture Ltd.
Rescan	Rescan Environmental Services Ltd.
UTM	Universal Transverse Mercator
VEC	valued ecosystem component

1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road (BIPR) Project (the Project) is located in the Kitikmeot region of Nunavut. The proposed port is located on the west side of Bathurst Inlet (66°33'N and 107°31'W), about 40 km south of the community of Bathurst Inlet. The proposed all-weather road will connect the port to the Tibbitt to Contwoyto winter road, a distance of 211 km.

The Project will reduce transportation costs in the region, thereby increasing the likelihood of development of known mineral deposits and encouraging new mineral exploration. Known mineral deposits include Back River (George Lake), Goose Lake, Izok Lake and Hackett River. The road will connect to the major diamond mines in the Northwest Territories and to Yellowknife *via* the winter road from Tibbitt to Contwoyto. The Project will reduce the costs of fuel and supplies for Kitikmeot communities, increase employment, training, business development, and taxation revenues to the Government of Nunavut.

1.1 Objectives

A meteorological and climatological baseline study began at the port site in the summer of 2001. Climate and climatic trends are major considerations for the design, engineering, construction, and maintenance of the proposed port and road. The current trend of gradual increase in ambient air temperatures will directly affect ice conditions at the port site and permafrost and snow conditions at the port and along the road.

The ship loading and docking activities at the port may be affected by wind loading. The Project design will have to accommodate snow and rain conditions along the road. Precipitation will affect the size and locations of culverts and/or bridges along the road route and the requirement for snow removal during winter. Wind speed and direction will directly affect the distribution and dilution of gaseous air contaminants and fugitive dust.

The objective of the meteorology and climate effects assessment is:

- to describe climatic conditions in the Project area; and
- to assess potential effects of Project emissions on the climate using the methodology established for the Project (Appendix A-5 of the Draft Environmental Impact Statement (DEIS)).

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2. ENVIRONMENTAL SETTING

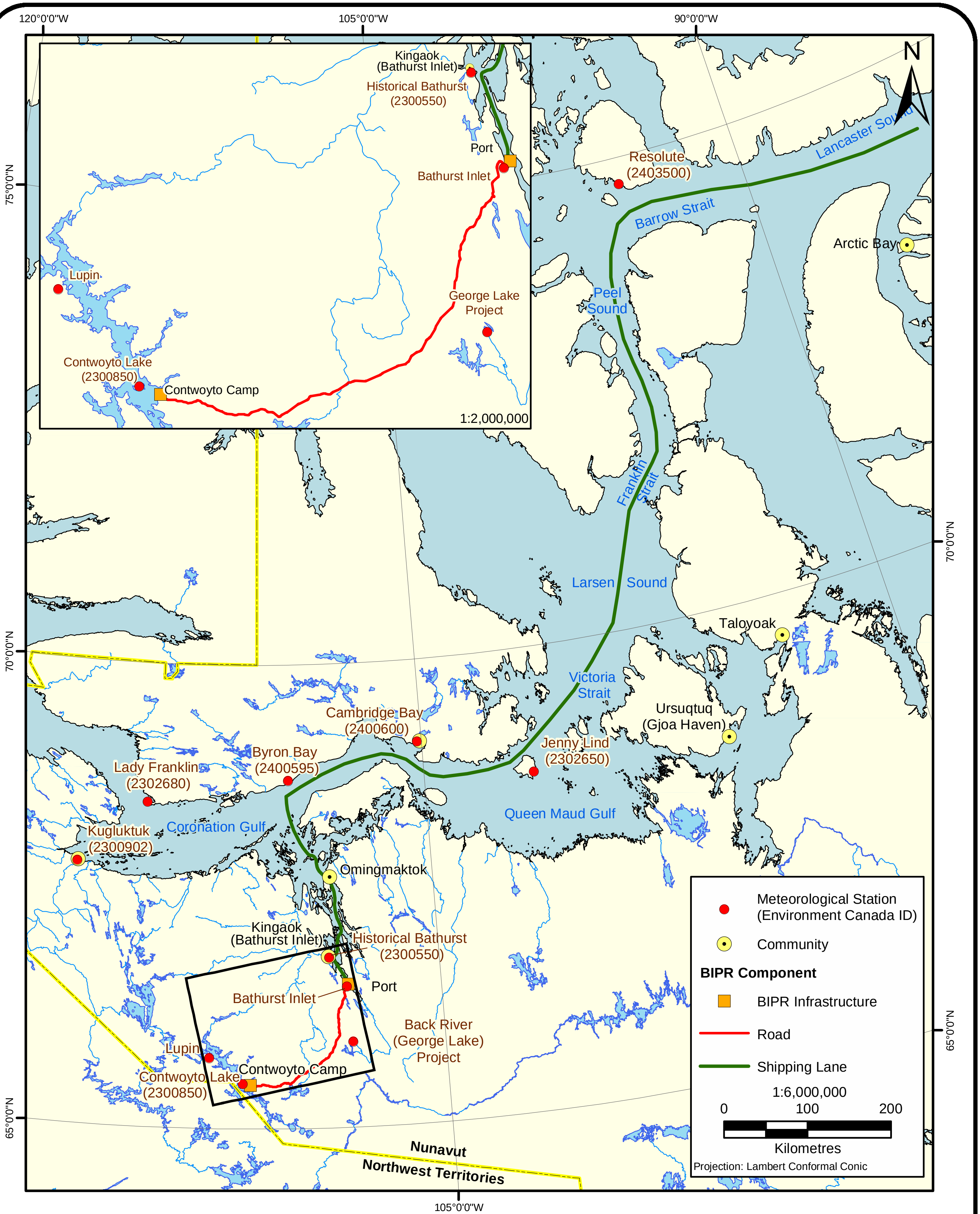
2. Environmental Setting

2.1 Data Sources

An automated meteorological station was installed near the proposed port site in 2001. Historical data are also available from a meteorological station operated by Environment Canada from 1958 to 1962 at the community of Bathurst Inlet. Climate normals from regional stations operated by Environment Canada at Contwoyto Lake, Lupin and Kugluktuk as well as a meteorological station at the Back River (George Lake) Project were used to describe the climate along the proposed road alignment. Data from stations at Byron Bay, Cambridge Bay, Jenny Lind, and Resolute are available to describe climatic conditions along the Kitikmeot leg of the shipping route (Table 2.1-1 and Figure 2.1-1).

Table 2.1-1
Meteorological Stations Used in the Meteorology and Climate Effects Assessment

Station	Environment Canada ID	Lat. (N)	Long. (W)	Elevation (masl)	UTM			Data Period Available
					Zone	Easting	Northing	
Bathurst Inlet	n/a	66.517	-107.567	170	13	385,895	7,379,846	Aug 2001 to Aug 2004
Byron Bay	2400595	68.750	-109.067	112	12	578,189	7,627,716	Climate Normal 1961 to 1990
Cambridge Bay	2400600	69.110	-105.140	27.4	13	494,429	7,666,634	Climate Normal 1971 to 2000 and 1961 to 1990
Contwoyto Lake	2300850	65.483	-110.367	451	12	529,325	7,262,470	Climate Normal 1961 to 1990
Back River Project (George Lake)	n/a	65.921	-107.458	150	13	388,114	7,313,290	Aug 2004 to May 2007
Historical Bathurst Inlet	2300550	66.833	-108.017	13	12	630,930	7,415,936	53 months between March 1953 and July 1962
Jenny Lind	2302650	68.650	-101.733	37	14	388,977	7,617,803	Climate Normal 1961 to 1990
Kugluktuk	2300902	67.820	-115.140	22.7	11	578,351	7,523,974	Climate Normal 1971 to 2000
Lady Franklin	2302680	68.500	-113.220	15.9	12	409,216	7,600,248	Climate Normal 1971 to 2000
Lupin	23026HN	65.760	-111.250	490.1	12	488,547	7,293,182	Climate Normal 1971 to 2000
Resolute	2403500	74.720	-94.990	67.4	15	441,471	8,293,347	Climate Normal 1971 to 2000



the Bathurst Inlet
Port and Road Project

Locations of Meteorological Stations Used in the Meteorology and Climate Effects Assessment, for the Bathurst Inlet Port and Road Project

FIGURE 2.1-1

Rescan

2.1.1 Bathurst Inlet Meteorological Station

The current climate monitoring program for the Project began in late August 2001 with the installation of an automated meteorological station near the port site (Plate 2.1-1). The station was installed in an open area that is not targeted for future development, such as development of bulk fuel storage facility (*i.e.*, tank farm), camp and bulk storage area.

Plate 2.1-1. The Bathurst Inlet meteorological station (April 25, 2002). The 30 Watt solar panel and the cross arm for the SR50 Sonic Ranger (monitors snow depth) are about one quarter of the way up the tower. The RM Young 05305 wind monitor can be seen at the top.

The climatic variables monitored are relative humidity, rain precipitation, snow depth, incoming global short-wave solar radiation, air temperature and wind speed and direction. A Campbell Scientific CR10X datalogger processes and records all measurements. The storage module for the datalogger is retrieved periodically by an operator. For a detailed description of the sensors and their specifications, see Rescan (2007).

The temperature and relative humidity probe was damaged by wildlife in July 2003. All other sensors operated without interruption until August 2004 when a bear destroyed the datalogger enclosure and wiring. New sensors were installed in June 2007 along with steel enclosures for the datalogger and batteries to prevent future wildlife damage. In addition, all wires within 5 m of the ground were place in metal conduits.

For the historical station at the community of Bathurst Inlet, 53 months of data were available between March 1953 and July 1962 (Environment Canada, 2007a). A comparison of the historical data to that of the current station near the port site is included below.

2.1.2 Road Alignment

Climate normals are published by Environment Canada for stations with at least 15 years of data in the three decades from 1971 to 2000 or 1961 to 1990 (Environment Canada, 2007a). At the southern terminus of the proposed road alignment climate normals for temperature and precipitation are available for Contwoyto Lake (1961 to 1990) and for Lupin (1971 to 2000). In addition, wind data are available from Lupin station. These hourly measurements were used to characterize wind speeds and directions.

The Back River Project (George Lake station) provided hourly measurements of relative humidity, total precipitation, incoming global short-wave solar radiation, air temperature and wind speed and direction from August 2004 to May 2007. The meteorological station is approximately 70 km south of the proposed Port Site. The closest point of the proposed road alignment passes within 20 km of George Lake.

2.1.3 Shipping Route

Apart from the station at the port site, data from four on-shore stations were available along the shipping route: Byron Bay and Jenny Lind provide 1961 to 1990 climate normals for temperature and precipitation; Cambridge Bay and Resolute have 1971 to 2000 climate normals for temperature and precipitation as well as wind speed.

2.2 Climate at Bathurst Inlet

Table 2.2-1 presents monthly values of all climate variables measured at the port site meteorological station from August 2001 to August 2004. Climate normals for each of the Environment Canada stations along with averages for the historical Bathurst Inlet and the George Lake stations are presented below.

2.2.1 Air Temperature

The average air temperature for the port station from August 2001 to July 2004 was -10.3ºC (-9.6ºC for the 2002 calendar year). The highest mean monthly air temperature was 12.4ºC (July 2002). The lowest mean monthly air temperature recorded at the port was -29.6ºC (February 2003). The highest 1 minute average air temperature recorded at the port station was 26.1ºC, on July 2, 2002, while the lowest one minute average air temperature was -40.8ºC for February 23, 2003.

Environment Canada operated a meteorological station near the community of Bathurst Inlet from March 1958 to July 1962 (53 months). The mean annual air temperature for this station over this period was -11.5ºC. The maximum temperature recorded was 17.9ºC, while the minimum was -43.7ºC.

Table 2.2-1
Monthly Averages of Measurements for the Port Site Meteorological Station

Month	Average Air Temperature (ºC)	Extreme Maximum Air Temperature (ºC)	Extreme Minimum Air Temperature (ºC)	Daily Mean Maximum Air Temperature (ºC)	Daily Mean Minimum Air Temperature (ºC)	Rain (mm)	Average Wind Speed (m/s)	Average Solar Radiation (W/m^2)	Snow Accumulation (cm)
2001 Aug.	9.3	19.0	1.0	13.2	5.2	17	4.5	146	0
2001 Sep.	6.6	21.2	-4.0	10.4	3.0	72	6.0	97	0
2001 Oct.	-8.0	5.8	-21.4	-6.0	-10.2	3	5.9	31	31
2001 Nov.	-17.9	-3.3	-30.0	-15.1	-21.2	0	5.4	7	73
2001 Dec.	-20.3	-3.2	-30.1	-16.7	-23.8	0	5.3	1	21
2002 Jan.	-26.3	-11.4	-40.1	-23.2	-29.5	0	4.9	4	8
2002 Feb.	-28.9	-18.3	-37.4	-25.7	-32.0	0	5.3	26	11
2002 Mar.	-24.5	-8.9	-37.1	-20.9	-28.2	0	6.2	98	33
2002 Apr.	-18.5	-0.5	-30.2	-14.1	-22.5	0	5.9	204	65
2002 May	-7.0	9.2	-22.6	-3.6	-10.6	0	6.5	275	31
2002 Jun.	7.4	24.4	-6.4	11.4	3.0	40	5.4	267	0
2002 Jul.	12.4	26.1	3.0	16.9	7.6	22	5.9	231	0
2002 Aug.	8.8	21.5	2.0	12.1	5.8	107	5.6	124	0
2002 Sep.	3.4	16.9	-5.2	5.8	1.1	19	6.6	75	7
2002 Oct.	-6.9	1.3	-16.9	-4.7	-9.7	0	6.7	40	20
2002 Nov.	-16.8	-7.2	-29.3	-13.7	-20.4	0	7.9	8	56
2002 Dec.	-18.4	-5.4	-31.6	-14.8	-22.3	0	5.6	1	20
2003 Jan.	-24.0	-3.3	-34.9	-20.5	-27.4	0	6.5	4	5
2003 Feb.	-29.6	-5.7	-40.8	-26.3	-32.8	0	6.0	31	0
2003 Mar.	-25.1	-8.3	-39.5	-21.6	-28.7	0	5.4	98	15
2003 Apr.	-13.7	1.5	-28.4	-9.1	-18.0	0	4.9	197	9
2003 May	-4.1	14.4	-18.9	-0.8	-7.8	20	6.3	244	5
2003 Jun.	5.6	18.6	-5.2	9.7	1.4	2	5.5	249	0
2003 Jul.	n/a	n/a	n/a	n/a	n/a	16	5.1	n/a	7
2003 Aug.	n/a	n/a	n/a	n/a	n/a	35	5.9	n/a	0
2003 Sep.	n/a	n/a	n/a	n/a	n/a	22	5.5	n/a	0
2003 Oct.	n/a	n/a	n/a	n/a	n/a	12	5.1	n/a	0
2003 Nov.	n/a	n/a	n/a	n/a	n/a	0	6.4	n/a	0
2003 Dec.	n/a	n/a	n/a	n/a	n/a	0	5.3	n/a	59
2004 Jan.	n/a	n/a	n/a	n/a	n/a	0	4.9	n/a	35
2004 Feb.	n/a	n/a	n/a	n/a	n/a	0	5.4	n/a	0
2004 Mar.	n/a	n/a	n/a	n/a	n/a	0	5.9	n/a	0
2004 Apr.	n/a	n/a	n/a	n/a	n/a	0	6.0	n/a	0
2004 May	n/a	n/a	n/a	n/a	n/a	0	5.1	n/a	0
2004 Jun.	n/a	n/a	n/a	n/a	n/a	26	5.6	n/a	62
2004 Jul.	n/a	n/a	n/a	n/a	n/a	12	5.3	n/a	0
2004 Aug.	n/a	n/a	n/a	n/a	n/a	114	6.4	n/a	0
Average	**-10.3**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**5.7**	**107**	**n/a**
Avg. 2002	**-9.6**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**6.0**	**113**	**n/a**
Sum 2002	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**188**	**n/a**	**n/a**	**275**
Sum 2002	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**106**	**n/a**	**n/a**	**137**
Max.	**n/a**	**26.1**	**n/a**	**16.9**	**n/a**	**n/a**	**4.5**	**275**	**n/a**
Min.	**n/a**	**n/a**	**-40.8**	**n/a**	**-32.8**	**n/a**	**7.9**	**1**	**n/a**

To estimate long-term average temperatures at the port site daily temperatures recorded between August 2001 and July 2004 at the port site meteorological station were compared to temperatures recorded at Lupin, Kugluktuk and Cambridge Bay. Multiple linear regression was used to determine a relationship between temperatures at the proposed port site and the three Environment Canada stations. The regression yielded the following relationship with a r^2 value of 0.984:

Daily average temperature:

$$\overline{T}_{\text{Bathurst}} = 0.282\,\overline{T}_{\text{Lupin}} + 0.189\,\overline{T}_{\text{Kugluktuk}} + 0.501\,\overline{T}_{\text{Cambridge Bay}} + 1.688$$

where

$\overline{T}_{\text{Bathurst}}$ is a vector of daily ambient temperatures for the Port,

$\overline{T}_{\text{Lupin}}$ is a vector of daily ambient temperatures for Lupin,

$\overline{T}_{\text{Kugluktuk}}$ is a vector of daily ambient temperatures for Kugluktuk, and

$\overline{T}_{\text{CambridgeBay}}$ is a vector of daily ambient temperatures for Cambridge Bay.

Substituting the daily average temperatures by monthly average temperatures given by the 1971 to 2000 climate normals for Lupin, Kugluktuk and Cambridge Bay, estimates of monthly climate normals for average monthly temperatures were calculated for the port site (Table 2.2-2).

Estimates of monthly average maximum and minimum temperatures were calculated in the same manner. First, linear regressions for daily minimum and maximum temperatures were derived:

Daily minimum temperature:

$$\overline{T}_{\text{Bathurst}} = 0.322\,\overline{T}_{\text{Lupin}} + 0.187\,\overline{T}_{\text{Kugluktuk}} + 0.445\,\overline{T}_{\text{Cambridge Bay}} + 1.651 \;\; (r^2{=}0.98)$$

Daily maximum temperature:

$$\overline{T}_{\text{Bathurst}} = 0.294\,\overline{T}_{\text{Lupin}} + 0.133\,\overline{T}_{\text{Kugluktuk}} + 0.545\,\overline{T}_{\text{Cambridge Bay}} + 1.671 \;\; (r^2{=}0.98)$$

These equations were then applied to monthly average maximum and minimum temperatures from climate normal values for the Environment Canada stations to obtain estimates for the port site (Table 2.2-2).

The climate normals tables for the Environment Canada stations also list extreme maximum and minimum temperatures recorded for the 1971 to 2000 period. These can be used as estimates for the expected 1-in-30 year extreme temperatures. Extreme temperature values do not necessarily occur on the same day at all three stations, and therefore the regression equations given above do not hold. Therefore, the predicted 1-in-30 year maximum temperature (31.6ºC) and minimum temperature (-46.5ºC) are associated with some uncertainty.

Table 2.2-2
Estimates of Monthly Average Temperatures at the Port

		Cambridge Bay	Kugluktuk	Lupin	Port Site Normal Estimate
a)	*Average Air Temperature (ºC)*				
	Jan	-32.8	-27.8	-30.4	-28.6
	Feb	-33.0	-27.4	-28.5	-28.1
	Mar	-29.7	-25.3	-24.9	-25.0
	Apr	-21.4	-17.0	-15.9	-16.7
	May	-9.2	-5.3	-5.7	-5.5
	Jun	2.4	5.2	6.5	5.7
	Jul	8.4	10.7	11.5	11.2
	Aug	6.4	8.8	8.8	9.0
	Sep	-0.3	2.8	1.8	2.6
	Oct	-11.5	-7.2	-8.6	-7.9
	Nov	-23.0	-19.6	-20.7	-19.4
	Dec	-29.6	-25.5	-26.8	-25.5
	Annual	**-14.4**	**-10.6**	**-11.1**	**-10.7**
b)	*Daily Mean Maximum Air Temperature (ºC)*				
	Jan	-29.3	-23.7	-26.8	-25.6
	Feb	-29.3	-23.0	-24.8	-24.9
	Mar	-25.7	-20.6	-20.9	-21.5
	Apr	-16.7	-12.1	-11.5	-12.6
	May	-5.3	-1.4	-1.9	-2.0
	Jun	5.6	9.5	11.0	9.3
	Jul	12.3	15.4	16.3	15.4
	Aug	9.4	13.1	12.6	12.4
	Sep	1.9	6.0	4.5	4.9
	Oct	-8.1	-4.0	-6.1	-5.1
	Nov	-19.3	-15.7	-17.2	-16.2
	Dec	-26.1	-21.4	-23.2	-22.5
	1-in-30 Year Extreme	**28.9**	**34.9**	**31.0**	**31.6**
c)	*Daily Mean Minimum Air Temperature (ºC)*				
	Jan	-36.3	-31.9	-34.0	-31.4
	Feb	-36.6	-31.7	-32.1	-30.9
	Mar	-33.7	-29.8	-28.8	-28.2
	Apr	-26.0	-21.8	-20.2	-20.5
	May	-13.0	-9.2	-9.4	-8.9
	Jun	-0.8	0.8	1.9	2.1
	Jul	4.6	6.0	6.7	7.0
	Aug	3.4	4.5	5.0	5.6
	Sep	-2.5	-0.4	-0.8	0.2
	Oct	-14.9	-10.3	-11.1	-10.5
	Nov	-26.5	-23.4	-24.2	-22.3
	Dec	-33.0	-29.6	-30.4	-28.4
	1-in-30 Year Extreme	**-52.8**	**-47.2**	**-49.0**	**-46.5**

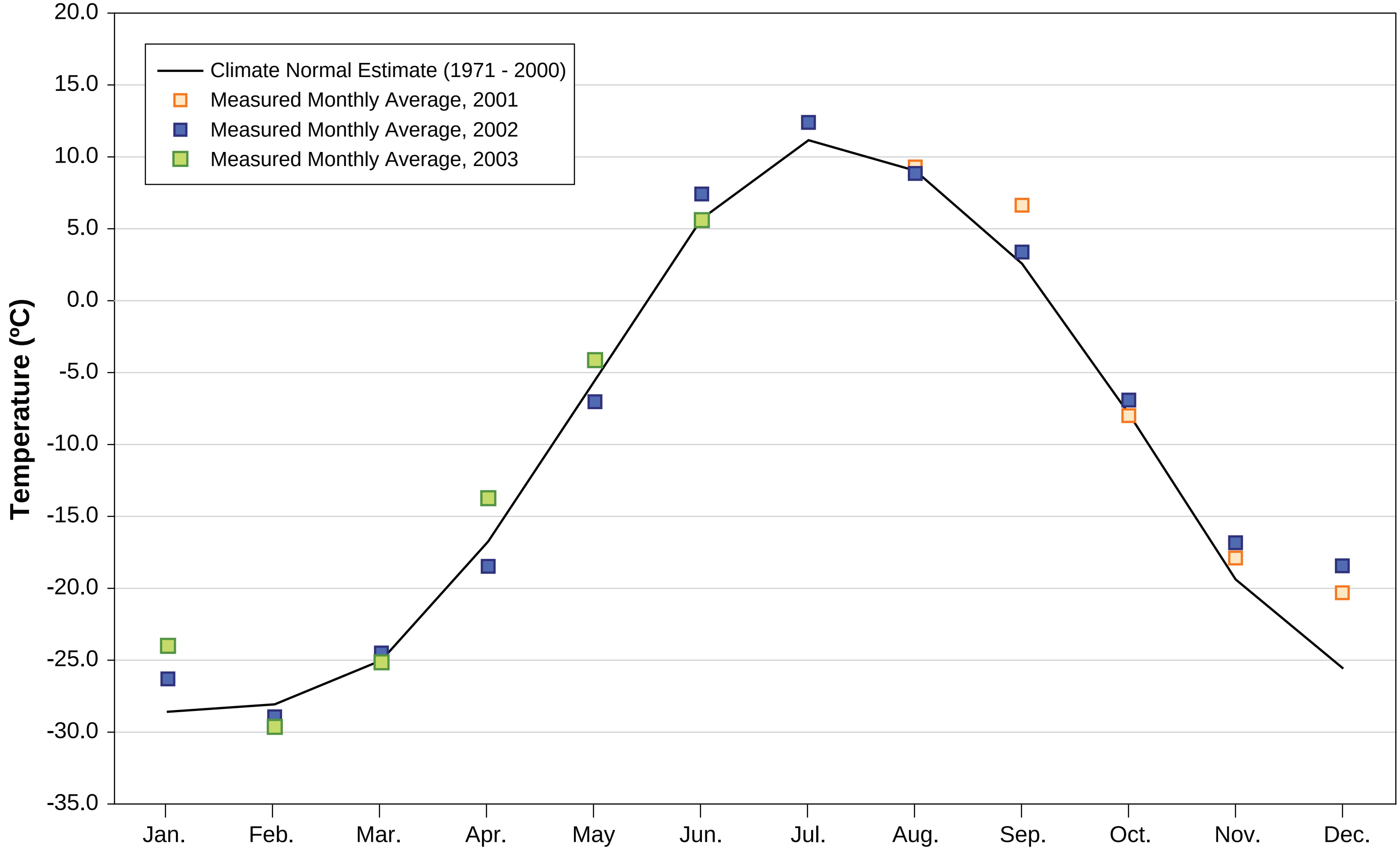
For the monthly temperature averages estimated from climate normals the warmest month is July with an average temperature of 11.2ºC, an average daily maximum of 15.4ºC and an average daily minimum of 7.0ºC. During the coldest month (January), the average monthly temperature is -28.6ºC and daily temperatures vary between an average maximum of -25.6ºC and an average minimum of -31.4ºC. The climate normal estimates for the port average temperatures tend to be slightly lower than the monthly averages measured at the station, especially in the fall and winter (Figure 2.2-1 to Figure 2.2-3): the average annual temperature estimated from climate normals is -10.7ºC, while the measured average temperature for the period of record is -10.3ºC. This estimated increase in annual average temperatures is consistent with regional trends (Environment Canada, 2007a). The port site station location is on the border between the Mackenzie District and the Arctic Tundra climate regions as defined by Environment Canada. For both these regions average temperatures for the years 2001 to 2003 were between 0.9ºC and 2.4ºC warmer than the 1951-1980 reference period averages.

2.2.2 Precipitation

Total precipitation is the combined water equivalence of liquid (rain) and frozen (snow, hail, sleet) precipitation. The meteorological station at the Port measures rain and snow depth, but not the water content of snow. Both measurements suffer from biases that introduce uncertainties in the determination of true precipitation. For snow, drift and sublimation occur even while snow is falling.

Snow accumulation was calculated from hourly changes in snow depth. Changes in snow depth greater than 1.0 cm was added to produce an estimate of total snow accumulation (sensor accuracy is specified as ±1 cm). Snow depth measurements were available from August 2001 to July 2003.

Rain measurements can be biased by wind undercatch (*i.e.*, rain systematically missing the gauge) as well as wetting and evaporation losses. Wetting losses are particularly important in the North where trace precipitation events are common; such events are not register by the precipitation gauge. However, Environment Canada has developed a methodology to correct for these systematic biases in precipitation measurements and publishes adjusted monthly precipitation values for 450 climate stations in the "Historical Adjusted Climate Database for Canada" (Environment Canada, 2007b). These values are used here alongside the measured data. However, it should be noted that the adjusted data are not official Meteorological Service of Canada *in situ* station record.

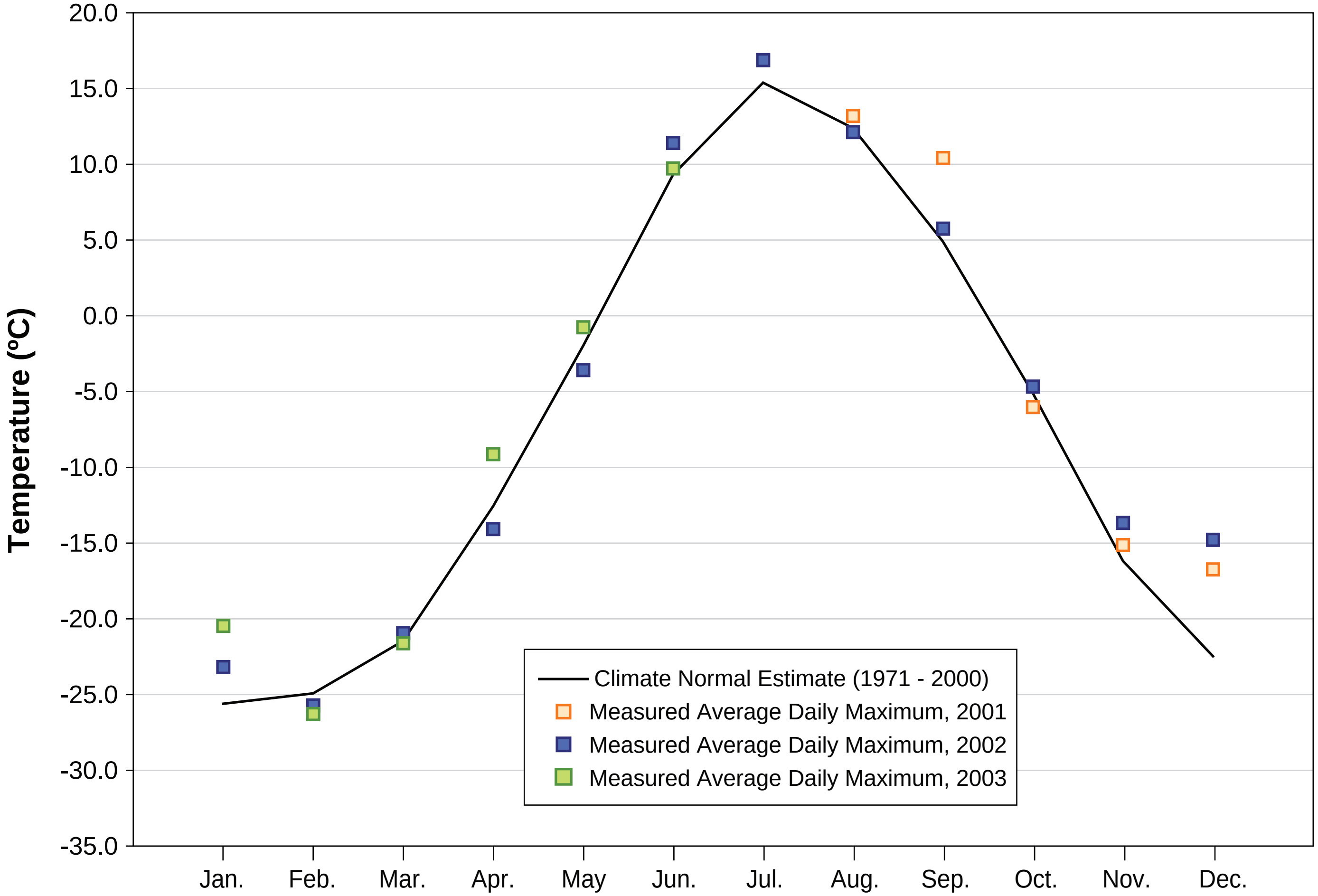


the BATHURST INLET PORT AND ROAD PROJECT

FIGURE 2.2-1

Monthly Average Temperatures at the Proposed Port Site

Rescan™

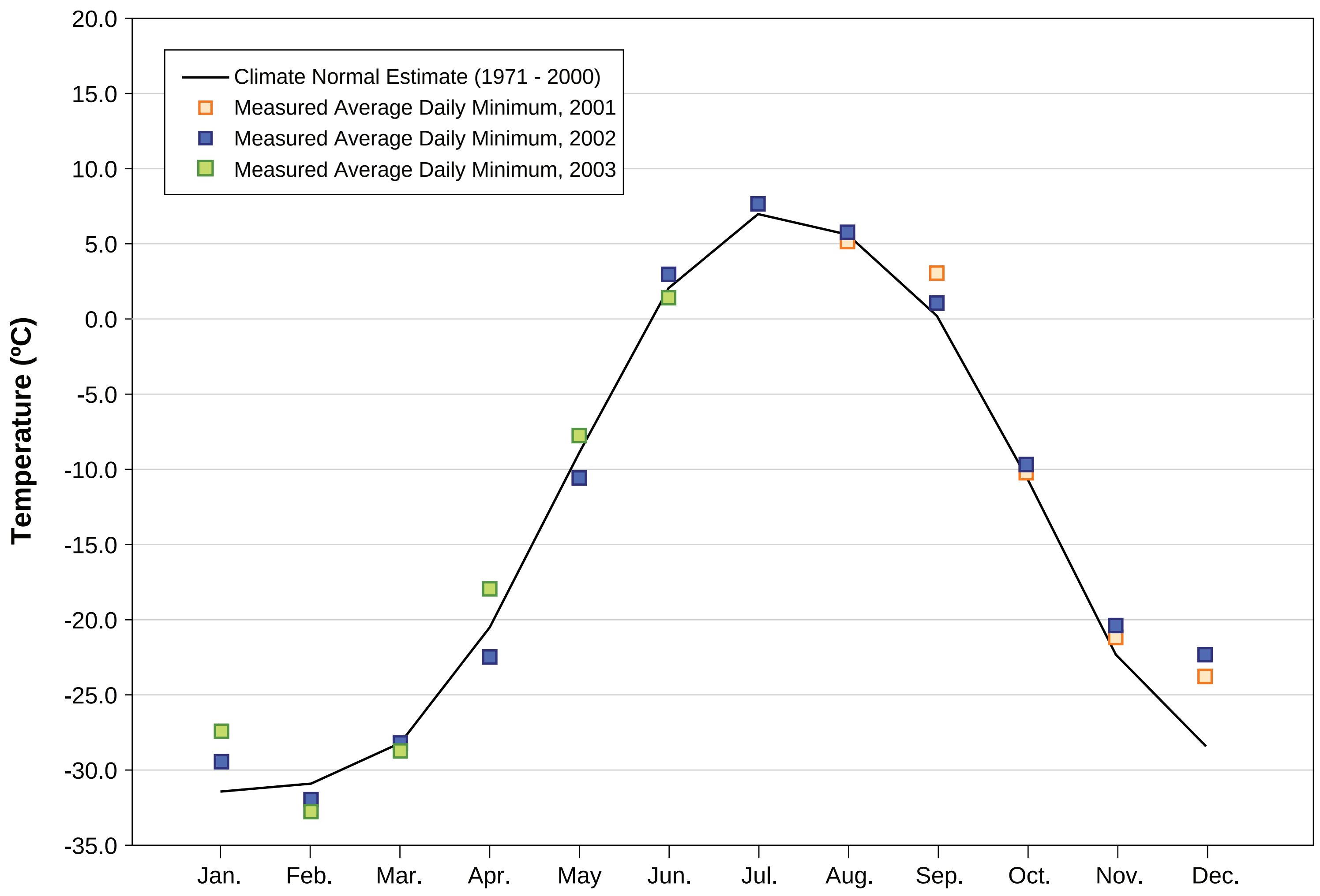


the BATHURST INLET PORT AND ROAD PROJECT

Maximum Daily Average Temperatures at the Proposed Port Site

FIGURE 2.2-2

Rescan™



the BATHURST INLET PORT AND ROAD PROJECT

FIGURE 2.2-3

Minimum Daily Average Temperatures at the Proposed Port Site

Rescan™

Rain at the station was measured between August 2001 and August 2004. In the summer of 2002, 188 mm of rain fell between June and September. In the summer of 2003, 106 mm were measured between May and October. The highest monthly rainfall (114 mm) was measured registered in August 2004.

The quality of the snow accumulation data collected at the port site meteorology station were questionable. Snow accumulation calculated for the 2001/2002 winter season (275 cm) is unrealistically high, while the 2002/2003 accumulation (137 cm) is more realistic. However the overall accuracy of the snow accumulation data was deemed insufficient for use in estimating climate normal values.

To estimate climate normal values for rain at the proposed port site, an approach similar that described for temperature (see Section 2.2.1) was applied, in which measurements for the available period of record at the port site were compared to measurements at Lupin. However, individual rain events are often localized and daily rain totals can differ considerably for stations located more than a couple of kilometres apart. Therefore, monthly totals were used for the analysis (Table 2.2-3; Figure 2.2-4).

Table 2.2-3
Monthly Rainfall (mm) at the Port, Lupin, Kugluktuk and Cambridge Bay

	Port	Lupin	Lupin (Adjusted)	Cambridge Bay	Kugluktuk
August 2001	17	46.2	49.6	31	26.4
September 2001	72	7.2	8.9	11.8	36.9
October 2001	3	1.2	2.2	0	4.2
November 2001	0	0	0.2	0	0
December 2001	0	0	0	0	0
January 2002	0	0	0	0	0
February 2002	0	0	0	0	0
March 2002	0	0	0	0	0
April 2002	0	0	0	0	0
May 2002	0	0	0.3	0	0
June 2002	40	33.8	36.3	9	17
July 2002	22	67	70.8	8.6	31.3
August 2002	107	91.4	96.2	33	25.3
September 2002	19	39.6	42.9	3.8	15.4
October 2002	0	0.2	0.3	0	0.2
November 2002	0	0	0	0	0
December 2002	0	0	0.2	0	0
January 2003	0	0	0	0	2
February 2003	0	0	0	0	0
March 2003	0	0	0	0	0
April 2003	0	0	0	0	0

(continued)

Table 2.2-3
Monthly Rainfall at the Port, Lupin, Kugluktuk and Cambridge Bay (completed)

	Port	Lupin	Lupin (Adjusted)	Cambridge Bay	Kugluktuk
May 2003	20	5.4	6.6	0.4	12.7
June 2003	2	9.6	11.2	2.2	3.8
July 2003	16	44	47.1	36.2	26
August 2003	35	69.2	73.3	34.4	132.9
September 2003	22	14.6	16.3	11	27.7
October 2003	12	1.4	2.6	0.8	12
November 2003	0	0	0	0	0
December 2003	0	0	0	0	0
January 2004	0	0	0	0	0
February 2004	0	0	0	0	0
March 2004	0	0	0	0	0
April 2004	0	0	0	0	0
May 2004	0	0.2	0.3	0.2	0
June 2004	26	20.8	23.3	11.6	23
July 2004	12	12.2	14.4	21.6	41.6
August 2004	114	110.6	115.8	16.8	36.8
Annual Total 2002	**188**	**232**	**247**	**54**	**89**
Annual Total 2003	**106**	**144**	**157**	**85**	**217**

The coefficients of determination (r^2) for linear regression between monthly values from the port and the regional stations was 0.74 for Lupin, 0.36 for Kugluktuk and 0.48 for Cambridge Bay. Using any combination of these three stations in a multiple linear regression did not increase r^2. Therefore, only the regression equation with Lupin was used.

To estimate climate normal values, precipitation data from the "Historical Adjusted Climate Database for Canada" (Environment Canada, 2007b) for Lupin were used. The intercept of the regression line for monthly data was set to 0 and the regression was only carried out for month with non-zero rainfall since otherwise a small but still unrealistic offset between the station would yield non-zero rainfall for the winter months. This yielded the following regression equation:

Monthly rainfall:

$$P_{Port} = 0.79\ P_{Lupin}$$

where

$P_{Bathurst}$ is the monthly precipitation at the Port, and

P_{Lupin} is the monthly precipitation at Lupin.

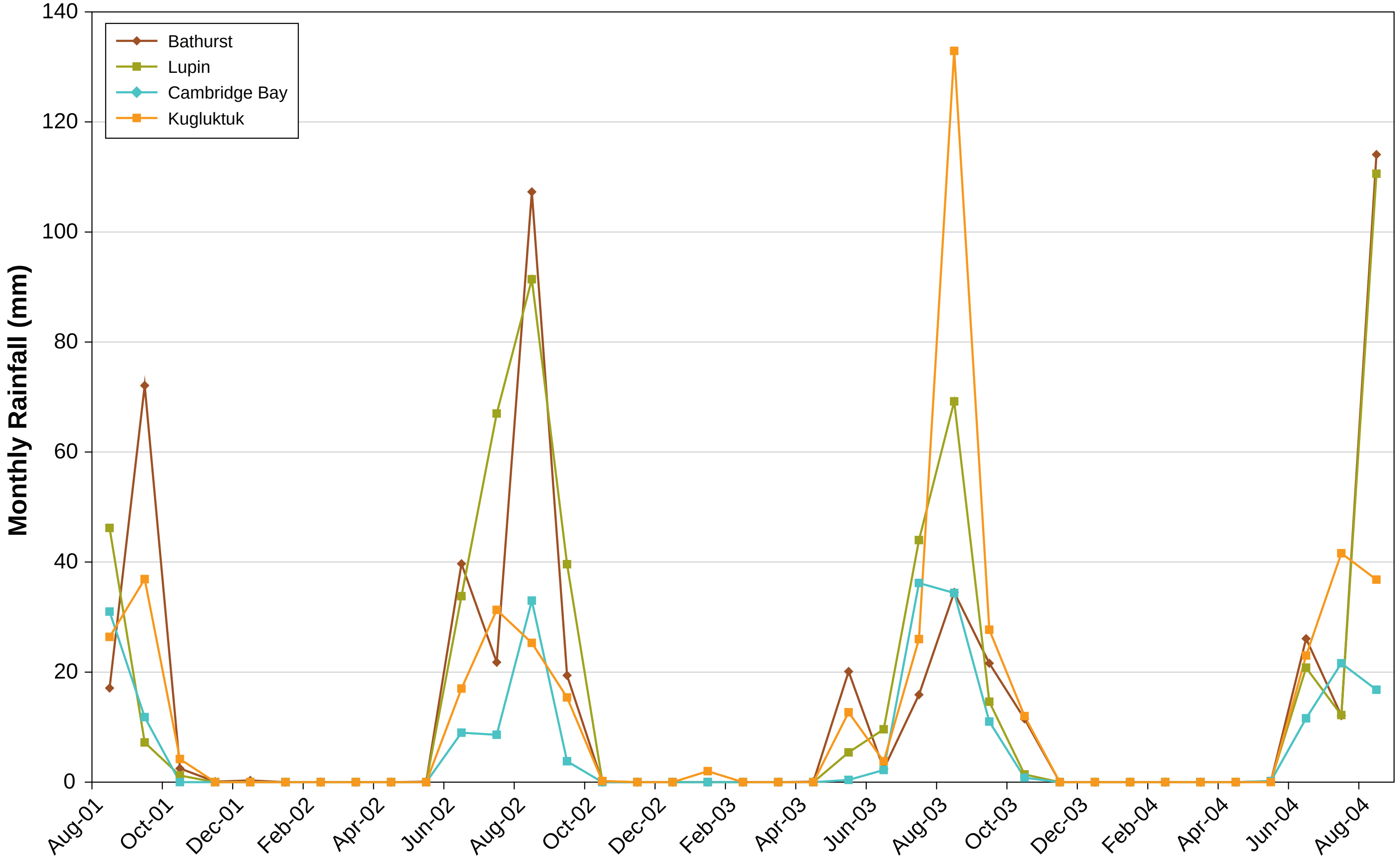


FIGURE 2.2-4

Monthly Rainfall at the Port, Lupin, Kugluktuk and Cambridge Bay

This equation was used to calculate monthly rainfall normals for the port site by applying it to monthly normals from Lupin, calculated from Environment Canada (2007b). The relationship was also applied to the adjusted snowfall normals, assuming that snowfall events bear a relation between the two locations similar to that for rainfall.

Using this method, the climate normal estimates resulted in a mean annual precipitation of 264 mm, with 128 mm falling as rain and 136 mm as snow (Table 2.2-4, Figure 2.2-5). The highest average rainfall is predicted for August (43 mm), the highest average snowfall for October (30 cm). 93% of the annual rainfall and about 15% of the annual snowfall occur between June and September, so that about 50% of the annual precipitation is registered during early summer to early fall.

Table 2.2-4
Precipitation Climate Normals for Lupin and Bathurst Inlet

	Lupin 1971 to 2000[a]			Lupin 1971 to 2000 - Adjusted[b]			Port Climate Normal Estimate		
Month	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)
Jan.	0	9	9	0	12	12	0	9	9
Feb.	0	8	8	0	12	12	0	9	9
Mar.	0	11	11	0	15	15	0	12	12
Apr.	0	14	14	1	16	17	0	13	13
May	6	12	19	8	16	23	6	12	19
Jun.	26	4	29	26	4	29	20	3	23
Jul.	43	1	43	41	0	42	33	0	33
Aug.	57	3	60	55	4	58	43	3	46
Sep.	28	18	46	29	18	47	23	14	37
Oct.	2	28	30	3	38	41	2	30	32
Nov.	0	15	15	0	20	20	0	16	16
Dec.	0	14	14	0	18	18	0	14	14
Annual	**161**	**138**	**299**	**162**	**172**	**333**	**128**	**136**	**264**

Notes:
[a]Climate normals (Environment Canada, 2007a).
[b]Historical Adjusted Climate Database for Canada (Environment Canada, 2007b).

2.2.3 Wind Speed and Direction

Figure 2.2-6 summarizes the wind speeds and directions at the port site meteorological station for the available period of record (August 2001 to July 2004). The most common wind direction was from the north-northwest (21.5% of time) and the wind was from the northwest to north sector 41.7% of the time.

The average wind speed at the station was 5.7 m/s and the wind was below 9 m/s 83.8% of the time while calm winds (*e.g.*, hourly average wind speed of less than 1 m/s) occurred approximately 3.4% of the time.

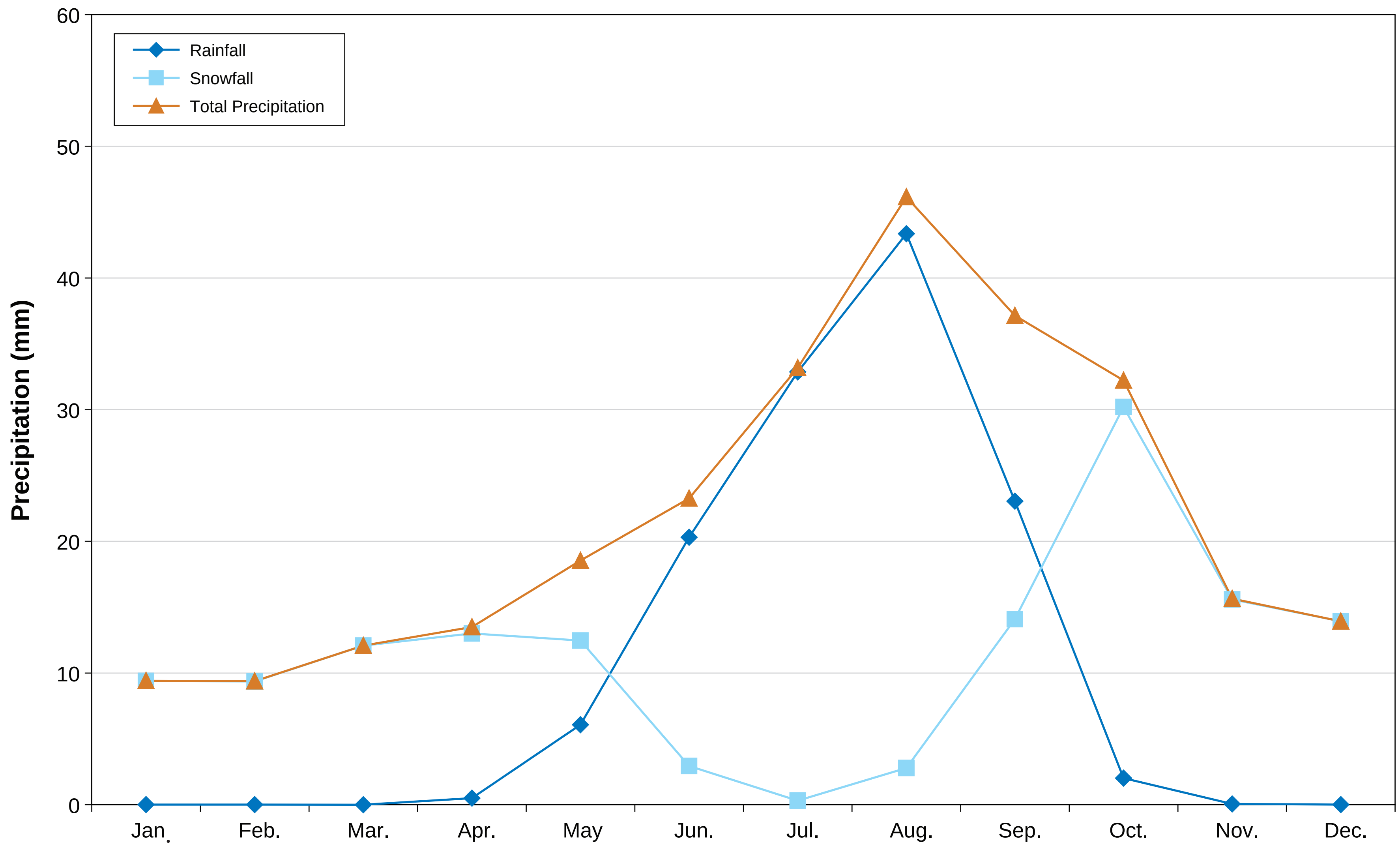


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FIGURE 2.2-5

Climate Normal Estimate for Precipitation at the Proposed Port Site

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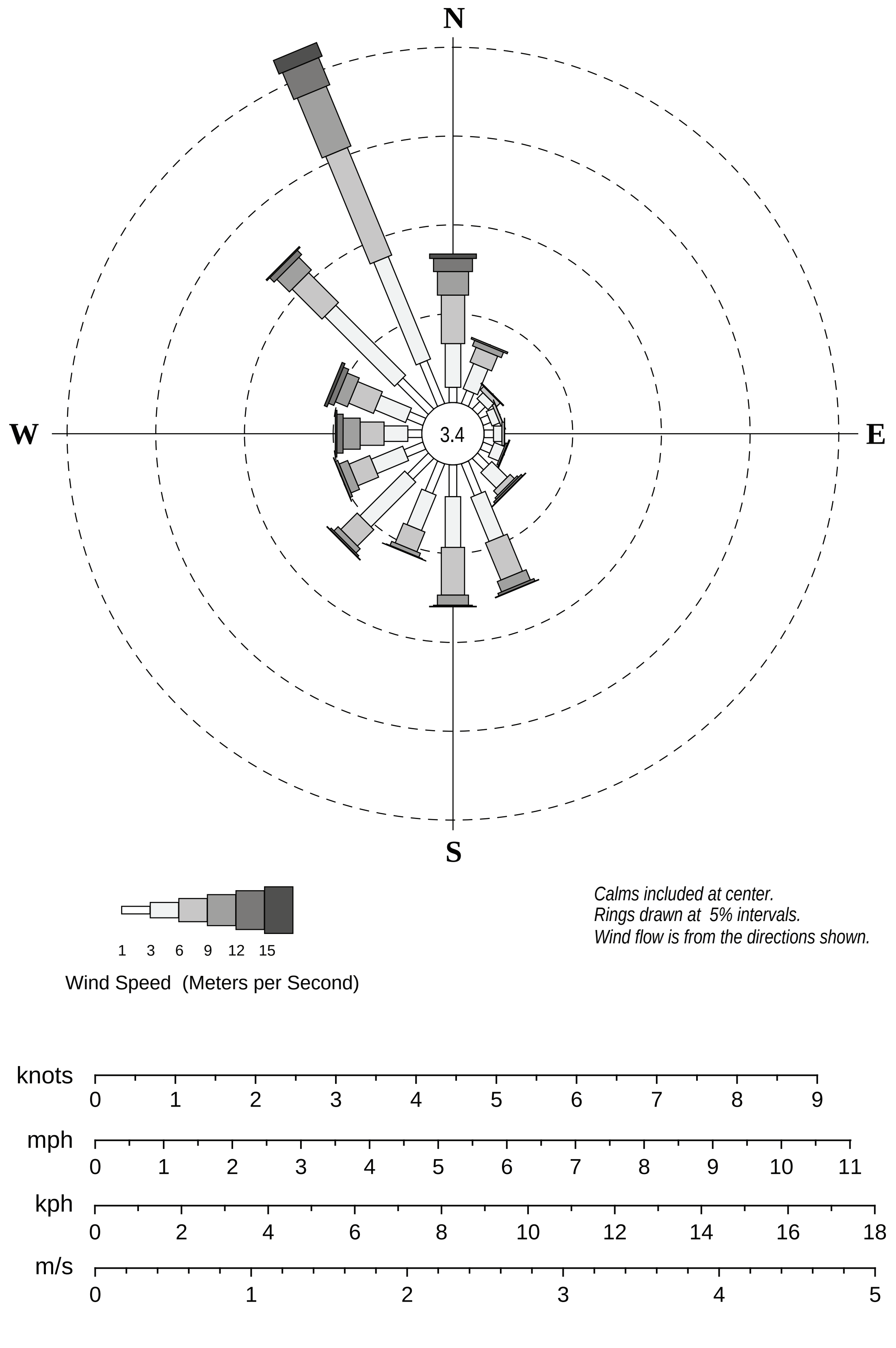

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is from the directions shown.

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Port Site Meteorological Station Wind Rose (August 2001 to July 2004)

FIGURE 2.2-6

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2.2.4 Solar Radiation

The silicon pyranometer at the port site meteorology station measures global solar radiation which is the total incoming direct and diffuse short-wave solar radiation received from the whole dome of the sky on a horizontal surface measured in Watts per square metre (W/m^2).

The most intense solar radiation occurs in July and gradually declines in August and September. The peak hourly values recorded during mid-day in July are approximately 650 W/m^2. A similar instrument located near the equator would record peak values near 1,000 W/m^2. The latitude of the port site (66º 31') causes the solar radiation to be less intense. Solar radiation data can be used to calculate the length of growing seasons and assist in the selection of vegetation for reclamation programs.

The hours of daylight at the port site vary depending upon the time of year. During July there are almost 24 hours of daylight with an average solar radiation of 250 W/m^2 to 275 W/m^2 for 2002 and 2003, respectively. During January, there are almost 24 hours of darkness and the average solar radiation is very close to zero. According to the Environment Canada Climate Atlas for Canada, the mean number of hours of bright sunshine for the port site would be approximately 1,680 hours (70 days) per year. This was based upon data collected between 1951 and 1980.

2.3 Climate along Road

Climate data was available from three stations along the road: The port site meteorological station, the Back River Project (George Lake meteorological station) about 65 km south of the Port Site and Environment Canada's Lupin station on the northern end of Contwoyto Lake (see Figure 2.1-1). The station at Lupin replaced a station on Contwoyto Lake, which collected data from 1956 to 1981. This station was located about 50 km to the southeast of Lupin.

2.3.1 Air Temperature

Temperature normals for the port (see Section 2.2.1) and Lupin are similar, with the annual average temperature at the port (-10.7ºC) slightly warmer than at Lupin (-11.1ºC; Table 2.3-1 and Figure 2.3-1). January at the port is 1.8ºC warmer on average than at Lupin (monthly averages: -28.6ºC and -30.4ºC, respectively), while June is 0.8ºC cooler (monthly averages: 5.7ºC and 6.5ºC). This slight decrease in the temperature range might be attributed to the moderating influence of the sea, which is about 1 km away from the port site meteorological station or to the relatively sheltered topography of Bathurst Inlet, which is surrounded by slopes that might modify the microclimate.

For George Lake, temperature normals were estimated by comparison of daily temperature averages with those from Lupin station for the period of record at George Lake (August 2004 to May 2007). Daily average temperatures were calculated from hourly temperature measurements at George Lake. A linear regression equation for average daily temperatures resulted in a 1:1 correlation for temperature for the two stations. Therefore, the long-term temperature averages for the two stations were assumed to be identical.

Table 2.3-1
Mean Monthly Temperatures along the Road

	Port Site Normal Estimate	Lupin	Contwoyto Lake
a) Monthly Mean Air Temperature (ºC)			
January	-28.6	-30.4	-31.4
February	-28.1	-28.5	-30.6
March	-25.0	-24.9	-27.2
April	-16.7	-15.9	-17.2
May	-5.5	-5.7	-5.2
June	5.7	6.5	4.8
July	11.2	11.5	9.9
August	9.0	8.8	9
September	2.6	1.8	2
October	-7.9	-8.6	-7.5
November	-19.4	-20.7	-20.1
December	-25.5	-26.8	-27.5
Annual	**-10.7**	**-11.1**	**-11.8**
b) Daily Mean Maximum Air Temperature (ºC)			
January	-25.6	-26.8	-27.9
February	-24.9	-24.8	-26.9
March	-21.5	-20.9	-22.6
April	-12.6	-11.5	-11.9
May	-2.0	-1.9	-0.9
June	9.3	11.0	9.5
July	15.4	16.3	14.9
August	12.4	12.6	12.8
September	4.9	4.5	4.7
October	-5.1	-6.1	-4.9
November	-16.2	-17.2	-16.4
December	-22.5	-23.2	-24.1
1-in-30 Year Extreme	**31.6**	**31.0**	**27.2**
c) Daily Mean Minimum Air Temperature (ºC)			
January	-31.4	-34.0	-35.1
February	-30.9	-32.1	-34.4
March	-28.2	-28.8	-32.1
April	-20.5	-20.2	-22.7
May	-8.9	-9.4	-9.6
June	2.1	1.9	0
July	7.0	6.7	4.8
August	5.6	5.0	5.2
September	0.2	-0.8	-0.8
October	-10.5	-11.1	-10.2
November	-22.3	-24.2	-23.9
December	-28.4	-30.4	-31
1-in-30 Year Extreme	**-46.5**	**-49.0**	**-53.9**

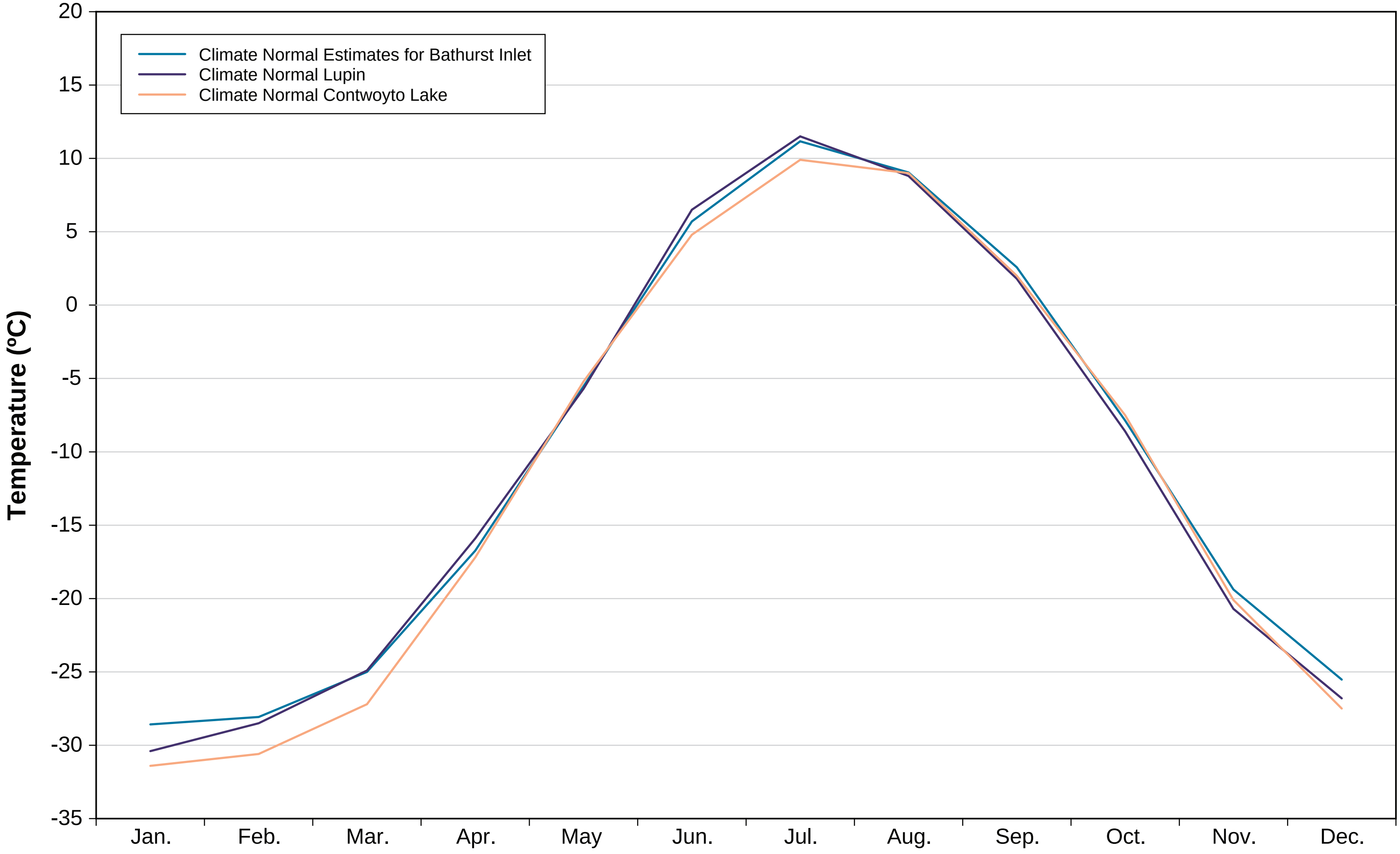

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FIGURE 2.3-1

Monthly Average Temperatures along the Road

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Daily average maximum temperatures along the road vary from -26.8ºC in January to 16.3ºC in July, with the Bathurst Inlet end of the road experiencing a slightly smaller range of maxima (-25.6ºC and 15.4ºC for January and July, respectively (Figures 2.3-2 and 2.3-3). The extreme maximum of 31.6ºC expected at the port is a good estimator of the 1-in-30 year extreme maximum temperature. Daily mean minimum temperatures are lowest in January (-34.0ºC) and highest in July (6.7ºC), with the port again experiencing a slightly smaller range (-31.4ºC to 7.0ºC for January and July). The extreme minimum temperature for Lupin (-49.0ºC) is the expected 1-in-30 year minimum.

The average temperature for Contwoyto Lake (-11.8ºC) is 0.7ºC lower than that for Lupin and daily mean maxima and minima show a similar difference. Contwoyto Lake climate normals are for 1961 to 1990 and given the close proximity of Lupin and Contwoyto Lake stations the difference in temperature is likely due to a warming of the climate from the 1961-1990 to the 1971-2000 period. Further implications of this possible warming trend are discussed in Appendix G-2 of the DEIS (Effects of the Environment on the Project).

2.3.2 Precipitation

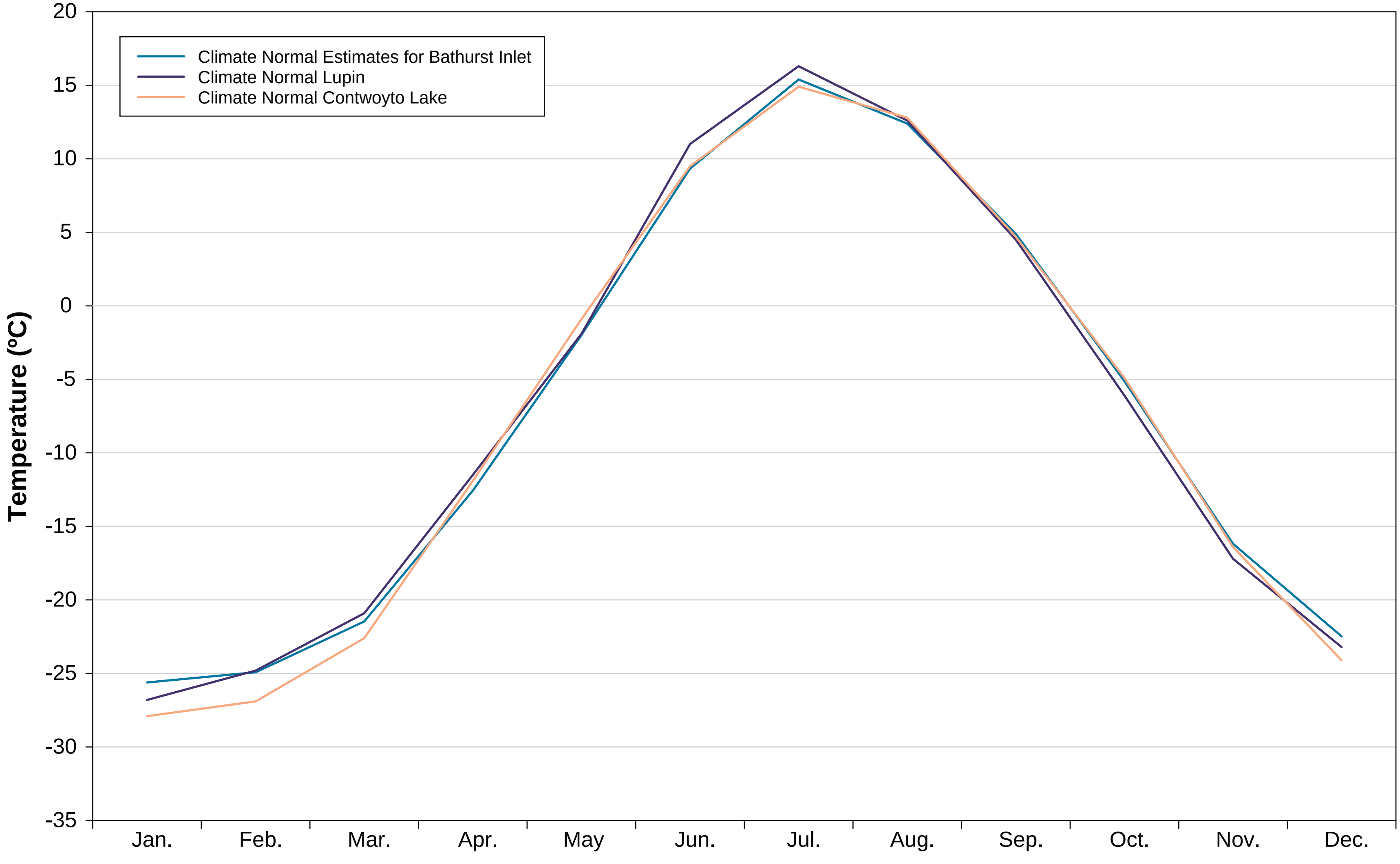
Precipitation data along the proposed road alignment was available from the port and Lupin. The precipitation measurement at George Lake had a high percentage of missing data. However, the temperature comparison suggests that climate variations between George Lake and Lupin are fairly small and precipitation data from Lupin are assumed to represent conditions along the alignment for most of the inland section of the road.

Adjusted precipitation normals (Table 2.2-4, Figure 2.3-4) for Lupin indicate a mean annual precipitation of 333 mm. Of this total, 172 mm fall as snow, mostly between September and May, and 162 mm fall as rain, the majority between June and September. August has the highest average rain (55 mm), and October the highest average snowfall (38 mm). Precipitation normals for the port were estimates to be 79% of those given for Lupin (see Section 2.2.2, Figure 2.2-5) and the annual distribution was assumed to be identical. Mean annual precipitation at the port was estimated to be 264 mm, with 136 mm falling as snow and 128 mm as rain.

2.3.3 Wind Speed and Direction

Wind speed and direction for the road section close to Bathurst Inlet can be expected to resemble those at the port site. The dominant wind direction is northwest to north with an average wind speed of approximately 6 m/s.

Wind speeds are influenced by local topography and regional weather patterns. Therefore, conditions along the inland section of the road exhibit some variability, as is apparent when comparing wind roses from Lupin (Figure 2.3-5) and George Lake (Figure 2.3-6). Both wind roses represent hourly measurements of wind speed and direction. Lupin data are for August 2001 to July 2004 to match the data record at the port station. George Lake data are for August 2004 to May 2007, the period of record available from the station.



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Monthly Average Daily Maximum Temperatures along the Road

FIGURE 2.3-2

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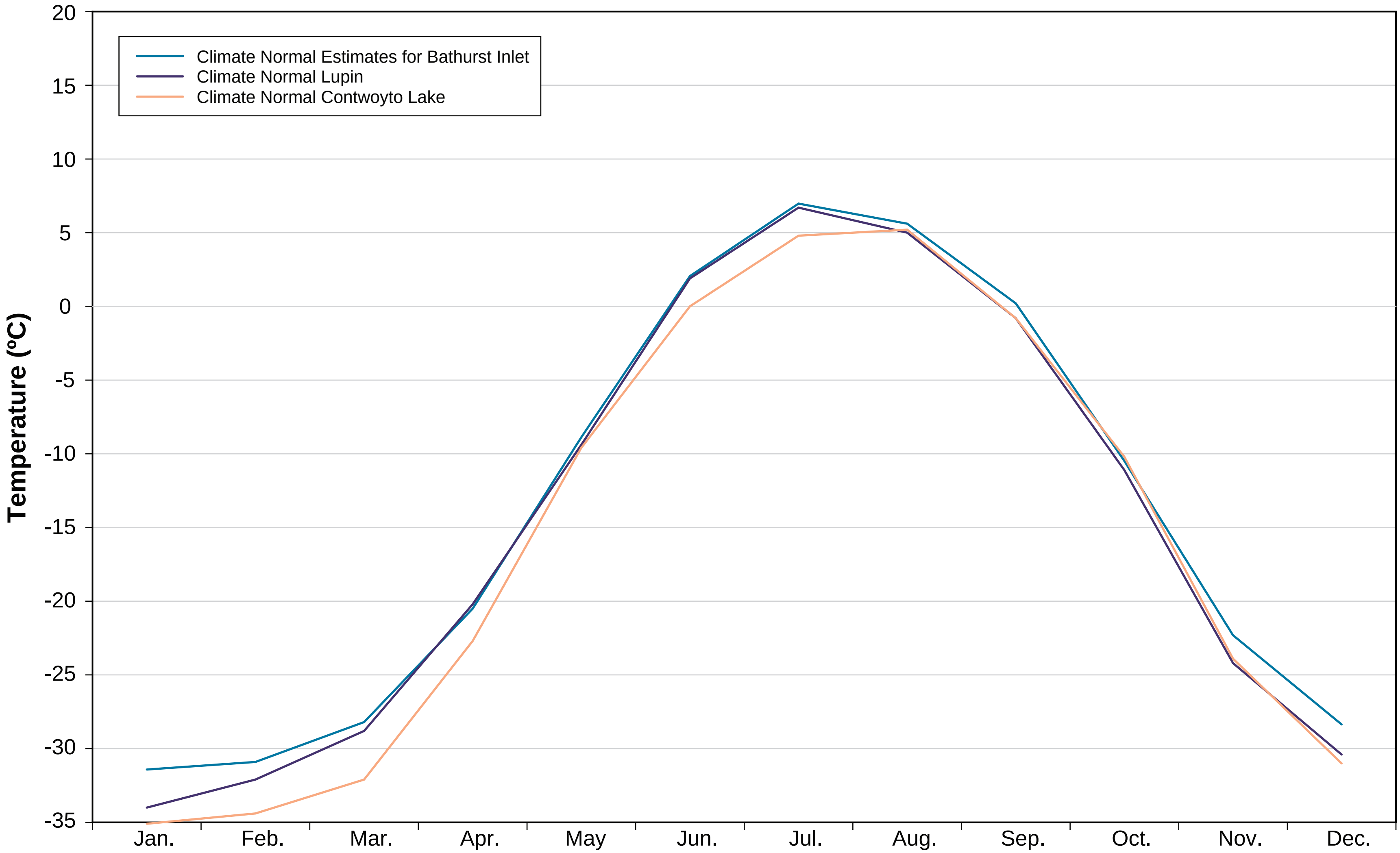

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Monthly Average Daily Minimum Temperatures along the Road

FIGURE 2.3-3

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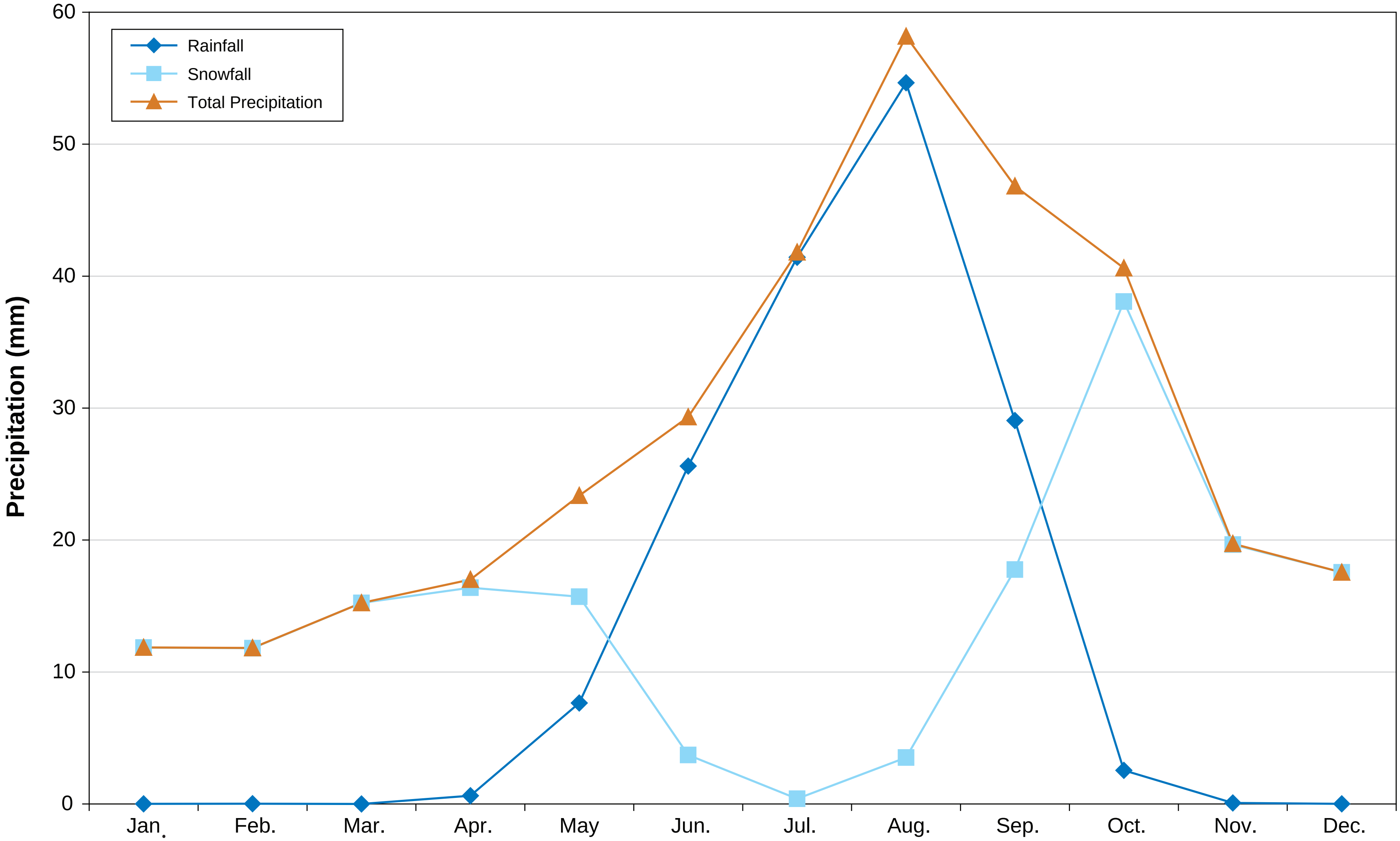

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FIGURE 2.3-4

Adjusted Climate Normals for Precipitation at Lupin

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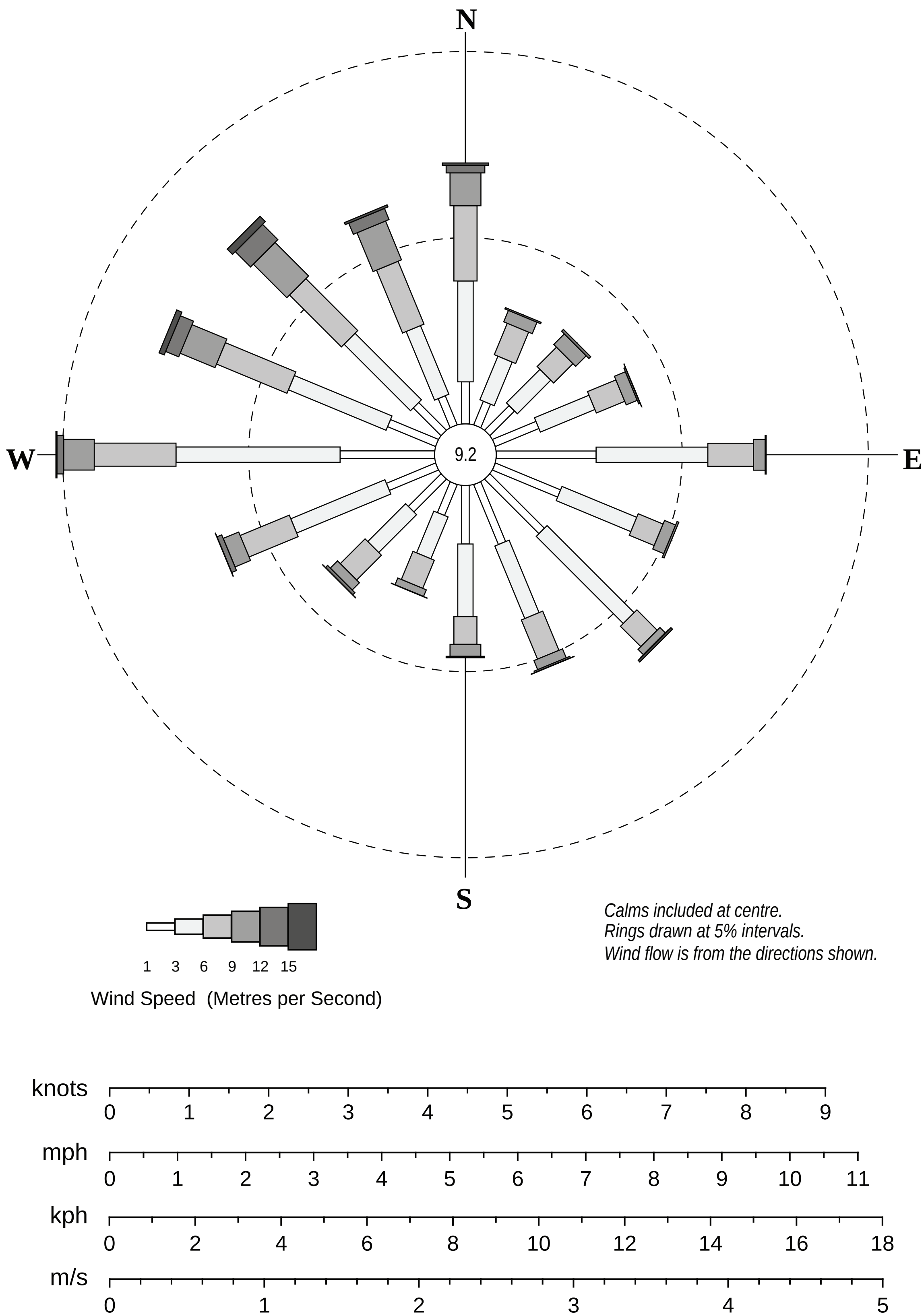

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Wind Rose for Lupin CS Station (July 2001 to July 2004)

FIGURE 2.3-5

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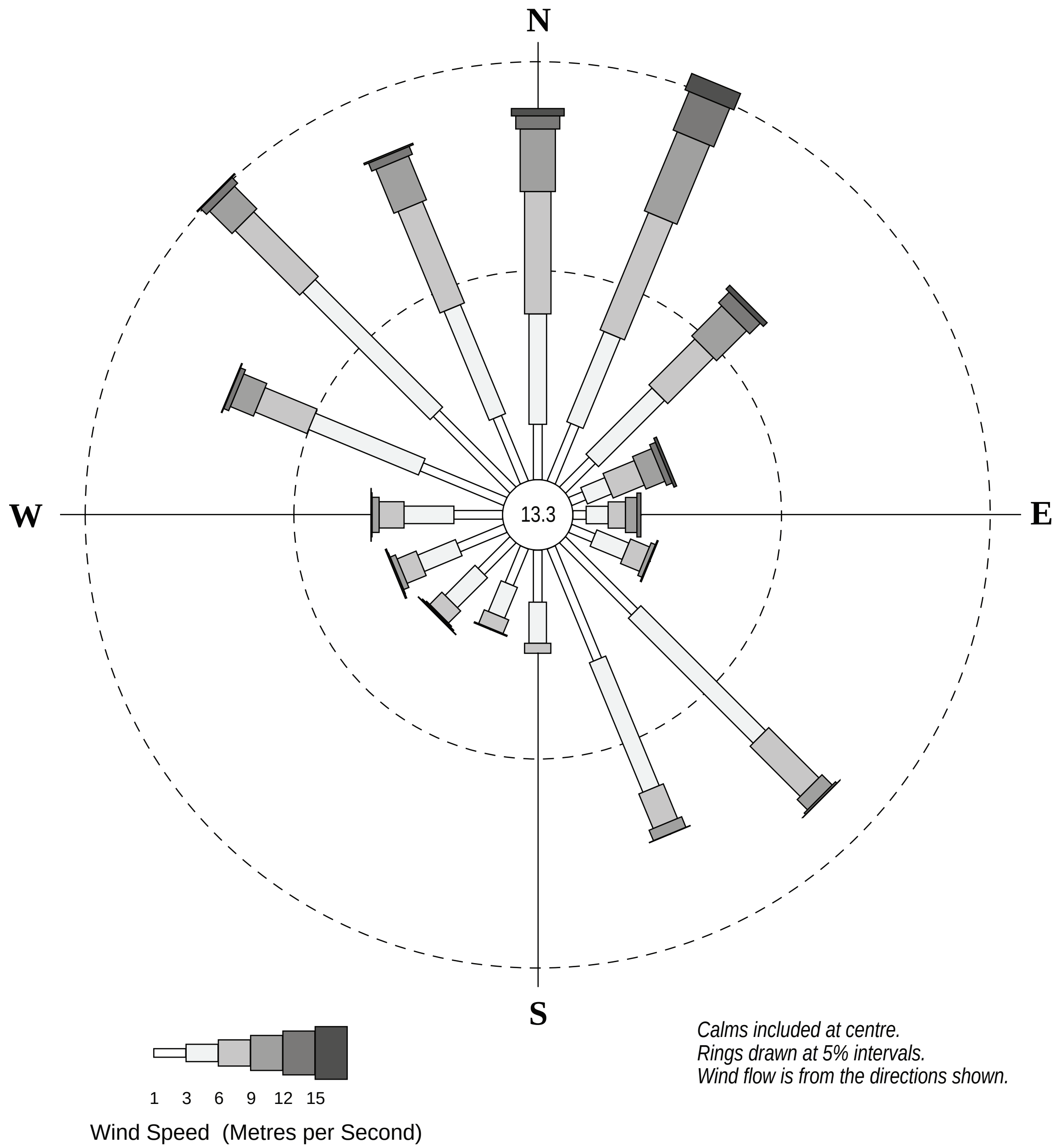
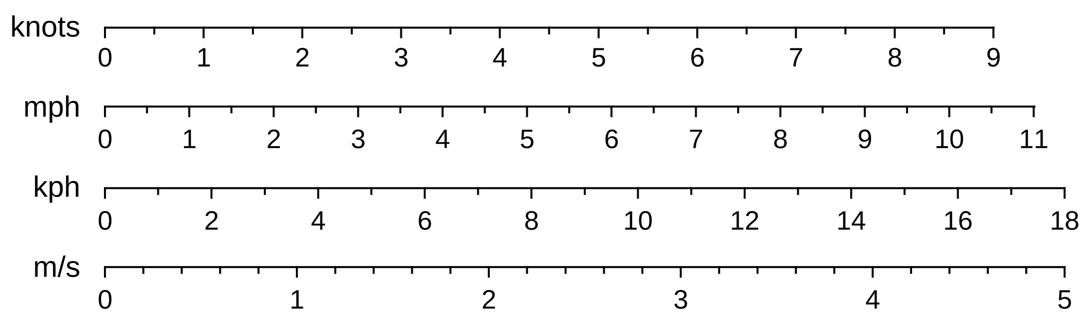


Calms included at centre.
Rings drawn at 5% intervals.
Wind flow is from the directions shown.



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Wind Rose for George Lake Station (August 2004 to May 2007)

FIGURE 2.3-6

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At Lupin, wind directions are more variable than at the port station. The wind direction was in the west to north sector 38.8% of the time, while winds from the east to south sector contributed 28.8%. Average wind speed for August 2001 to July 2004 at Lupin was 4.7 m/s, calms (*i.e.*, hourly average wind speeds lower than 1 m/s) were measured 9.2% of the time, and the wind was below 6 m/s 80.2% of the time. Winds above 12 m/s were predominantly from the west to north sector (70.3% of the time).

At George Lake, winds were from the west-northwest to northeast sector 50.2% of the time. However, there was a secondary peak in the wind direction distribution from the southeast to south-southeast sector with winds coming from this direction 16.2% of the time. The average wind speed for the period of record was 4.8 m/s, calms were registered 13.3% of the time and winds were below 6 m/s 74.3% of the time. As with Lupin, winds above 12 m/s were from the north to northeast sector (68.2% of the time).

2.4 Climate along the Shipping Route

Data used to characterize the climate along the shipping route are from the port as well as Environment Canada stations at Cambridge Bay, Resolute, Byron Bay, and Jenny Lind. All these stations are on shore, typically about 1 km away from the ocean at elevations between 13 m and 172 m (Table 2.1-1).

2.4.1 Air Temperature

As expected mean air temperature along the shipping route drops with latitude, from -10.7ºC at the Port Site, to -14.4ºC at Cambridge Bay to -16.4ºC at Resolute (Table 2.4-1). At the beginning of the shipping season in July, mean monthly temperatures vary from 11.2ºC at the Port Site to 4.2ºC at Resolute. In September mean monthly temperature are already below zero at Cambridge Bay (-0.3ºC) and Resolute (-4.7ºC) and in October, at the end of the shipping season they vary from -7.9ºC at the Port Site to -14.9ºC at Resolute (Figure 2.4-1).

To add further detail to the spatial temperature variation, average temperature from the historic Bathurst Inlet station and climate normals for 1961 to 1990 for Byron Bay, Cambridge Bay, Jenny Lind and Resolute are shown in Table 2.4-1. Using the 1961 to 1990 normals avoids the introduction of temporal variability (climate change) and allows for an analysis spatial variations only (Figure 2.4-2). For this set of mean monthly temperatures, Bathurst Inlet is again the warmest, and Resolute the coldest. Byron Bay, at a slightly more southern location than Cambridge Bay, is 1ºC warmer than Bathurst Inlet. However, June to August temperatures at Jenny Lind were 1ºC to 2ºC colder than at Cambridge Bay, even though Jenny Lind is at a more southerly latitude.

Compared to the more recent climate normal estimate for the port site station, January to March mean monthly temperature at the historic Bathurst Inlet station are about 2ºC to 3ºC colder, even though the historic station was located just 40 km north of the port site. Mean temperature from June to August was about 1ºC warmer at the historic station than at the port site. Annual average temperatures for Cambridge Bay and Resolute were about 1ºC warmer for the 1971-2000 period compared to the 1961-1990 climate normals. This is further evidence of a warming of the

Table 2.4-1
Mean Monthly Temperatures along the Shipping Route

	Port Site (Climate Normal Estimate)	Cambridge Bay (1971 to 2000)	Resolute (1971 to 2000)	Bathurst Inlet– Historic Station (1953 to 1962)
a) Average Air Temperature (ºC)				
January	-28.6	-32.8	-32.4	-31.2
February	-28.1	-33.0	-33.1	-31.0
March	-25.0	-29.7	-30.7	-28.0
April	-16.7	-21.4	-22.8	-17.8
May	-5.5	-9.2	-10.9	-6.0
June	5.7	2.4	-0.1	6.6
July	11.2	8.4	4.3	12.1
August	9.0	6.4	1.5	9.7
September	2.6	-0.3	-4.7	2.5
October	-7.9	-11.5	-14.9	-8.2
November	-19.4	-23.0	-23.6	-20.8
December	-25.5	-29.6	-29.2	-25.3
Annual	**-10.7**	**-14.4**	**-16.4**	**-11.5**

	Byron Bay (1961 to 1990)	Cambridge Bay (1961 to 1990)	Jenny Lind (1961 to 1990)	Resolute (1961 to 1990)
b) Average Air Temperature (ºC) Normals (1961 to 1990)				
January	-32.3	-33.4		-32
February	-32	-33.5		-33
March	-29.5	-30.7	-29.9	-31.2
April	-20.7	-22	-21.6	-23.5
May	-8.8	-9.5	-9.3	-11
June	2.7	1.9	0.7	-0.6
July	9.2	8	6.1	4
August	6.6	6.2	4.5	1.9
September	-0.3	-0.6	-0.9	-5
October	-10.5	-11.5	-10.4	-15.2
November	-22.9	-23.7	-22.7	-24.3
December	-28.3	-29.6	-28.6	-29
Annual	**-13.9**	**-14.9**	**n/a**	**-16.6**

	Port Site (Climate Normal Estimate)	Cambridge Bay (1971 to 2000)	Resolute (1971 to 2000)
c) Daily Mean Maximum Air Temperature (ºC)			
January	-25.6	-29.3	-28.8
February	-24.9	-29.3	-29.7
March	-21.5	-25.7	-27.2

(continued)

Table 2.4-1
Mean Monthly Temperatures along the Shipping Route (completed)

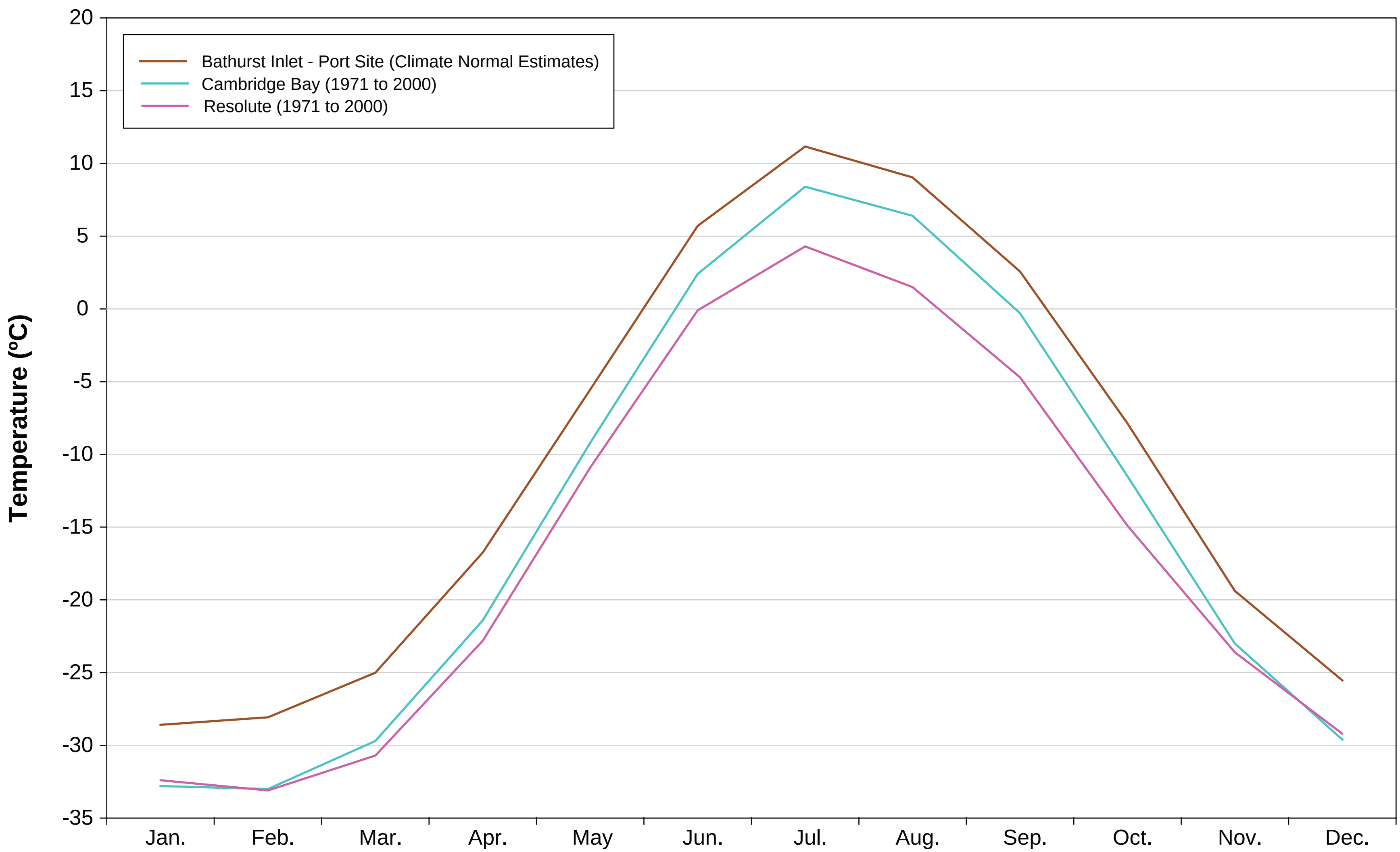
		Port Site (Climate Normal Estimate)	Cambridge Bay (1971 to 2000)	Resolute (1971 to 2000)
	April	-12.6	-16.7	-19.1
	May	-2.0	-5.3	-7.7
	June	9.3	5.6	2.2
	July	15.4	12.3	7.1
	August	12.4	9.4	3.8
	September	4.9	1.9	-2.5
	October	-5.1	-8.1	-11.8
	November	-16.2	-19.3	-20.1
	December	-22.5	-26.1	-25.6
	1-in-30 Year Extreme	**31.6**	**28.9**	**18.3**
d)	*Daily Mean Minimum Air Temperature (ºC)*			
	January	-31.4	-36.3	-35.9
	February	-30.9	-36.6	-36.6
	March	-28.2	-33.7	-34.2
	April	-20.5	-26.0	-26.5
	May	-8.9	-13.0	-14.0
	June	2.1	-0.8	-2.5
	July	7.0	4.6	1.4
	August	5.6	3.4	-0.8
	September	0.2	-2.5	-6.9
	October	-10.5	-14.9	-18.0
	November	-22.3	-26.5	-27.0
	December	-28.4	-33.0	-32.7
	1-in-30 Year Extreme	**-46.5**	**-52.8**	**-51.2**

climate from the 1961-1990 to the 1971-2000 period. Further implications of this possible warming trend are discussed in Appendix G-2 of the DEIS (Effects of the Environment on the Project).

Daily mean maximum temperatures for the port, Cambridge Bay and Resolute based on the 1971 to 2000 climate normals are above 0ºC for all stations from June to August and drop below zero at Resolute in September and are below -5ºC at all stations in October (Table 2.4-1, Figure 2.4-3). Daily mean minimum temperatures above zero are found at the port from June to September, at Cambridge Bay in July and August and at Resolute only in July (Table 2.4-1, Figure 2.4-4).

2.4.2 Precipitation

The 1971-2000 precipitation normals calculated from the "Historical Adjusted Climate Database for Canada" (Environment Canada, 2007b) for Cambridge Bay and Resolute are about 25% to



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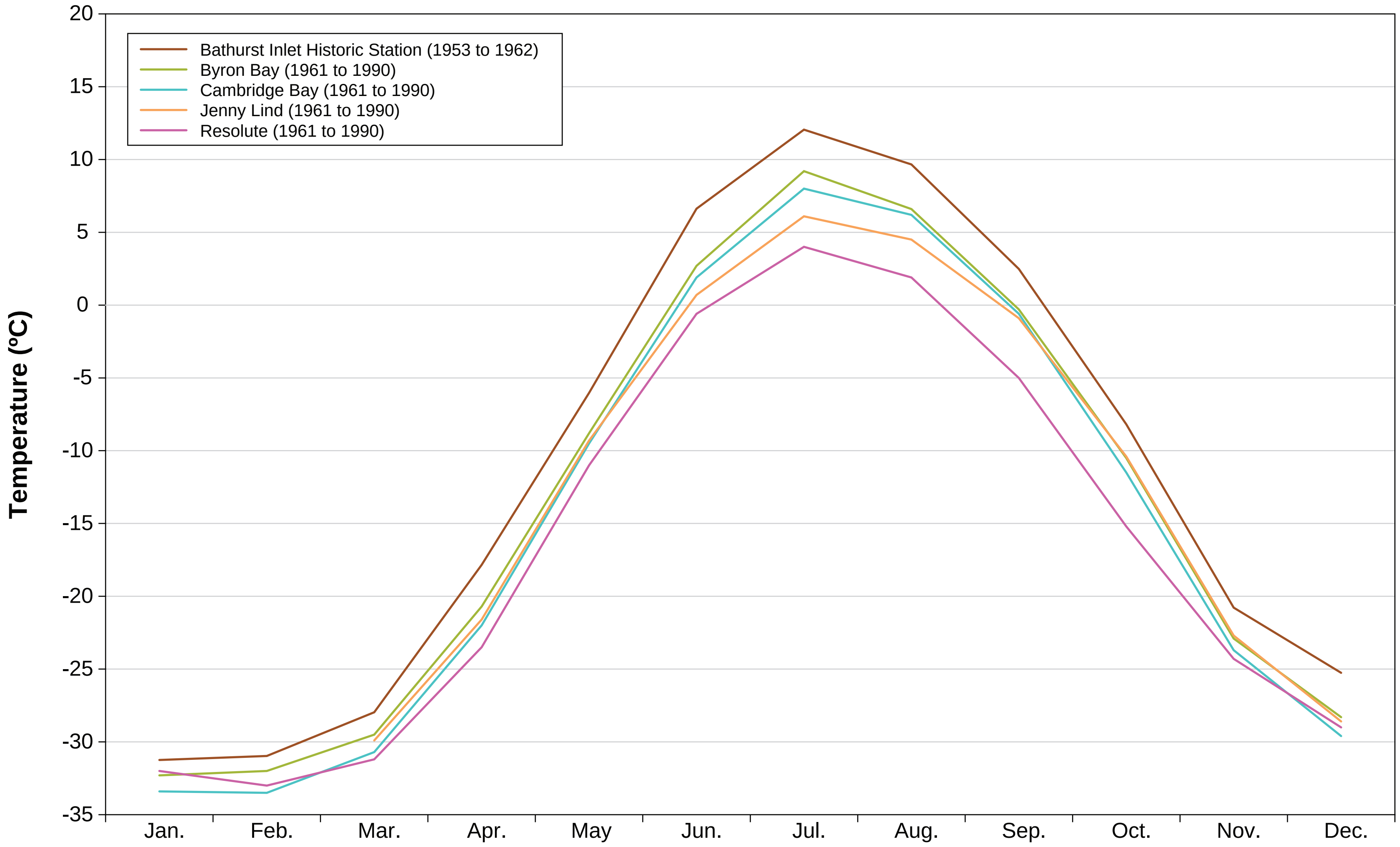
Monthly Average Temperatures along the Shipping Route for the 1971 to 2000 Climate Normals

FIGURE 2.4-1

Rescan™

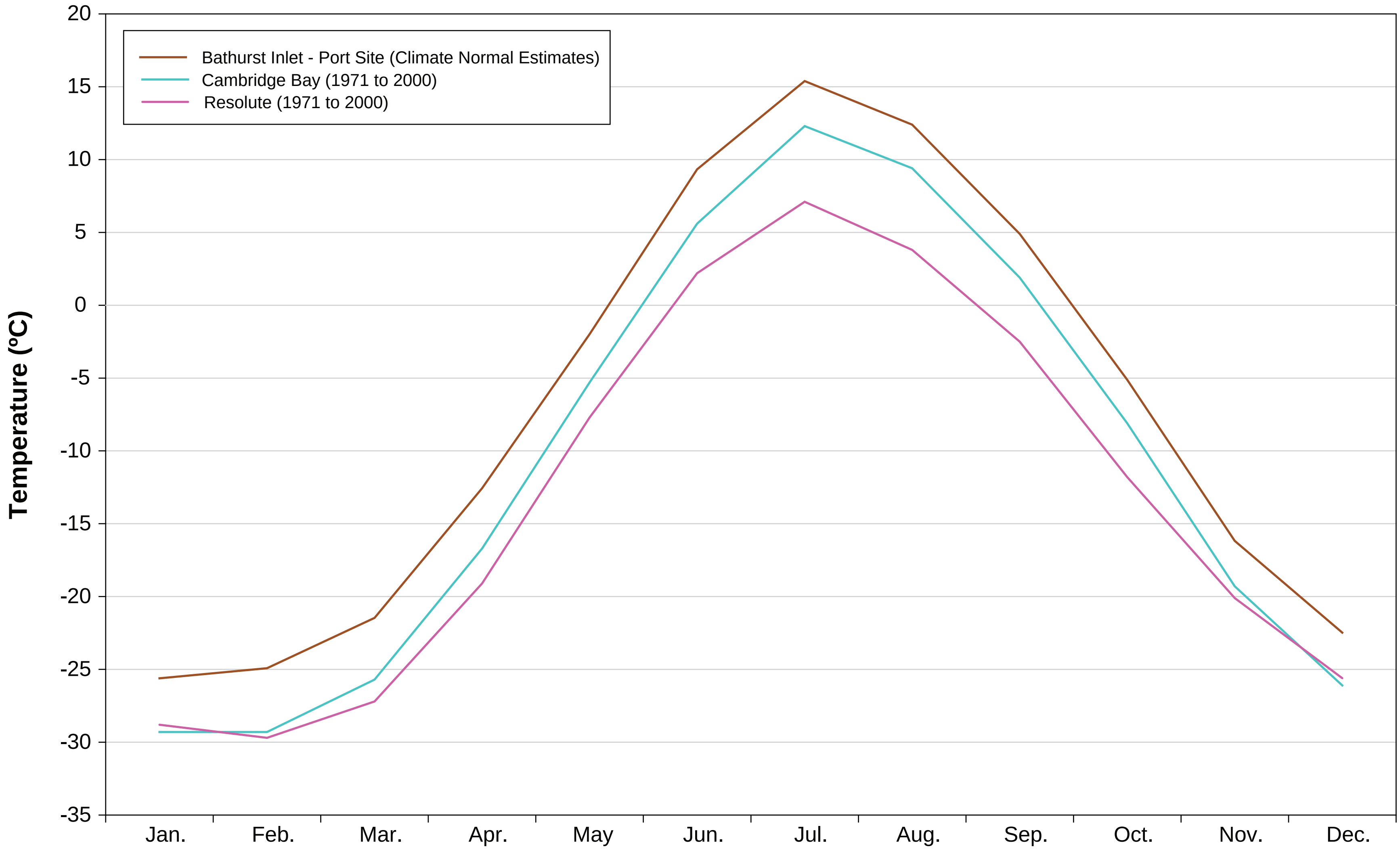


the BATHURST INLET PORT AND ROAD PROJECT

Monthly Average Temperatures along the Shipping Route for the 1961 to 1990 Climate Normals

FIGURE 2.4-2

Rescan™

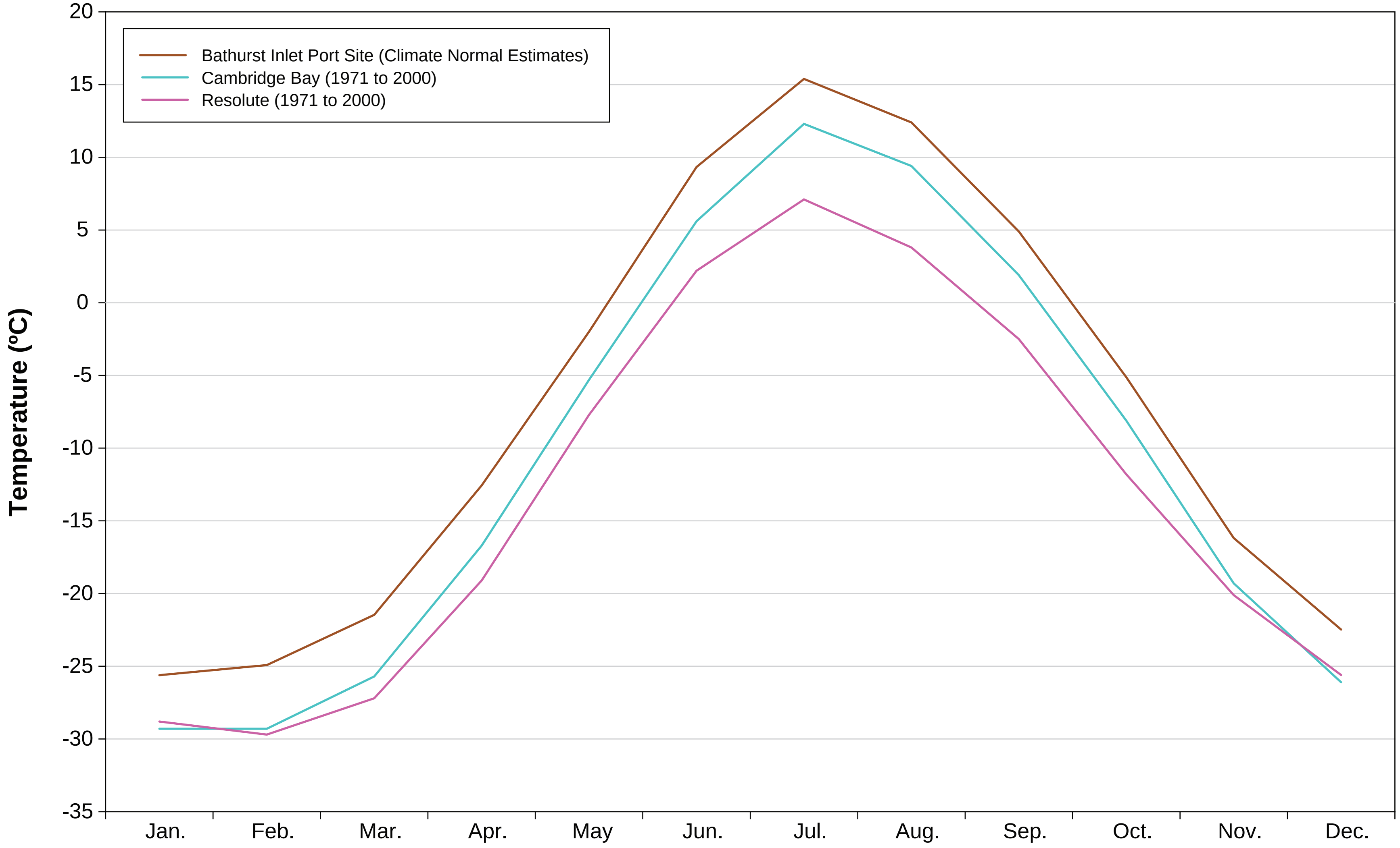


the BATHURST INLET PORT AND ROAD PROJECT

Monthly Average Maximum Temperatures along the Shipping Route for the 1971 to 2000 Climate Normals

FIGURE 2.4-3

Rescan™



Monthly Average Minimum Temperatures along the Shipping Route for the 1971 to 2000 Climate Normals

FIGURE 2.4-4

30% above the measured normals for precipitation and about 60% above measured normals for snow (Table 2.4-2), highlighting the importance of undercatch in biasing the precipitation measurements. The sum of rain and snowfall in the climate normals published by Environment Canada (2007a) is larger than the published value for total precipitation and therefore the adjusted total precipitation is also 60% above the measured climate normal (as opposed to 45% expected from the sum of rain and snow).

Annual precipitation was 264 mm at the port and 221 mm at Cambridge Bay. Annual rainfall was 128 mm at the port in the south, 87 mm at Cambridge Bay and only 64 mm at Resolute in the north. This trend translates to approximately 50% rainfall in total precipitation at the port, 40% at Cambridge Bay and 25% at Resolute. As the port site and Cambridge Bay receive very similar amounts of snow (136 mm and 133 mm, respectively) the difference in total precipitation between these two stations is largely due to a difference in rainfall.

The seasonal pattern of precipitation along the shipping route is driven by temperatures decreasing toward the north. While snowfall is similar at Bathurst Inlet, Cambridge Bay, and Resolute from October to May, Resolute has higher snowfall than the other two stations from June to September (Figure 2.4-5). Snowfall is highest in October at Bathurst Inlet and Cambridge Bay and in September at Resolute. A secondary maximum of snowfall occurs in May at all stations and Resolute has a minimum of monthly snowfall of 6 mm even in July when the two southern stations have average snowfall below 1 mm. At all three stations along the shipping route measurable rainfall occurs between May and October and August has the highest monthly precipitation. Total precipitation is also highest in August, although at Bathurst Inlet and Cambridge Bay the contribution of snowfall to total precipitation is less than 10%.

2.4.3 Wind Speed and Direction

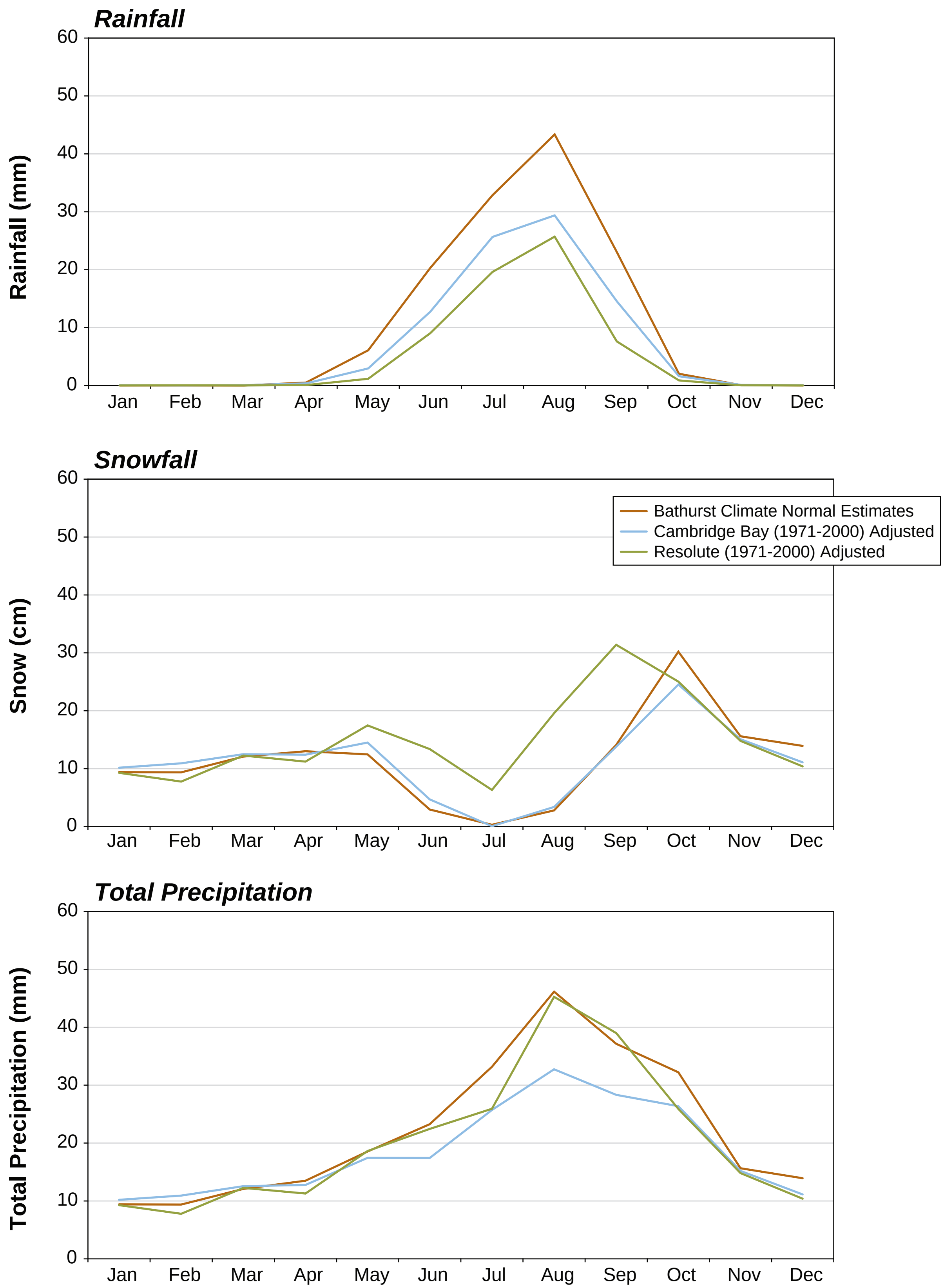
Wind speed and direction measurements along the shipping route are available from the port site station, Cambridge Bay and Resolute. Winds measured on shore are influenced by the roughness as well as energy and momentum fluxes associated with the terrain. Therefore, the wind conditions recorded by the on shore meteorological stations will differ to some extent from wind conditions along the shipping route during the open water season. However, the data was thought to be reasonably representative of wind conditions along the shipping route. Average and maximum wind speeds along with the most common wind direction are shown in Table 2.4-3.

Average monthly wind speeds are very similar at all three stations, varying between 5.4 m/s and 6.6 m/s with wind speeds toward the higher end of the range between October and December. At the port site station, winds are predominantly from the northeast; at Cambridge Bay they are from the northeast between April and July and northwest between September and March; at Resolute, winds are predominantly from the northwest all year except August, which predominantly sees westerly wind.

Table 2.4-2
Precipitation Normals along the Shipping Route

	Port Site Climate Normal Estimate			Cambridge Bay (1971 to 2000)[a]			Cambridge Bay (1971 to 2000) Adjusted[b]			Resolute (1971-2000)[a]			Resolute (1971-2000) Adjusted[b]		
	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)
Jan.	0.0	9.4	9.4	0.0	5.6	4.6	0.0	10.2	10.2	0.0	4.7	4.3	0.0	9.3	9.3
Feb.	0.0	9.4	9.4	0.0	6.4	5.1	0.0	10.9	10.9	0.0	3.7	3.4	0.0	7.8	7.8
Mar.	0.0	12.1	12.1	0.0	7.4	6.0	0.1	12.5	12.6	0.0	7.0	6.5	0.0	12.3	12.3
Apr.	0.5	13.0	13.5	0.1	7.5	6.5	0.4	12.4	12.8	0.0	6.6	6.1	0.1	11.2	11.3
May	6.1	12.5	18.5	1.6	9.3	9.4	2.9	14.5	17.4	0.5	11.1	9.5	1.2	17.5	18.6
Jun.	20.3	2.9	23.3	9.8	2.8	12.5	12.8	4.7	17.4	6.5	8.7	14.7	9.0	13.4	22.4
Jul.	32.9	0.3	33.2	21.7	0.0	21.7	25.7	0.1	25.7	15.7	4.2	20.2	19.6	6.3	25.9
Aug.	43.4	2.8	46.1	24.5	2.2	26.7	29.4	3.4	32.7	21.8	13.1	34.3	25.7	19.6	45.3
Sep.	23.1	14.1	37.1	11.4	8.9	19.3	14.5	13.8	28.3	5.4	21.0	25.0	7.6	31.4	39.0
Oct.	2.0	30.2	32.2	0.4	16.2	14.6	1.6	24.5	26.4	0.5	16.2	13.8	0.9	25.0	25.9
Nov.	0.1	15.6	15.6	0.0	9.3	7.2	0.1	15.1	15.2	0.0	8.6	7.6	0.0	14.8	14.8
Dec.	0.0	13.9	13.9	0.0	6.3	5.3	0.0	11.1	11.1	0.0	5.5	4.7	0.0	10.4	10.4
Annual	**128.3**	**136.2**	**264.4**	**69.5**	**81.9**	**138.9**	**87.4**	**133.1**	**220.8**	**50.4**	**110.4**	**150.1**	**64.1**	**178.8**	**243.0**

Notes:
[a]Climate normals (Environment Canada, 2007a).
[b]Historical Adjusted Climate Database for Canada (Environment Canada, 2007b).



Climate Normals for Precipitation along the Shipping Route

FIGURE 2.4-5

Table 2.4-3
Wind Speeds and Directions along the Shipping Route

	Port Site (2001 to 2004 Average)		Cambridge Bay (1971 to 2000)		Resolute (1971 to 2000)	
	Wind Speed (m/s)	Most Frequent Direction	Wind Speed (m/s)	Most Frequent Direction	Wind Speed (m/s)	Most Frequent Direction
January	5.4	Northeast	6.2	Northwest	5.7	Northwest
February	5.6	Northeast	6.0	Northwest	5.7	Northwest
March	5.8	Northeast	5.9	Northwest	5.8	Northwest
April	5.6	Northeast	5.7	Northeast	5.6	Northwest
May	6.0	North	5.8	Northeast	5.6	Northwest
June	5.5	North	5.4	Northeast	5.6	Northwest
July	5.4	North	5.5	North	5.8	Northwest
August	5.6	North	6.0	West	5.8	West
September	6.1	Northeast	6.2	Northwest	6.6	Northwest
October	5.9	Northeast	6.4	Northwest	6.4	Northwest
November	6.5	Northeast	5.8	Northwest	6.1	Northwest
December	5.4	Northeast	5.9	Northwest	5.4	Northwest
Annual	**5.7**	**Northeast**	**5.9**	**Northwest**	**5.8**	**Northwest**

2.5 Additional Climatic Observations

2.5.1 Evaporation

A 'Class A' evaporation pan was used at the Hope Bay Belt Gold Exploration Project (Hope Bay Joint Venture). The evaporation data from this station was assumed to be a reasonable estimate of open-water evaporation for the port site as well as the road.

Pan evaporation was measured between 1995 and 2000. However, the 1998 and 2000 data were of questionable quality because of the high number of missing days and the presence of animals drinking from the pan that would over-estimate the mean daily evaporation rate. Overall, the data from 1997 was considered most representative because of the length of the period of record with only a few missing days. For an 88 day period of record (June 15 to September 11) the Class A pan evaporation was approximately 261 mm (3.1 mm/day).

Open water or lake evaporation may be estimated by applying a coefficient to the Class A pan evaporation. Pan evaporation is typically higher than lake evaporation because of radiation and boundary effects. Pan coefficients for the Yellowknife airport for 1992 to 1994 were in the range 0.69 to 0.72[1] and a mean pan coefficient of 0.77 was reported by Linacre (1994) for the U.S.

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[1] Mr. Bob Reid, Head-Water Resources/Water Management, Canadian Department of Indian Affairs and Northern Development (DIAND). *Personal communication* (e-mail) to Dan Jarratt, P.Eng., Rescan Environmental Services Ltd., November 21, 2002.

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Applying a pan coefficient of 0.75 to the 1997 Class A pan data for an assumed open-water season at the Boston site (124 days), an estimated lake evaporation of 288 mm was obtained. In absence of additional site-specific information, it was assumed that the open water evaporation at the Bathurst port site would be approximately the same.

2.5.2 Arctic Inversions and Ice Fog

The term "inversion" refers to a layer in the atmosphere in which there is an increase in air temperature with height. This differs from normal tropospheric conditions in which temperature decreases with height from the surface. Polar inversions are generally caused by an energy deficit at the surface. The presence of Arctic inversion is closely related to the snow and ice that dominate surface areas in the Arctic regions. For this reason, low-level inversion features are present almost continuously over the entire Arctic region in winter and over snow and ice covered areas during the summer. The combination of the long duration of calm or light winds and persistent Arctic inversion provides an indication of the potential for poor air quality in the Canadian Arctic (Environment Canada, 1983).

Table 2.5-1 summarizes the mean number of days per month with surface based inversions at Cambridge Bay Airport and Kugluktuk (Coppermine) for 1100 and 2300 GMT. Upper air inversions occur less frequently than surface based inversions. The mean number of days per month with surface based inversions at the port site (based on the period 1967 to 1976) is approximately 20.5 (67%) during December to May at 1100 GMT. During June to November the mean number of days per month with surface based inversions at 1100 GMT falls to approximately 13.1 (43%). Surface based inversions at the port at 2300 GMT have roughly the same mean number of days as 1100 GMT except the mean number of days per month decreases substantially to 6.4 (21%) from March to November. The lowest inversion thickness values occur during June to September and the highest in November to March. Generally, the main inversion layer is 1,000 m to 1,500 m thick in winter, decreasing to 200 m to 400 m by summer.

Table 2.5-1
Mean Number of Days with Surface Based Inversions at 1100 and 2300 GMT

Station	Month												Annual Total
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
At 1100 GMT													
Cambridge Bay	23.9	21.6	24.8	24.0	24.8	12.9	13.3	13.3	12.6	13.0	12.6	23.9	220.7
Kugluktuk (Coppermine)	20.2	18.2	21.1	20.4	21.1	13.5	14.0	14.0	12.3	12.7	12.3	20.2	199.8
Port Site[a]	20.2	18.2	21.7	21.0	21.7	14.1	14.6	14.6	11.7	12.1	11.7	20.2	201.6
At 2300 GMT													
Cambridge Bay	23.3	21.0	7.8	7.5	7.8	3.0	3.1	3.1	10.5	10.9	10.5	23.3	131.6
Kugluktuk (Coppermine)	19.8	17.9	7.8	7.5	7.8	6.6	6.8	6.8	8.4	8.7	8.4	19.8	126.3
Port site[a]	19.8	17.9	6.8	6.6	6.8	3.0	3.1	3.1	9.3	9.6	9.3	19.8	115.3

Notes:
[a]These values were extrapolated from percentage isolines produced by gridding data from regional meteorological stations.
Period of record: Cambridge Bay Airport (1970 to 1976).
Kugluktuk (Coppermine) (1967 to 1970).
Source: Environment Canada (1983).

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The phenomenon of ice fog is important in the Arctic because of its potential for disrupting both air and ground transport in the area. These effects must be considered in the construction of facilities such as pipeline pumping stations, buildings and roads. Ice fog has been studied by various authors: Environment Canada meteorological stations report "ice fog" when "a suspension of numerous minute ice crystals in the air" reduces visibility to 10 km (6 miles) or less (Environment Canada, 1983). The mean number of days per month with ice fog and blowing snow for selected stations near Bathurst Inlet are summarized in Table 2.5-2. The total number of days with fog per year is between 28 and 54 and the total number of days per year with blowing snow is between 48 and 77. The ice fog season is generally restricted to the November through April period although it may begin or end a month earlier or later, respectively, depending upon the particular location. The month of maximum mean percentage occurrence is equally likely to be January, February or March. Ice fog and blowing snow are of particular importance for the Project because it has the potential to disrupt travel along the road, mostly during November to April. Based on the regional data, the port site would be expected to have reduced visibility caused by either fog, ice fog, freezing fog or blowing snow between 76 and 131 days per year.

Table 2.5-2
Mean Number of Days with Ice Fog or Blowing Snow at Regional Meteorology Stations (1971 to 2000)

Station	Parameter	Month												Annual Total
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Cambridge Bay Airport	Fog, Ice Fog or Freezing Fog	3.9	5.1	4.2	3.3	6.8	5.3	4.7	3.8	5.6	5.7	2.3	3.1	53.6
	Blowing Snow	13.0	11.5	10.8	7.3	4.7	0.63	0.0	0.13	1.2	8.0	9.0	10.8	77.1
Kugluktuk (Coppermine) Airport	Fog, Ice Fog or Freezing Fog	1.8	2.2	1.7	3.6	5.1	3.3	2.0	2.0	2.1	1.6	1.0	1.5	27.8
	Blowing Snow	9.4	9.5	6.5	2.9	1.1	0.0	0.0	0.0	0.26	4.3	5.2	9.0	48.1

Notes :
No data available for Lupin Airport.
Source: Environment Canada (2007a).

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

Climate was selected as a valued ecosystem component (VEC) because it is a fundamental aspect of the natural environment. Changes to the climate will affect many other ecosystem components. The global climate is influenced by the presence of natural and man-made greenhouse gases (GHGs). Naturally occurring GHGs (water vapour, CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide) and O_3 (ozone)) help the earth's atmosphere trap the sun's heat, creating a 'greenhouse effect' that keeps the earth warm and sustains life.

The amount of GHGs in the atmosphere has been increasing over the past century due, in part, to anthropogenic GHG emissions resulting primarily from fossil fuel combustion. Atmospheric GHG levels may have also been increasing as a result of reductions in large-scale carbon sinks due to deforestation. The rising levels of GHGs mean more heat stays in the earth's atmosphere causing increases in the global climate. The primary GHGs from anthropogenic sources are CO_2, CH_4 and N_2O. Construction and operation of the road will lead to the emission of GHGs, mostly in the form of CO_2 from the combustion of diesel fuel.

3.2 Boundaries

3.2.1 Spatial Boundaries

The lifetime of CO_2 in the atmosphere is on the order of 50 to 200 years (IPCC, 2001). CO_2 emitted by Project activities will be dispersed globally. Therefore, effects of CO_2 emissions do not have spatial boundaries.

3.2.2 Temporal Boundaries

The temporal boundary of the potential effects related to CO_2 emissions on climate is set to 200 years, the lifetime of CO_2 in the atmosphere. Any climate effects attributed to these emissions are assumed to last for this period.

3.3 Approach and Methods

This assessment evaluates potential effects of Project emissions on the climate using the methodology established for the Project (Appendix A-5 of the DEIS).

CO_2 from diesel combustion will be the major GHG emission from port and road construction and operation. The effects of the Project on the VEC Climate will be assessed using the emission of CO_2 due to Project activities. In addition to the total amount of CO_2 emitted, the emission intensity, *i.e.*, the amount of CO_2 emitted per litre of diesel fuel, will be assessed.

It was assumed that standard diesel trucking equipment and diesel generators will be used for the Project. Maintenance will be carried out on a regular basis to keep engines efficient. Under these conditions the combustion of diesel generates 2.73 kg of CO_2 per litre as well as CH_4 and N_2O in amounts that will have the equivalent greenhouse effect as 30 g of CO_2 per litre (Environment Canada, 2005). Therefore, the CO_2 emissions from diesel combustion are assumed to equal 2.76 kg CO_2 equivalents (CO_2 eq) per litre diesel fuel.

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4. EFFECTS ASSESSMENT

4. Effects Assessment

Approximately 2.4 million litres of diesel will be used annually over three years for construction of the Project, which will generate approximately 6,600 tonnes of CO_2 eq emissions. Once in operation, approximately 2.5 million litres of diesel will be used for maintenance and operation of the Project components (generator sets, mobile maintenance and support equipment, *etc*) and another 3.5 million litres will be used by haul trucks contracted by prospective road users. Thus, approximately 6.0 million litres of diesel will be used annually by the Project and road users, which will generate approximately 16,600 tonnes of CO_2 eq emissions.

Environment Canada (2005) estimated that 1.6 million tonnes of CO_2 eq was emitted in the Northwest Territories and Nunavut in 2004. Based on this estimate, the emissions contributed by the Project would contribute approximately 0.4% of total emissions in the Northwest Territories during construction and approximately 1.0% of total emissions during operation. Potential secondary reductions or increases in CO_2 eq emissions resulting from development of the Project will be discussed in the cumulative effects assessment (Appendix G-5 of the DEIS). The potential reduction in over-land haul truck traffic represents a potential reduction in GHG emissions while development of new mining projects made possible by the development of the Bathurst Inlet Port and Road project are examples of potential secondary emissions increase.

It is important to note that the GHG emissions associated with Project activities will be off-set by a reduction in emissions from trucks hauling fuel and supplies from Edmonton to mines in the region *via* Yellowknife and the Tibbitt to Contwoyto Winter Road. Overland hauling is generally much more emissions intensive than ocean transport. A preliminary comparison of total GHGs emitted by hauling diesel fuel overland from Edmonton to Diavik *vs.* transporting fuel to the mine *via* ship from the Middle East and then by truck from Bathurst Inlet resulted in a 35% reduction in total GHG emissions.

Ratings assigned to the assessment criteria for the potential effects of CO_2 emission on climate are shown in Table 4-1.

- the **magnitude** of the effects of the CO_2 emissions are rated **moderate**, because the Project emissions constitute on the order of 1% of total emissions for the Northwest Territories and Nunavut but also because emission intensity is about average. This rating reflects that no single industrial operation within an economy contributes a large enough fraction of emissions that would allow the effect of GHG emissions on the global climate to be attributed solely to that operation. Man-made GHG emissions are collective and any operation or individual who does 'business as usual' contributes to the problem of excess GHGs in the global atmosphere.
- the **spatial extent** of the effect of CO_2 emissions is **trans-boundary** since emissions will be dispersed throughout the global atmosphere;
- the **duration** of effect of CO_2 emissions is **long-term**, since the lifetime of CO_2 in the atmosphere is on the order of 200 years;

- The **frequency** of the effect of CO_2 emissions is **continuous** since once in the atmosphere, CO_2 will contribute to the greenhouse effect, even if the emission of the Project temporarily cease;
- The **reversibility** of the effect of CO_2 emissions is **long-term**, since the lifetime of CO_2 in the atmosphere is on the order of 200 years;
- **Resilience** is not applicable in this case;
- The **influence on resource capacity** is **moderate** for the same reasons that led to the rating of the magnitude of effect of CO_2 emission as moderate; and
- The **probability of occurrence** is of the effect of CO_2 emissions is rated **high** in accordance with the IPCC (Alley *et al.*, 2007).

Because the residual effects associated with GHG emissions primarily are determined by the total quantity of emissions the **significance** of the effect of CO_2 equivalent emissions is rated **moderate,** which is also the rating assigned to the magnitude and the long-term duration of the effects of CO_2 emission on climate.

The **confidence** of this assessment is **intermediate**, because even though climate change appears to be ongoing, the relative roles of contributing factors and predictions of its magnitude are still associated with considerable uncertainties.

Table 4-1
Summary of Effects Assessment for Climate

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)**	**Project Component**	**Direction**	**Nature**	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation)**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Limit**
Emission of CO_2	Construction and Operation	Port Site and Road	Adverse	Direct	Enforce speed limits	6,600 and 16,600 tonnes of CO_2 eq will be emitted annually during construction and operation phases, respectively	Moderate	Trans-boundary	Long-term	Continuous	Long-term	n/a	Moderate	High	**Moderate**	Intermediate

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

This mitigation and management plan is offered as a recommendation and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

The Proponent is committed to the conservation and preservation of natural resources and of the environment, as well as the application of best industry practices and techniques to project operations. Theses commitments extend to energy consumption and GHG emissions. Additionally, costs of energy supply will be one of the largest expenditures for the Project. Therefore, energy efficiency will be a major consideration in Project operations from a fiscal as well as an environmental perspective.

The proponent will implement a number of design features and practices that will minimize CO_2 emissions, including:

- a thorough maintenance program that will help maximize energy efficiency for all diesel powered equipment;
- rigorous monitoring of fuel and electrical consumption;
- consideration of energy efficiency when purchasing new and replacement equipment; and
- consideration of energy efficiency policies of outside service providers (*e.g.*, shipping and trucking companies) when acquiring their services.

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

A meteorological station is in place and operating near the port site. Maintenance of the station and analysis of collected data will continue throughout the life of the Project (see Appendix B-5 of the DEIS).

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix B-2
Air Quality Effects Assessment

Author: Rescan Environmental Services Ltd.
Date: November 2007

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Bathurst Inlet Port and Road Project Air Quality Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

AQMS	Air Quality Modelling Study
BIPR	Bathurst Inlet Port and Road
CAC	criteria air contaminant
CCME	Canadian Council of Ministers of the Environment
CO	carbon monoxide
DEIS	Draft Environmental Impact Statement
NAAQOs	National Ambient Air Quality Objectives
NO_2	nitrogen dioxide
$PM_{2.5}$	particulates with diameters of up to 2.5 μm
the Project	the Bathurst Inlet Port and Road Project
SO_2	sulphur dioxide
TSP	total suspended particulate
VEC	Valued Ecosystem Component

1. INTRODUCTION

1. Introduction

The proposed Bathurst Inlet Port and Road (BIPR) Project (the Project) includes the construction of a port and dock that will accommodate 50,000 tonne ice-class vessels. The port will be located in the Kitikmeot region of Nunavut, on the west side of Bathurst Inlet (66°33'N and 107°31'W), about 40 km south of the community of Bathurst Inlet. A road will connect the port to a camp and the existing winter ice road on Contwoyto Lake, 211 km to the southwest. The Project would service a number of existing and potential mine developments in the region. The proponents are Kitikmeot Corporations and Nuna Logistics Limited, both Inuit-owned companies, who have formed a joint venture to build and operate the Project.

The construction and operation of the port and road will produce air contaminant emissions from mobile and stationary diesel equipment. To assess the potential impact of these emissions, an air dispersion modelling study was conducted (Appendix B-4 of the Draft Environmental Impact Statement (DEIS)), comprising an emission inventory for Project activities during construction and operation, and three model runs aimed at characterizing worst-case concentrations to be expected during construction and operation of the Project.

The objective of this assessment is to use the results of the air dispersion modelling study in the context of the assessment methodology established for the Project (Appendix A-5 of the DEIS) to determine whether potential Project air emissions might adversely affect the atmospheric environment. Effects of air quality on human health, including the effect on workers, are discussed in Appendix F-2 of the DEIS Socio-economic Effects Assessment.

2. ENVIRONMENTAL SETTING

2. Environmental Setting

The air quality at Bathurst Inlet as well as along the road and shipping route can generally be classified as pristine. Local emissions are limited to stationary (power generation and heating) and mobile sources (trucks, snowmobiles, ATVs, *etc*.) operated by local residents. During the open-water season, additional emissions are contributed by barge traffic bringing supplies to the local communities. Mines operating in the region represent the only major industrial emission source. Because of the limited local emissions sources, long-range transport of air contaminants is an important influence on ambient air quality.

Ambient air quality data were not available for Nunavut. The Government of Northwest Territories operates long-term air quality monitoring stations in Yellowknife, Ford Liard, Norman Wells and Inuvik. A seasonal station measured concentrations of particulates with diameters of up to 2.5 μm ($PM_{2.5}$) at Daring Lake (250 km southwest of Bathurst Inlet) during the summers of 2003 to 2006 (Government of the NWT, 2006). The long-term monitoring stations are located near communities and the air contaminant concentrations at these stations may therefore not be representative of the pristine air quality at Bathurst Inlet. However, the remote Daring Lake station is representative of background $PM_{2.5}$ levels typical in the Northwest Territories and Nunavut.

Twenty-four hour average concentrations of $PM_{2.5}$ ranged from 0 to 5 $\mu g/m^3$ for the 16 measurements taken at Daring Lake during the summer of 2006. The Government of the NWT (2006) indicates that this is typical for background levels and that measurements were not influenced by forest fires, as in previous years. At Inuvik, which has a coastal location similar to Bathurst Inlet, the annual average $PM_{2.5}$ concentration was 2 $\mu g/m^3$, with monthly 24-hour maximum concentrations ranging from 3 to 6 $\mu g/m^3$ in the summer to 7 to 12 $\mu g/m^3$ in the winter.

Generally, air quality in Inuvik was slightly worse in winter when inversions trap emissions close to the ground and limit their dispersion in the atmosphere. The annual average sulphur dioxide (SO_2) concentration was 2 $\mu g/m^3$, with a 24-hour maximum concentration of 14 $\mu g/m^3$ measured in February. The only air contaminant that showed concentrations above background levels was nitrogen oxide (NO_2) with hourly maximum concentrations as high as 60 $\mu g/m^3$. However, since the main source of contamination was localized vehicle idling, these results cannot be used to estimate background concentrations at remote sites like Bathurst Inlet.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

This assessment is based on existing ambient air quality standards. Canada's national, provincial, and territorial governments have established ambient air quality objectives for criteria air contaminants (CACs) that are intended to ensure long-term protection of public health and the environment. Table 3.1-1 lists concentrations stated in these regulations.

The Government of Nunavut has established guidelines for maximum concentrations of ambient SO_2 and total suspended particulate (TSP) but not for other air contaminants. Therefore, the National Ambient Air Quality Objectives (NAAQOs) established under the *Environmental Protection Act* were used as a reference for ambient NO_2 and carbon monoxide (CO) concentrations. For $PM_{2.5}$, the Canada Wide Standard for maximum ambient 24-hour concentrations of $PM_{2.5}$ served as the reference. It was developed by the Canadian Council of Ministers of the Environment (CCME, 2005). Dustfall objectives are available from several provinces but not from the federal government (BC MOE, 1979; Newfoundland and Labrador, 2004; Alberta Environment, 2005; Québec, 2007). The lowest guideline value is in effect in Newfoundland and Labrador; this is the guideline used in this assessment.

The VEC selected for this assessment is ambient air quality as characterized by the six following parameters:

- the atmospheric concentration of NO_2;
- the atmospheric concentration of SO_2;
- the atmospheric concentration of CO;
- the atmospheric concentration of TSP;
- the atmospheric concentration of $PM_{2.5}$; and
- dustfall.

3.2 Boundaries

Air quality was assessed by running three model scenarios:

1. road operation;
2. port construction; and
3. port operation.

Table 3.1-1
Federal, Provincial, and Territorial Ambient Air Quality Guidelines and Objectives

Contaminant	Averaging Period	Nunavut Ambient Air Quality Guideline[a]	NWT Ambient Air Quality Standards[b]	Range of Provincial Guideline Values[c]	Canada Wide Standard[d]	National Ambient Air Quality Objectives[e]		
						Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide (NO_2)	1 hour	-	-	-	-	-	400	1,000
	24 hour	-	-	-	-	-	200	300
	annual mean	-	-	-	-	60	100	-
Sulphur dioxide (SO_2)	1 hour	450	450	-	-	450	900	-
	24 hour	150	150	-	-	150	300	800
	annual mean	30	30	-	-	30	1,578	-
Carbon monoxide (CO)	1 hour	-	-	-	-	15,000	35,000	-
	8 hour	-	-	-	-	6,000	15,000	20,000
Total suspended particulate (TSP)	24 hour	120	120	-	-	-	120	400
	annual mean	60	60	-	15[b]	27	70	-
$PM_{2.5}$	24 hour	-	30	-	302	-	-	-
Dustfall	annual	-	-	55.2 to 91.3	-	-	-	-

Notes:
All values are in mg/m^3, except dustfall, which is given in g/m^2/year.
[a]Guideline concentrations for Nunavut (Government of Nunavut, 2002a).
[b]Government of the NWT (2002).
[c]BC MOE (1979), Newfoundland and Labrador (2004), Alberta Environment (2005), Québec (2007).
[d]CCME (2005), 98[th] percentile over three years.
[e]Health Canada (2002).

Emissions during road construction will be localized and temporary and are expected to be lower than during operation. Similarly, emissions from the ships visiting the port between July and October are small compared to those generated during port operations over the winter period. Therefore it was decided that road construction and shipping lane emission did not warrant air quality modelling. A detailed rationale for the choice of these scenarios as well as further information on the implementation of the model runs can be found in the *Air Quality Modelling Study for the Bathurst Inlet Port and Road Project* (AQMS; Appendix B-4 of the DEIS).

The model scenarios used two different modelling domains (road and port site) and were run using meteorological data for January through April of 2002 and 2003 (eight months total), which corresponds to the seasonal operation period of the road. Using these model runs, the study area boundaries for air quality are defined below.

3.2.1 Spatial Boundaries

The port site domain was centered over the proposed port facility and measured 30 km by 30 km (Figure 3.2-1). Since it was impractical to model the entire length of the road, a section representative of typical road conditions was selected and the predicted pattern and gradients of air contaminant concentrations with distance from the chosen road section was assumed to be indicative of the air contaminant concentrations along the entire road. The domain was centered around km 55 of the road and extended 20 km in the north-south direction and east-west direction (Figure 3.2-1).

The sizes of the modelling domain were established such that the majority of air contaminant species would approach background concentrations within the modelling domains. For species with predicted maximum concentrations that were well above background concentrations, areas of potential exceedances of standards and objectives were ascertained to be well within the modelling domains.

Using modelling results from these two modelling domains, the assessment study area covers a 30 by 30 km square centered on the port and a 20 km wide strip centered on the road and covering its entire length.

3.2.2 Temporal Boundaries

The dispersion model scenarios were set up to represent worst-case scenarios that could occur at any point during operation or construction. Therefore, the temporal extent of the assessment covers the construction and operation phases of the Project.

3.3 Approach and Methods

This assessment evaluates the results of the air dispersion modelling study (Appendix B-4 of the DEIS) using the methodology established for the Project (Appendix A-5 of the DEIS) to determine whether potential Project air emissions might adversely affect the atmospheric environment.

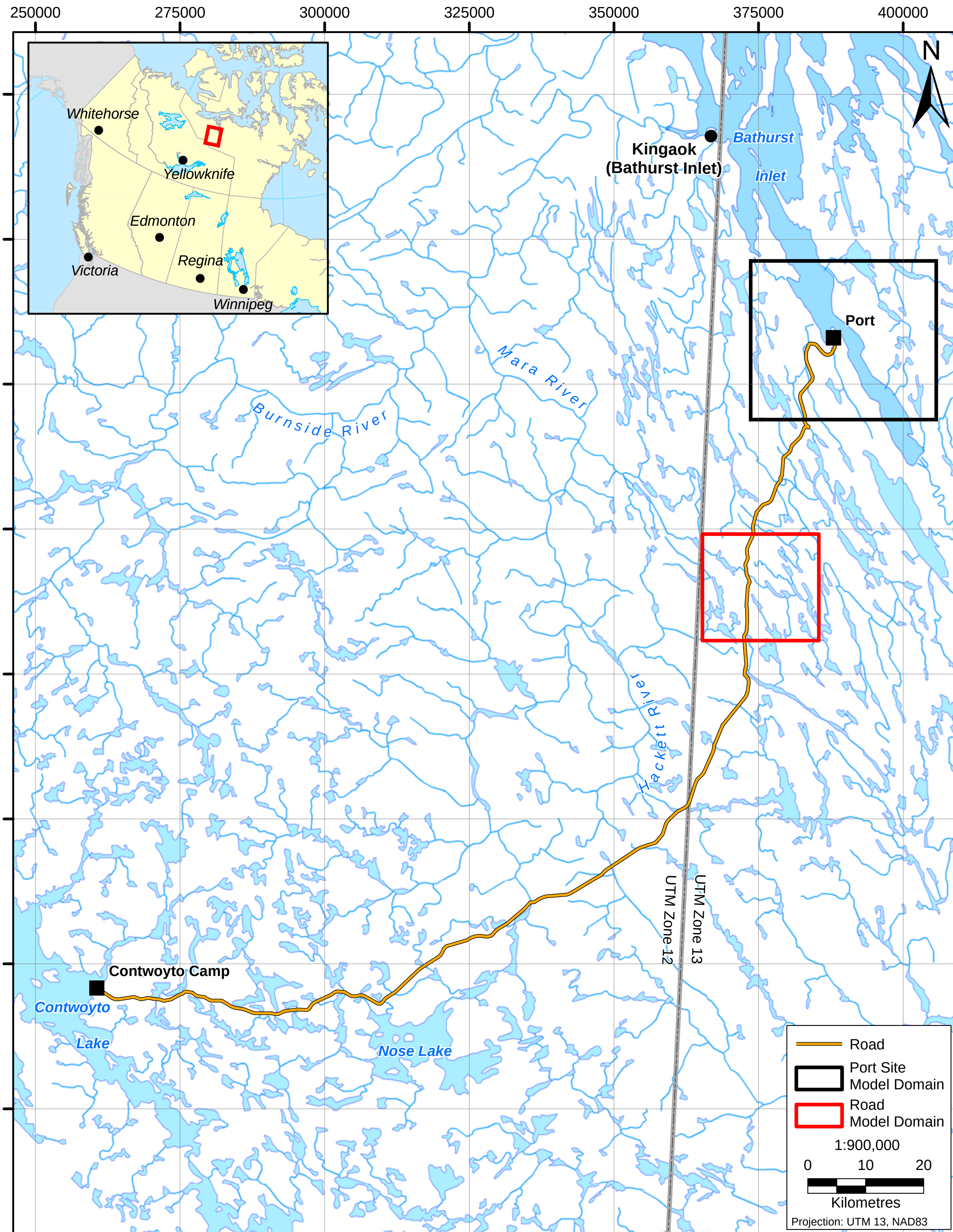

FIGURE 3.2-1

Port Site and Road Domains for the Air Quality Modelling Study

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An emissions inventory detailing air emission of CACs from all project activities was compiled. Using source emission rates from this inventory, the CALPUFF air dispersion model (Scire *et al.*., 2000) was parameterized using meteorological data from January to April in both 2002 and 2003 (eight months in total) for the three model scenarios described above. The modelling scenarios include mitigation of SO_2 emissions by use of ultra-low sulphur diesel fuel and the suppression of fugitive dust emissions by precipitation. The assessment of air quality effects is based on the results of the AQMS, which contains a detailed description of the model assumption, inputs and results as well as discussions of the uncertainties.

All model assumptions and inputs were chosen to represent a reasonable worst case scenario. For example, based on anticipated road usage an average of 2.5 trucks would pass the modelled road section every hour. However, because maximum hourly traffic would be greater than the season average, it was assumed that 12 trucks would pass a road section every hour for the entire model run. This ensured that the peak traffic rate would be combined with those meteorological conditions in the model run that are least conducive to air dispersion (*i.e.*, will lead to the highest ambient concentrations of CACs).

4. EFFECTS ASSESSMENT

4. Effects Assessment

4.1 Common Effects Assessment Ratings

All six parameters characterizing air quality are influenced through dispersion by wind. Therefore, their effect assessment rating is the same for the following criteria (Table 4.1-1):

- The **spatial extent** of changes in air contaminant concentrations is limited to the **landscape**, because in most cases changes in concentrations are significant only with the model domain (*i.e.*, within approximately 20 km of the project footprint).
- The **duration** of the change in air contaminant concentration is **short-term** during construction and **medium-term** during operation, since ambient air contaminant concentrations will revert to background levels once the Project ceases operation and dustfall will be washed away gradually.
- The **frequency** of the effect is **regular** rather than continuous, because the port and road will only operate at certain times of the year. For example, in the spring, when there are no project vehicle emissions along the road, ambient air contaminant concentrations will be lower than the model results for winter conditions.
- The **reversibility** of the effect on all five VECs is **reversible short-term**, because ambient air contaminant concentrations will revert to background levels once the Project ceases operation and dustfall will be washed away gradually.
- The **resilience** of air quality to emissions of air contaminants is **neutral,** because the magnitude of the air quality effects will vary linearly with the magnitude of emissions (air quality in neither highly sensitive nor insensitive to the proposed emissions).
- The **probability of occurrence** is rated **high**, since the Project will generate emissions that will affect air quality.

The following sections explain the rationale for assigning **magnitude** and **significance** ratings for each individual air quality parameter and discuss the uncertainties reflected in the **confidence limit** rating. The comparisons of contaminant concentration maxima found in the AQMS to air quality standards (Table 4.1-2) serve as a means to determine the magnitude of the air quality effects; at the same time the air quality standards reflect the contaminant concentrations that will presumably have no harmful effects on human health or the environment. Therefore **magnitude** and **influence on resource capacity** are assigned the same rating for each parameter.

4.2 Change in Ambient SO_2 Concentration

The predicted ambient concentration of SO_2 is below the guideline values for maximum hourly, daily and annual averages for all three model scenarios. The highest fraction of guideline values arises for the port construction scenario, with a run-time average maximum concentration of 7.3 $\mu g/m^3$ reaching 24.3% of the guideline value. Therefore the **magnitude** ratings assigned to the changes in the ambient SO_2 concentration were **low**. This in combination with the short-term reversibility of the effect led to significance ratings of **low** for all three model scenarios.

Table 4.1-1
Summary of Effects Assessment for Air Quality

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)**	**Project Component**	**Direction**	**Nature**	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation)**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence**
Change in ambient SO_2 concentration	Construction	Port Site	Adverse	Direct	Use of ultra-low sulphur diesel fuel, enforcement of speed limits	All maxima far below guideline value	Low	Landscape	Short-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
	Operation	Port Site	Adverse	Direct	Use of ultra-low sulphur diesel fuel, enforcement of speed limits	All maxima far below guideline value	Low	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
	Operation	Road	Adverse	Direct	Use of ultra-low sulphur diesel fuel, enforcement of speed limits	All maxima far below guideline value	Low	Landscape	Medium-term	Regular	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
Change in ambient NO_2 concentration	Construction	Port Site	Adverse	Direct	Enforcement of speed limits	Hourly and daily maxima exceed guidelines up to 2 km from port	High	Landscape	Short-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
	Operation	Port Site	Adverse	Direct	Enforcement of speed limits	All maxima below guideline value	Low	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
	Operation	Road	Adverse	Direct	Enforcement of speed limits	All maxima below guideline value	Low	Landscape	Medium-term	Regular	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Intermediate
Change in ambient CO concentration	Construction	Port Site	Adverse	Direct	Enforcement of speed limits	All maxima well below guideline value	Low	Landscape	Short-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	High
	Operation	Port Site	Adverse	Direct	Enforcement of speed limits	All maxima well below guideline value	Low	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	High
	Operation	Road	Adverse	Direct	Enforcement of speed limits	All maxima well below guideline value	Low	Landscape	Medium-term	Regular	Reversible Short-term	Neutral Resilience	Low	High	**Low**	High
Change in ambient TSP concentration	Operation	Road / Port Site[a]	Adverse	Direct	Enforcement of speed limits	Daily maximum exceeds guideline value	Moderate	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Moderate**	Low
Change in ambient $PM_{2.5}$ concentration	Operation	Road / Port Site[a]	Adverse	Direct	Enforcement of speed limits	24-hour average below guideline value	Low	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Low
Change in dustfall	Operation	Road / Port Site[a]	Adverse	Direct	Enforcement of speed limits	Annual total below guideline value	Low	Landscape	Medium-term	Continuous	Reversible Short-term	Neutral Resilience	Low	High	**Low**	Low

Notes:

[a]No separate modelling scenario was run for the Port Site but results from the Road are assumed to apply.

Table 4.1-2
Maximum Air Contaminant Concentrations in the Three Model Scenarios

					Maximum Values[a] (% of guideline in brackets)					
Contaminant	**Units**	**Averaging Period**	**Guideline**	**Background**	**Road Operation**		**Port Construction**		**Port Operation**	
Sulphur dioxide (SO_2)	$\mu g/m^3$	1 hour	450	7	7.6	(1.7)	19	(4.2)	12	(2.7)
		24 hour	150	7	7.2	(4.8)	10	(6.7)	8.6	(5.7)
		annual mean	30	7	7.01	(23.4)	7.3	(24.3)	7.1	(23.7)
Nitrogen dioxide (NO_2)	$\mu g/m^3$	1 hour	400	9.4	320	(80.0)	**889**	(222.3)	374	(93.5)
		24 hour	200	9.4	46	(23.0)	**310**	(155.0)	162	(81.0)
		annual mean	60	9.4	16	(26.7)	92[d]	(153.3)	78[d]	(130.0)
Carbon monoxide (CO)	$\mu g/m^3$	1 hour	15,000	115	235	(1.6)	2,990	(19.9)	1,350	(9.0)
		8 hour	6,000	115	175	(2.9)	1,578	(26.3)	777	(13.0)
Total suspended particulate (TSP)	$\mu g/m^3$	24 hour	120	7.5	**199**	(165.8)	n/a	n/a	n/a	n/a
		annual mean	60	7.5	42	(70.0)	n/a	n/a	n/a	n/a
$PM_{2.5}$	$\mu g/m^3$	24 hour	30	5	24	(80.0)	n/a	n/a	n/a	n/a
Dustfall	$g/m^2/year$	annual total	55.2[b]	0.8	15[c]	(27.2)	n/a	n/a	n/a	n/a

Notes:
n/a: not available.
Bold face number indicate exceedance of guideline value.
[a]Runtime means are used as worst-case estimates for annual means; see text for rationale.
[b]Newfoundland and Labrador (2004); guideline requires arithmetic mean of monthly values to be below 4.6 g/m^2.
[c]Runtime total for 8-month model run was scale by a factor of 12/8 to reflect annual total.
[d]Even though the runtime average value exceeds the guideline the annual average will likely meet it.

The **confidence** in this assessment is **intermediate**, since SO_2 sources are well characterized in the modelling and predicted maximum concentrations are so far below guideline values that even relatively large changes in model emissions rates or wind speeds would not bring concentrations close to guideline values.

4.3 Change in Ambient NO_2 Concentration

The port construction scenario is predicted to exceed NO_2 guideline values (hourly and daily maxima). For the road operation scenario, no exceedance is predicted. Runtime averages are 92 $\mu g/m^3$ for port construction and 78 $\mu g/m^3$ for port operation. However, the runtime averages are for the winter months only, and annual averages are lower by a factor of approximately three.

Figure 4.3-1 shows the areas that exceeded the hourly and daily guideline values at least once during the model run. These exceedances are confined to locations less than 2 km away from the port site. Due to these exceedences, the effect of the Project on ambient NO_2 concentrations was assigned the **magnitude** rating **high**. The **significance** rating of this effect is **low**, as it is limited to the construction phase and its duration therefore is only short-term.

The **confidence** in this assessment is **intermediate**. NO_2 sources are well characterized in the modelling, and while the locations of individual exceedances might differ from model predictions, maximum concentrations are well above guideline values.

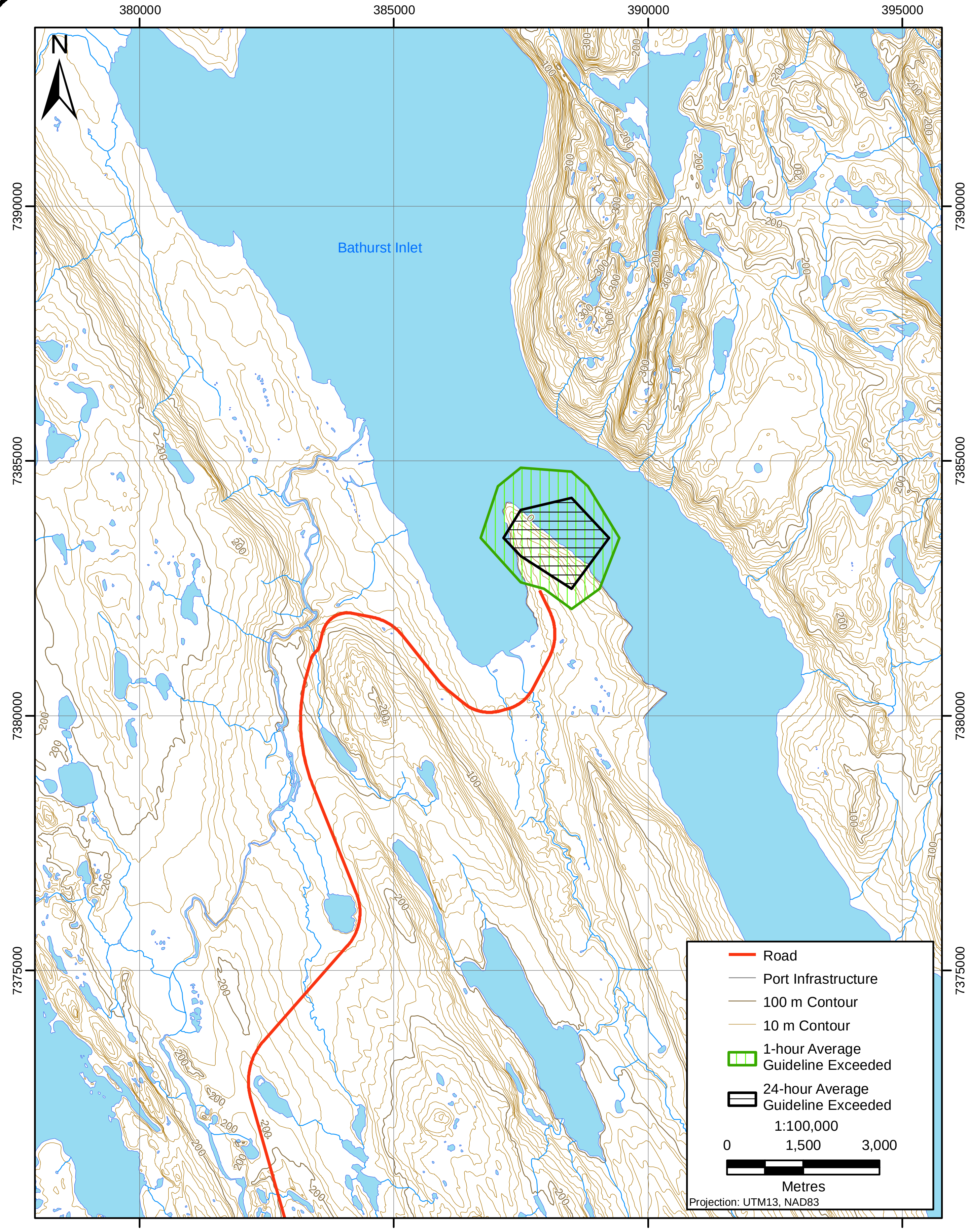
4.4 Change in Ambient CO Concentration

For all three model scenarios, the ambient concentration of CO is well below the guideline values for maximum hourly and 8-hour averages. The highest fraction of a guideline value arises for the 8-hour maximum concentration for the port construction scenario (1,578 $\mu g/m^3$), representing 26% of the guideline value. Therefore, the **magnitude** rating assigned to the change in the ambient CO concentration was **low**. This, in combination with the short-term reversibility of the effect, led to a significance rating of **low**.

The **confidence** in this assessment is **intermediate**, since CO sources are well characterized in the modelling, and predicted maximum concentrations are so far below guideline values that even relatively large changes in model inputs would not bring concentrations close to guideline values.

4.5 Change in Ambient TSP Concentration

The maximum 24-hour average TSP concentration for the road operation scenario was 199 $\mu g/m^3$, 166% of the Nunavut guideline value of 120 $\mu g/m^3$, while the runtime average was 42 $\mu g/m^3$, 70% of the guideline value of 60 $\mu g/m^3$. The guideline value was exceeded (at least once during the model run) at isolated points within an area confined to 500 m of the road (Figure 4.5-1).



Exceedance of NO_2 Concentration Guidelines for 1-Hour Averages (400 μg/m^3) and 24-hour Averages (200 μg/m^3) for Port Construction Scenario

FIGURE 4.3-1

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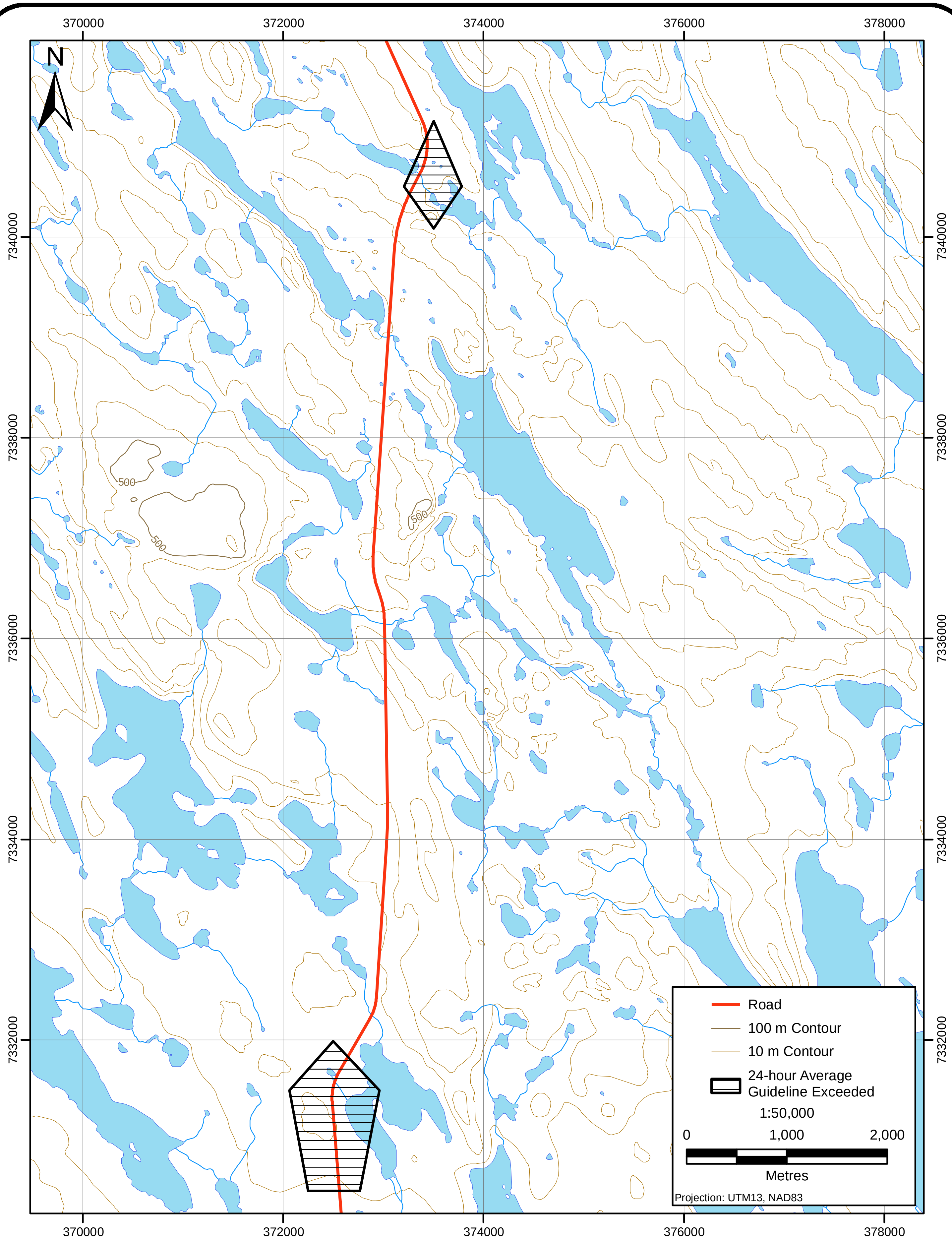

Exceedance of Total Suspended Particulate (TSP) Concentration Guidelines for 24-hour Averages (120 μg/m^3) for Road Operation Scenario

FIGURE 4.5-1

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Because of the isolated occurrence of the exceedances, the **magnitude** rating **moderate** was assigned to the effect of the Project on ambient TSP concentrations. Due to the high uncertainty associated with estimating fugitive dust emissions, the **significance** rating of this effect is **moderate.**

At the Port the activity rates for vehicles will be higher since in addition to haul trucks loading equipment will be operating there; however vehicle speeds will be lower and overall it is assumed that the effects assessment rating found for the Road will apply to the Port Site as well.

The **confidence** in this assessment is **low** since emission factors for particulate matter, which ultimately determine the TSP concentrations, are associated with high uncertainty.

4.6 Change in Ambient $PM_{2.5}$ Concentration

For the road operation scenario, the maximum 24-hour $PM_{2.5}$ concentration is 24 $\mu g/m^3$. This value is below the guideline of 30 $\mu g/m^3$, and therefore a **magnitude** rating of **low** was assigned to the effect of the Project on ambient $PM_{2.5}$ concentrations and therefore the **significance** rating of this effect is **low**.

As with TSP, **confidence** in this assessment is **low**, since emission factors for particulate matter have very low confidence ratings.

4.7 Change in Dustfall

For the road operation scenario, the maximum runtime total dustfall found in the model domain is 42 g/m^2/year, representing 76% of the lowest available guideline value (55.2 g/m^2/year for Newfoundland and Labrador). Therefore the **significance** rating of this effect is **low.**

Confidence in this assessment is **low**, since emission factors for particulate matter, which ultimately determine dustfall rates, have very low confidence ratings. Therefore it is recommended that dustfall be measured by assessing dust concentrations in the snow pack. This will allow determining whether mitigation measures for fugitive dust emissions need to be implemented.

4.8 Summary

Table 4.1-1 summarizes the effects assessment for air quality. Of the six parameters assessed, five have a **significance** rating of **low**. The change in TSP concentration, which is predicted to exceed guideline values at isolated locations during operation, has a **significance** rating of **moderate**. Because of the low confidence associated with all predictions relating to fugitive dust emissions (TSP and $PM_{2.5}$ concentrations and dustfall) it is recommended that dustfall is monitored during construction and operation of the port and road to determine whether mitigation measures for fugitive dust emissions need to be implemented.

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5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

Mitigation and management plans are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

5.1 Air Quality Management Plan (AQMP)

The AQMP will be in effect during the construction and operation of the port.

5.1.1 Objectives

The air quality effects assessment rated the magnitude of the change in NO_2 concentrations during construction of the port high. Therefore the issue of increased NO_2 concentrations has to be addressed. The proponent has committed to minimizing the concentrations of NO_2 around the port during both construction and operation. This plan describes best management practices that will be considered to minimize NO_2 emissions.

Weather conditions conducive to deterioration of air quality can be detected using secondary indicators like wind speed even if no direct measurements of NO_2 are available. The objective of the AQMP is to establish management practices to minimize NO_2 emissions during these weather conditions.

5.1.2 General Practices to Minimize Emissions from Diesel Equipment

NO_2 emissions are generated by diesel engines operated at the port site. A number of best management practices can be employed independent of weather conditions to minimize emission of NO_2 and other air contaminants.

- Speed limits for all mobile equipment will be enforced.
- A regular maintenance program for all stationary and mobile diesel equipment will be implemented.
- Ultra-low sulphur diesel fuel will be used.
- Transportation equipment will be used only with full loads to reduce the number of trips.

5.1.3 Weather-specific Emission Reduction Management

High concentrations of air contaminants accumulate in the atmosphere whenever conditions suppress atmospheric dispersion. This is typically the case for combinations of low wind speeds and strong inversions. Inversions are characterized by an increase of temperature with height above the ground, suppressing the movement of colder, denser air away from the surface. When wind speeds during these conditions are low, emissions are trapped close to the source, leading to increased concentrations of air contaminants. The AQMS indicated that weather conditions at the port site lead to increase of NO_2 concentrations above the guideline value of 400 $\mu g/m^3$ for about 24 to 48 hours during January through April.

The head of operations for the port site will determine when weather conditions necessitate the implementation of air quality management measures to prevent a deterioration of air quality. Measures considered in this case will include:

- The use of diesel equipment will be limited to the minimum required to ensure the safety and well-being of personnel.
- Garbage incineration will be postponed until conditions improve.

5.2 Fugitive Dust Management Plan

This Fugitive Dust Management Plan will be in effect during construction and operation of the port and road.

5.2.1 Objectives

The air quality effects assessment highlights changes in concentrations of TSP, $PM_{2.5}$ and dustfall as a moderate significant effect. The proponent has committed to minimizing the fugitive dust emissions during construction and operation of the port and road.

The objective of this plan is to outline the measures that will be considered to minimize fugitive dust emissions during construction and operation of the Project.

5.2.2 General Practices to Minimize Fugitive Dust Emissions

The main source of fugitive dust emissions will be trucks travelling on unpaved roads. The proposed measures to minimize fugitive dust at the Project site are listed below.

- The road will be constructed according to best management practices to ensure that it has adequate bearing capacity, drainage, and that the surface-wearing materials have proper gradation and are compacted (InfraGuide, 2005).
- During and after construction, road surfaces will be monitored and in the summer they will be watered as required to reduce dust emissions. Suitable dust suppressants may be used in accordance with the Environmental Guideline for Dust Suppression (Government of Nunavut, 2002b). The project Description indicates that no hauling will occur in summer.
- Speed limits will be enforced.
- The road will be maintained regularly.

Adaptive management will improve the Fugitive Dust Management Plan throughout the life of the Project.

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

6.1 Dustfall Monitoring Plan

The Dustfall Monitoring Plan will be in effect during the construction and operation of the Port and Road.

6.1.1 Objectives

The air quality effects assessment indicated that confidence in predictions of TSP, PM2.5 and dustfall have high uncertainty due to the low confidence placed in emission factors for fugitive dust. Therefore it is recommended that dustfall be measured by assessing dust concentrations in the snow pack. This will allow assessment to determine if mitigation measures for fugitive dust emissions are required. Mitigation measures in turn will not only decrease dustfall but also concentrations of TSP and PM2.5.

The objective of the Dustfall Monitoring Plan is to outline a sampling procedure and establish critical dustfall levels that will trigger the mitigation of fugitive dust emissions.

6.1.2 Sampling Procedure

Dustfall will be assessed by analyzing snow cores collected after the end of the winter operations period.

Snow cores are sampled by means of a snow corer consisting of a clear plastic tube with markings to indicate snow depth (cm) and a metal bit with teeth attached to the bottom end of the tube. Melted snow samples will be sent to ALS Environmental Laboratories in pre-cleaned sample containers supplied by the lab. Standard testing methods will be used to analyze snow chemistry. Table 6.1-1 provides a full list of variables to be analyzed.

Snow will be sampled at six locations spaced evenly along the road. Cores will be obtained at these locations at distances of 30, 100 and 300 m from the road center on the east (downwind) side and at 30 m on the west (upwind) side of the road. Another sampling site located at least 10 km away from the road will be used to determine the background dustfall levels for the season. All sampling locations will be located using GPS to ensure samples are taken at the same location each year and thus allow inter-annual comparison of results.

6.1.3 Critical Dustfall Levels

The lowest available guideline for dustfall is 55.2 g/m^2/year (Newfoundland and Labrador, 2004), corresponding to 18.4 g/m^2 for a four-month period. If the average of all samples collected 100 m downwind side of the road exceeds this four-month value, measures to reduce fugitive dust emissions will be implemented.

Table 6.1-1
Water Quality Variables for Snow Core Samples

Parameters	Units	Parameters	Units
Physical/Ion Parameters		**Total Metals**	
Alkalinity, Total	mg/L	Aluminum (Al)	mg/L
Bicarbonate (HCO_3)	mg/L	Antimony (Sb)	mg/L
Carbonate (CO_3)	mg/L	Arsenic (As)	mg/L
Conductivity (EC)	µS/cm	Barium (Ba)	mg/L
Hydroxide	mg/L	Beryllium (Be)	mg/L
pH	pH	Boron (B)	mg/L
Chloride (Cl)	mg/L	Cadmium (Cd)	mg/L
Potassium (K)	mg/L	Calcium (Ca)	mg/L
Silicon (Si)-Total	mg/L	Chromium (Cr)	mg/L
Sulphate (SO_4)	mg/L	Cobalt (Co)	mg/L
Total Suspended Solids	mg/L	Copper (Cu)	mg/L
Turbidity	NTU	Iron (Fe)	mg/L
Hardness	mg/L	Lead (Pb)	mg/L
Ion Balance	%	Magnesium (Mg)	mg/L
TDS (Calculated)	mg/L	Manganese (Mn)	mg/L
		Mercury (Hg)	mg/L
Nutrients/Organics		Molybdenum (Mo)	mg/L
Total Ammonia-N	mg/L	Nickel (Ni)	mg/L
Nitrate-N	mg/L	Selenium (Se)	mg/L
Nitrite-N	mg/L	Silver (Ag)	mg/L
Orthophosphate (PO_4-P)	mg/L	Sodium (Na)	mg/L
Total Phosphorus	mg/L	Strontium (Sr)	mg/L
Total Organic Carbon	mg/L	Uranium (U)	mg/L
Total Kjeldahl Nitrogen	mg/L	Vanadium (V)	mg/L

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix B-3
Noise Effects Assessment

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Date: October 2007

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Noise Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

Alberta EUB	Alberta Energy and Utilities Board
BIPR	Bathurst Inlet Port and Road
dB	decibel
De Beers	De Beers Canada Mining Inc.
DEIS	Draft Environmental Impact Statement
Diavik	Diavik Diamond Mines Inc.
the Project	the Bathurst Inlet Port and Road Project
rms	root mean square
Wolfden	Wolfden Resources Inc.

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NOISE EFFECTS ASSESSMENT

Noise Effects Assessment

1. Introduction

1.1 Scope and Objectives

The proposed Bathurst Inlet Port and Road (BIPR) Project (the Project) includes the construction of a port and wharf that will accommodate 50,000 tonne ice-class vessels. The port will be located in the Kitikmeot region of Nunavut, on the west side of Bathurst Inlet (66°33'N and 107°31'W), about 40 km south of the community of Bathurst Inlet. A road will connect Bathurst Inlet to Contwoyto Lake, 211 km to the southwest. The port and road would service a number of existing and potential mine developments in the region. The proponents are Kitikmeot Corporation and Nuna Logistics Limited, both Inuit-owned companies, who have formed a joint venture to build and operate the Project.

Construction and operation of the port and road will generate noise. This assessment reviews studies that have estimated noise levels typically associated with traffic on unpaved road, with aircraft take-off and landing and with construction activities. The objective of this assessment is to evaluate these results following the assessment methodology established for the Project (Appendix A-5 of the Draft Environmental Impact Statement (DEIS)) to determine potential effects of project noise on the environment. Effects of noise on human health, including the effect on workers, are discussed in Appendix F-2 of the DEIS, Socio-economic Effects Assessment.

1.2 Noise Level Descriptors

Noise is generally defined as unwanted sound. It is characterized in terms of the pressure of the sound wave. Human perception of sound pressure is non-linear: a ten-fold increase in sound pressure is perceived as a doubling of the noise level by the average person. This non-linearity is reflected in the use of the decibel (dB), a logarithmic measure of noise level. The dB is the logarithm of the ratio of the root mean square (rms) sound pressure relative to a standard rms sound pressure, usually 20 μPa, the hearing threshold below which sound is not detectable by the human ear.

Since human sound detection ability is frequency dependent, the sound pressure is commonly weighted by frequency to model human perception. The "A" weighting is the most common; A-weighted noise levels are given in units of "dBA." A change in noise level of 3 dBA is barely noticeable, while a 10 dBA change is perceived as a doubling of the noise level. Typical noise levels are

- **0 dBA:** the threshold of human hearing (roughly a mosquito flying 3 m away);
- **10 dBA:** rustling leaves;
- **20 to 40 dBA:** very calm room;
- **40 to 60 dBA:** normal conversation;
- **60 to 80 dBA:** passenger car at 10 m;

- **80 to 90 dBA:** major road at 10 m;
- **100 dBA:** jackhammer at 1 m;
- **110 to 130 dBA:** jet takeoff at 100 m; and
- **130 dBA:** human pain threshold.

Because of the non-linearity nature of the dB scale, sound levels cannot simply be added. Instead the logarithm has to be inverted before adding and then applied to the sum (Alberta EUB, 2007):

$$L_{total} = 10\log_{10}(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}})$$

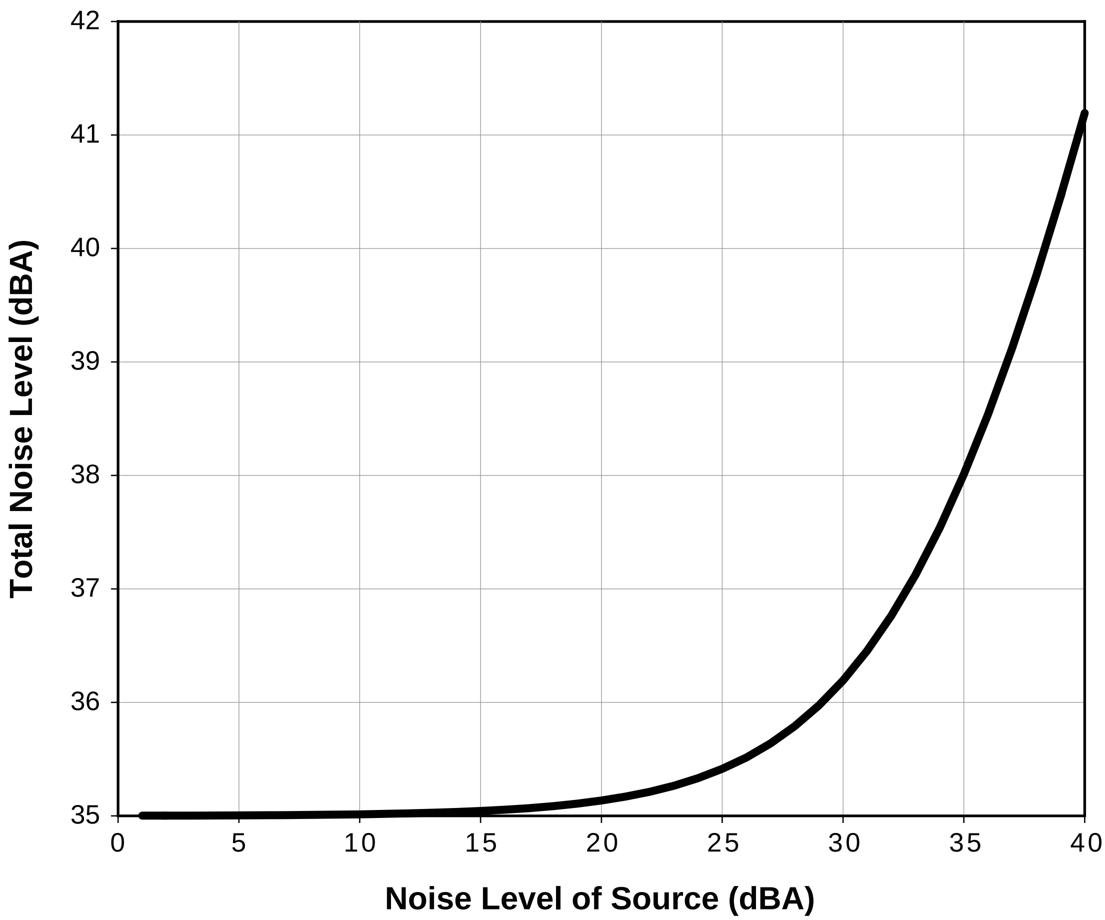
For example, people talking (50 dBA) in a very calm room (35 dBA) do not bring up the noise level in the room to that close to a major road (85 dBA). In fact, the background noise will no longer be audible once people start talking. Adding the noise levels in this example according to the formula above will raise total noise levels to 50.1 dBA; the 0.1 dBA increase is much lower than the 3 dBA difference required by the average person to notice any alteration in noise level. Figure 1.2-1 illustrates the change in overall noise level if a source of a given level is being added to a background noise of 35 dBA. For the noise source to be audible it has to be at least at loud as the background (*i.e.*, a background noise level of 35 dBA and a 35 dBA noise source have a total noise level of 38 dBA). On the other hand, if the total noise level is 41.2 dBA "switching off" the background noise and leaving only a noise source of 40 dBA (a 1.2 dBA change) will not be audible.

Noise levels will vary over time and they are characterized by the equivalent continuous sound level (L_{eq}). This is the dBA level of a constant rms sound pressure containing the same energy as the time varying noise. It is usually given for a specific time interval, typically 1 hour or 24 hours.

2. Environmental Setting

The noise environment in the Project area is pristine. No industrial site or human settlement is close enough to the road or port to be audible; consequently, only natural sources like wind, waves, tide effects on ice, and precipitation will contribute to background noise levels.

Measurements of noise levels at similarly remote locations in northern Canada were carried out as part of baseline studies for the diamond projects at Snap Lake (De Beers, 2002) and Diavik (Diavik, 1998) in the Northwest Territories. At Snap Lake, hourly L_{eq} levels ranged from 23.2 to 40.1 dBA. Night-time L_{eq} was 35.6 dBA, while daytime L_{eq} was 29.9 dBA. However, measurements were run only for 12 hours, so day and night-time coverage was only partial, and no 24-hour L_{eq} could be calculated. The assessment identified wind as the main influence on the ambient noise level. Sound levels reported for the Diavik Project were very similar, ranging from 25 to 40 dBA.



the BATHURST INLET PORT AND ROAD PROJECT

FIGURE 1.2-1

Adding Background Noise and Source Noise

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Baseline noise levels along the road and at the port site will be very similar to those reported for Snap Lake and Diavik. For the purpose of this assessment, it was assumed that the 24-hour L_{eq} in the Project area is 35 dBA.

3. Methodology

3.1 Valued Ecosystem Component Selection

Noise has been selected as a VEC because a change in the noise environment may adversely affect wildlife. The L_{eq} for hourly to daily time intervals will be used to quantify changes in the noise environment and comparison to existing standards will be used to assess the magnitude of the change.

3.2 Boundaries

3.2.1 Spatial Boundaries

The assessment for the Snap Lake Project showed that traffic noise at a distance of 10 km from a road will not be audible over the background noise level (De Beers, 2002). Therefore, the assessment area for noise comprises a band of 10 km on either side of the road and a zone with a radius of 10 km around the port site.

3.2.2 Temporal Boundaries

Since no noise will be generated after the decommissioning of the road, the noise effects assessment will be conducted for the construction and operation phase of the road and port.

3.3 Approach and Methods

This assessment evaluates results from noise modeling studies conducted in northern Canada following the assessment methodology established for the Project (Appendix A-5 of the DEIS) to determine potential effects of project noise on the environment.

3.3.1 Standards for Environmental Noise

There are no guidelines regulating the evaluation and management noise in Nunavut. Most noise regulations in place in Canadian provinces are designed to ensure the comfort and health of human receptors. However *Directive 038 – Noise Control*, issued by the Alberta Energy and Utilities Board (Alberta EUB, 2007), is designed to address environmental noise, not health-related impacts. It stipulates that new facilities must meet a “permissible sound level” of 40 dBA L_{eq} (night-time) at 1.5 km from the facility fence line, if there are no closer dwellings.

Magnitude ratings for noise levels predicted at a distance from of 1.5 km from the road and port will be compared to the guideline value of 40 dBA L_{eq}.

3.3.2 Review of Noise Modelling in Northern Canada

Noise modelling studies in Nunavut were conducted for environmental impact assessments for the High Lake (Wolfden, 2006) and Doris North (Miramar, 2005) projects. However, these assessments are for mine sites; noise from traffic on roads was not modelled. A road traffic noise assessment was carried out for the Snap Lake Project (De Beers, 2002) in the Northwest Territories because this mining project will use the Tibbitt-Contwoyto winter road.

The Snap Lake traffic modelling study used the SoundPLAN Outdoor Noise Prediction software to predict noise levels generated by an average of three trucks per hour at various distances from the road and by small aircraft landing on an airstrip. These are modelling scenarios for conditions very similar to those for the BIPR Project, and will be used to simulate the conditions for this Project. The construction modelling scenario results for Snap Lake will also be used, though they are likely higher than noise levels expected at the Project, due to the much larger scope of the Snap Lake mining project.

4. Effects Assessment

4.1 Change in the Hourly to Daily L_{eq}

The effects assessment is conducted for the operation of the road using results of the Snap Lake noise modelling study for traffic on the Tibbitt-Contwoyto winter road (Table 4.1-1). The airstrip at the port site is assessed using air craft noise during landing and takeoff modelled for Snap Lake (Table 4.1-2). The assessment for construction of the port and road is based on Snap Lake results for construction (Table 4.1-3). Changes in environmental noise levels will only be audible if they are greater than 3 dBA. To estimate environmental noise levels, a background noise level of 35 dBA was added to the modelling results in Tables 4.1-1 to 4.1-3 as described in Section 1.2. These sound levels were compared to the permissible sound level of 40 dBA set by Alberta EUB (2007) in the determination of the magnitude rating for the change in the hourly and daily L_{eq}.

Table 4.1-1
Predicted Sound Levels for Truck Traffic at Various Distances from a Road

Distance from the Road (km)	Snap Lake Modelled Sound Level[a] (dBA)		Bathurst Predicted Sound Level (dBA) Including Background of 35 dBA	
	Maximum L_{eq}	24-hour L_{eq}	Maximum L_{eq}	24-hour L_{eq}
0.75	64.3	28.1	64.3	35.8
1.5	55.1	18.9	55.1	35.1
3	44.4	8.4	44.9	35.0

[a] De Beers (2002). No background included.

The daily L_{eq} is predicted to be close to background for traffic noise, even though maximum L_{eq} values indicate that an individual truck might be audible beyond 3 km distance from the road. For the airstrip the hourly L_{eq} is predicted to be 46.4 dBA at 1.5 km from the airstrip and 40.7 dBA at 3 km. Aircraft will be audible for a much larger distance for short periods of time, as is reflected in the 5-minute L_{eq}. However, only one aircraft takeoff and landing per day is expected and the daily L_{eq} will be below 40 dBA, even at a distance of 1.5 km from the airstrip.

A noise level of 38 dBA is predicted for the daily L_{eq} at 1.5 km during construction (Table 4.1-3). Based on these results, the following ratings were assigned to the assessment criteria set out in the assessment methodology (Appendix A-5 of the DEIS) and are presented in Table 4.1-4.

Table 4.1-2
Predicted Sound Levels for Air Traffic at Various Distances from the Airstrip

Distance from Airstrip (km)	Snap Lake Modelled Sound Level[a] (dBA)		Bathurst Predicted Sound Level (dBA) Including Background of 35 dBA	
	5-minute L_{eq}	1-hour L_{eq}	5-minute L_{eq}	1-hour L_{eq}
1.5	56.7	46.1	56.7	46.4
3	49.9	39.3	50.0	40.7
6	42	31.5	42.8	36.6
9	36.5	26.1	38.8	35.5

[a]De Beers (2002). No background included.

Table 4.1-3
Predicted Average Sound Levels for Construction Site Noise at Various Distances from the Site

Distance from Site (km)	Snap Lake Modelled Sound Level[a] (dBA)	Bathurst Predicted Sound Level (dBA) Including Background of 35 dBA
1.5	35.7	38.4
3	26.9	35.6
6	17.9	35.1
9	8.9	35.0

[a]De Beers (2002). No background included.

The noise affects assessment for the Project resulted in the following ratings:

- the **magnitude** of the change in noise levels is **low**, since noise from traffic, aircraft, and construction is close to ambient levels over 24 hours 1.5 km from the Project area;
- the **spatial extent** of changes in the L_{eq} is limited to the **landscape**, because in most cases changes can be detected only up to several kilometres from the Project area;
- The **duration** of the change in the L_{eq} is **medium-term**, since noise levels will revert to background levels once the Project ceases operation;
- The **frequency** of the effect is **regular** rather than continuous, because the port and road will only operate at certain times of the year;
- The **reversibility** of the change in L_{eq} is **reversible short-term**, because noise levels will revert to background levels once the Project ceases operation;

Table 4.1-4
Summary of Effects Assessment for Noise

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)**	**Project Component**	**Direction**	**Nature**	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Potential Residual Effect (after mitigation)**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence**
Change in hourly and daily noise levels (L_{eq})	Construction and Operation	Port Site and Road	Adverse	Direct	Enforce speed limits; limit number of trucks per hour and number of flights per day	All daily L_{eq} below 40 dBA, some short-term L_{eq} above 40 dBA	Low	Landscape	Medium-term	Regular	Reversible Short-term	n/a	Low	High	**Low**	Intermediate

- The **resilience** is not applicable in this case;
- The **influence on resource capacity** is **low**, because noise level are changed, but the magnitude of the change is deemed low;
- The **probability of occurrence** is rated **high**, since the Project will generate noise;
- Based on the rating assigned above, the **significance** of the change in L_{eq} is **low**; and
- The **confidence limit** of the assessment is **intermediate**, because the noise assessment is based on results from a similar project, not actual modelling of Project conditions.

For a detailed discussion of the effects of noise on wildlife see Appendix D-3 of the DEIS (Wildlife and Wildlife Habitat Effects Assessment).

5. Mitigation and Management Plans

This mitigation and management plan is offered as a recommendation and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

The principal concern for local wildlife is avoidance of areas where noise levels may be elevated, or where humans or human activities are visible. The objective of this management plan is to facilitate the implementation of measures that will help reduce the effect of noise on local wildlife.

Numerous mitigation measures will be considered to control environmental noise within the Project area. The following noise mitigation strategies are planned for the Project:

- fitting all diesel-powered equipment with silencers (mufflers) meeting manufacturers' recommendations for optimal attenuation, and maintaining these silencers in effective working condition;
- carrying out regular maintenance on all equipment, including lubrication and replacement of worn parts, especially exhaust systems;
- engines will be operated at speeds required to efficiently perform the required task;
- where practical, planning and developing work sites to minimize the need for trucks and other equipment to back up and thereby reduce the frequency of backup alarms;
- limiting the number trips by hauling full loads as opposed to partial loads;
- where more than one type/model of equipment or construction technique can be used to do a particular job with similar efficiency, using the quietest one; and
- supplying and operating all equipment with appropriate covers, hoods, shields, *etc.*, in place and latched shut.

Research indicates that animals may habituate to periodic noises if the noises are predictable. In some studies, for example, animals were not affected by airplane noise when they could see the airplane before hearing it, but responded negatively when the noise occurred without warning (Weisenberger *et al.*, 1996; Conomy *et al.*, 1998).

The Head of Operations for the port site will be responsible for scheduling activities to minimize noise effects on wildlife.

6. Monitoring and Evaluation

Sound level meters will be used to determine sound levels in and around the workplace. Where it is not possible to attenuate sound levels to a point that they are less than maximum threshold values for workers, workers will be required to wear hearing protection. Where practical, sound levels emanating from machinery or other operations will be reduced to the greatest reasonable extent at the source through muffling, enclosures and shields.

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix B-4
Air Quality Modelling Study

Author: Rescan Environmental Services Ltd.
Date: November 2007

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the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project

Nunavut, Canada

Bathurst Inlet Port and Road Air Quality Modelling Study

Prepared by:

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November 2007

Rescan™

EXECUTIVE SUMMARY

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Executive Summary

An air quality modelling study for the proposed Bathurst Inlet Port and Road (BIPR) Project (the Project) was developed to provide a basis for an air quality effects assessment, which is a required component of the Environmental Impact Statement for the Project.

The air dispersion model CALPUFF was used for the study (Scire, 2000). Air contaminants considered included sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total suspended particulates (TSP), and respirable particulate matter ($PM_{2.5}$). In addition, dry deposition of particulate matter (dustfall) was modelled.

CALPUFF was used in ISC-3 mode using surface meteorology data recorded at the Bathurst Inlet meteorology station in 2002 and 2003. An emissions inventory that estimated maximum hourly emissions rates associated with project activities was used as input for the air dispersion model.

Three scenarios were considered: operation of the Bathurst Inlet road, construction of the Bathurst Inlet port facility and operation of the port facility.

SO_2 concentrations for all scenario runs were well below Nunavut's standards for ambient SO_2 concentrations. The low rates of SO_2 emissions and resulting ambient concentrations can be attributed to the use of ultra low sulphur diesel fuel for the equipment used for the Project.

Predicted maximum 1-hour and 24-hour NO_2 concentrations for the port construction scenario exceeded the maximum acceptable National Ambient Air Quality Objectives (NAAQOs) but were of the same order as the maximum tolerable NAAQOs. Runtime average concentrations of NO_2 for the port construction and operation scenarios approach the maximum acceptable NAAQO for annual average NO_2. However, annual average NO_2 concentrations for the two scenarios are expected to be lower than the predicted runtime averages by a factor of approximately three and are therefore not expected to exceed the NAAQO for annual average NO_2 concentrations. Predicted 1-hour and 24-hour NO_2 concentrations for the road operation and port operation scenarios did not exceed the NAAQOs for NO_2.

Predicted maximum 1-hour and 8-hour carbon monoxide concentrations were well below the corresponding NAAQOs for all three scenarios.

Maximum TSP and $PM_{2.5}$ concentrations as well as predicted dustfall rates were associated with high uncertainty because of inherent uncertainties associated with TSP and $PM_{2.5}$ emission factors. The modelling results suggest that there may be localized exceedances of Nunavut's standard for 24-hour TSP concentrations and the Canada Wide Standard for 24-hour $PM_{2.5}$ in areas that are in close proximity to the road. Implementation of a fugitive dust management plan would help minimize TSP and $PM_{2.5}$ emissions.

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

BC MOE	British Columbia Ministry of Environment
BIPR	Bathurst Inlet Port and Road
CACs	criteria air contaminants
CCME	Canadian Council of Ministers of the Environment
CO	carbon monoxide
EIS	Environmental Impact Statement
H_2S	hydrogen sulphide
Hp	Horsepower
INAC	Indian and Northern Affairs Canada
NAAQOs	National Ambient Air Quality Objectives
NIRB	Nunavut Impact Review Board
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NWT	Northwest Territories
O_3	Ozone
$PM_{2.5}$	respirable particulate matter
the Project	the Bathurst Inlet Port and Road Project
SO_2	sulphur dioxide
TSP	total suspended particulates
US EPA	United States Environmental Protection Agency
VKT	vehicle kilometres travelled
VMT	vehicle miles travelled
VOCs	volatile organic compounds
WMO	World Meteorological Organization

1. INTRODUCTION

1. Introduction

The proposed Bathurst Inlet Port and Road (BIPR) Project (the Project) includes the construction of a port and wharf at Bathurst Inlet to accommodate large 50,000 tonnes ice class vessels, and a 211 km weather road from Bathurst Inlet to Contwoyto Lake. The port and road will service a number of existing and potential mine developments in the region. The project proponents are Kitikmeot Corporation and Nuna Logistics Limited, both Inuit-owned companies, who have formed a joint venture to build and operate the Project (BIPR Joint Venture, 2003).

The potential environmental effects associated with the development of the Project will be evaluated by stakeholders through the Environmental Assessment review process. The Nunavut Impact Review Board (NIRB) and Indian and Northern Affairs Canada (INAC) have determined that the Project must undergo a Part 5 review under Article 12 of the Nunavut Land Claims Agreement. The objective of the review process is to enable NIRB, INAC and any interested party to understand and assess the potential adverse and beneficial bio-physical, environmental and socio-economic effects that are related to the Project (BIPR Joint Venture, 2003).

This report describes the air quality modelling study that was prepared for the Project. The study will provide a basis for evaluating potential air quality effects associated with construction and operation of the Project.

2. AIR QUALITY GUIDELINES AND OBJECTIVES

2. Air Quality Guidelines and Objectives

Canada's national, provincial, and territorial governments have established ambient air quality objectives for criteria air contaminants (CACs) that are intended to ensure long-term protection of public health and the environment. The Government of Nunavut has established guidelines for maximum concentrations of ambient sulphur dioxide (SO_2) and total suspended particulate (TSP), but not for other air contaminants. Therefore, the federal National Ambient Air Quality Objectives (NAAQOs) defined under the *Environmental Protection Act* and the Canada Wide Standard for $PM_{2.5}$, were used as a reference for the air quality modelling study for the Project (Table 2-1). The Canada Wide Standard for maximum ambient 24-hour concentrations of $PM_{2.5}$ was developed by the Canadian Council of Ministers of the Environment (CCME).

Table 2-1
Federal and Territorial Ambient Air Quality Guidelines and Objectives

Contaminant	Averaging Period	Nunavut Ambient Air Quality Guidelines[a]	NWT Ambient Air Quality Standards[c]	Canada Wide Standards[d]	National Ambient Air Quality Objectives[e]		
					Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide (NO_2)	1 hour	-	-	-	-	400	1000
	24 hour	-	-	-	-	200	300
	annual mean	-	-	-	60	100	-
Sulphur Dioxide (SO_2)	1 hour	450	450	-	450	900	-
	24 hour	150	150	-	150	300	800
	annual mean	30	30	-	30	60	-
Carbon Monoxide (CO)	1 hour	-	-	-	15,000	35,000	-
	8 hour	-	-	-	6,000	15,000	20,000
Total suspended particulate (TSP)	24 hour	120	120	-	-	120	400
	annual mean	60	60	-	60	70	-
$PM_{2.5}$	24 hour	-	30	30[b]	-	-	-

Notes:
[a]Guideline concentrations for Nunavut established under the *Environmental Protection Act*, January 2002 (Government of Nunavut, 2002).
[b]Canada Wide Standard, 98th percentile over three years.
[c]http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg_e.html#2.
[d]http://lisin.rwed-hq.gov.nt.ca/NWTAQ/standards.aspx.
[e]http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg_e.html#3.

Air quality standards and objectives are generally intended to protect all members of the general public, including sensitive individuals such as the elderly, infants, and persons with compromised health. Therefore, standards are applicable in areas that are accessible to the general public. Air quality modelling predictions are typically compared to standards and objectives at the fence-line of the industrial property where emissions occur. A fence-line is defined as the limit beyond which public access is restricted. Air quality standards or criteria for industrial settings are defined by occupational health and safety codes. Occupational health air quality standards and criteria allow for higher concentrations of air contaminants because working individuals are assumed to be of reasonably good health and therefore have higher tolerance than sensitive receptors, and because exposure is limited to the time spent at the workplace.

The air quality in the Bathurst Inlet region can generally be classified as pristine. Local emissions are limited to stationary (power generation and heating) and mobile sources (trucks, snowmobiles, all-terrain vehicles, *etc.*) operated by local residents. During the open water season, additional emissions are contributed by barges that are used to bring supplies to the local communities. Mines operating in the region represent the only major industrial emission source. Because of the limited local emission sources, long-range transport of air contaminants is an important influence on ambient air quality.

Ambient air quality data are not available for Bathurst Inlet. The Government of the NWT operates long-term air quality monitoring stations in Yellowknife, Ford Liard, Norman Wells, and Inuvik. A station measuring $PM_{2.5}$ concentrations at Daring Lake (250 km southwest of Bathurst Inlet) was in operation during the summers of 2003 to 2006 (Government of the NWT, 2006). While the long-term monitoring stations are located near communities and the air contaminant concentrations at these stations may not be representative of the air quality at Bathurst Inlet, the Daring Lake station is likely representative of background $PM_{2.5}$ levels typical in the NWT and Nunavut.

Twenty-four hour concentrations of $PM_{2.5}$ ranged from 0 to 5 $\mu g/m^3$ for the 16 measurements taken at Daring Lake during the summer of 2006. The Government of the NWT (2006) indicates that this is typical for background levels and that measurements were not influenced by forest fires, as in previous years. At Inuvik, which has a coastal location similar to Bathurst Inlet, the annual average $PM_{2.5}$ concentration was 2 $\mu g/m^3$, with monthly 24-hour maximum concentrations ranging from 3 to 6 $\mu g/m^3$ in the summer to 7 to 12 $\mu g/m^3$ in the winter.

Generally, air quality in Inuvik is slightly worse in winter, when inversions trap emissions close to the ground and limit their dispersion in the atmosphere. The annual average SO_2 concentration was 2 $\mu g/m^3$, with a 24-hour maximum concentration of 14 $\mu g/m^3$ measured in February. The only air contaminant that showed concentration much above background levels was NO_2, with hourly maximum concentrations as high as 60 $\mu g/m^3$. However, local emissions were the main sources of contaminants; therefore, these results cannot be used to estimate background concentrations at remote sites like Bathurst Inlet.

In air quality modelling studies, air contaminant background concentrations are typically added to concentrations resulting from project activities to produce predictions of total concentrations. When background concentrations are unknown or uncertain, conservative (high) estimates of background concentrations are used to avoid under-predicting total maximum concentrations. Table 2-2 shows the background air contaminant concentrations assumed for the BIPR air quality modelling study. The concentrations represent medium to upper range of observed concentrations in the Northwest Territories and Nunavut (Government of the NWT, 2006).

Table 2-2
Assumed Background Air Contaminant Concentrations

Air Contaminant	Assumed Background Concentration (μg/m^3)
Sulphur Dioxide (SO_2)	7
Nitrogen Dioxide (NO_2)	10
Carbon Monoxide (CO)	100
$PM_{2.5}$	5
Total Suspended Particulates (TSP)	7.5
Ozone (O_3)	60
Total Dustfall (g/m^2/year)	0.8

3. EMISSIONS INVENTORY

3. Emissions Inventory

An emissions inventory was prepared for the air quality modelling study for the Project. The objective of the emissions inventory was to estimate probable maximum hourly air emissions of air contaminants from project activities. The hourly emission estimates were used for input to the air quality modelling study. The estimated maximum hourly emission rates (provided in units of g/s) should not be viewed as the expected steady state emission rates from project activities. Calculation of total annual emissions associated with the Project should account for equipment downtime and seasonal variability in project activities.

3.1 Air Contaminants

Air contaminants included in the modelling study are listed in Table 3.1-1.

Table 3.1-1
Air Contaminants Included in the Air Quality Modelling Study

Species	Description
Sulphur dioxide (SO_2)	Fossil fuel contains a small amount of organic sulphur compounds. During fuel combustion, the sulphur is oxidized and emitted as SO_2 gas with the engine exhaust. In the atmosphere, SO_2 can further oxidize to sulphate particles, which contributes to acid deposition.
Oxides of nitrogen (NO_x)	NO_x gas primarily consists of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The gasses are emitted with exhaust from combustion engines and products from blasting operations. NO_x can be converted to nitric acid in the atmosphere and thus contribute to acid deposition.
Total suspended particulates (TSP) matter	TSP are airborne particles that have a diameter of 30 μm or less. Sources of TSP include vehicle and engine exhaust and fugitive dust. Most particles with diameters between 2 and 30 μm are a result of fugitive dust. Fugitive dust is derived from the mechanical disturbance of granular material exposed to the air. Common sources of fugitive dust include unpaved roads, aggregate storage piles and construction operations. Particles can be composed of a wide range of materials, including minerals (sand, rock dust), engine soot, organic materials or salt.
Respirable particulate matter ($PM_{2.5}$)	$PM_{2.5}$ particles are a subset of TSP and are defined as particles with a diameter less than 2.5 μm. These particles are small enough to enter deep into the respiratory system. The majority of particulate matter emitted with diesel engine exhaust are $PM_{2.5}$.
Carbon monoxide (CO)	Carbon monoxide is formed as a result of incomplete combustion of fossil fuels. The gas prevents oxygen from attaching to red blood cells and is therefore toxic at high concentrations.

Other air contaminants of potential concern include ground level ozone (O_3), volatile organic compounds (VOCs) and hydrogen sulphide (H_2S). Detectable concentrations of ozone occur naturally everywhere. Typical background concentrations in Canada range from 40 $\mu g/m^3$ to 80 $\mu g/m^3$. A background concentration of 60 $\mu g/m^3$ was assumed for the Project air quality modelling study. Ground level ozone is not emitted in large quantities but is formed in series of

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complex atmospheric reactions that involve primary air pollutants such as NO_x gasses and VOCs. The CALPUFF model does not include routines for calculating rates formation of ground level ozone. However, hourly ambient ozone concentrations data can be used by the model to calculate SO_2, NO and NO_2 conversion rates.

Emissions of VOCs from project activities could affect the ambient air quality at Bathurst Inlet because of its role in the formation of secondary air contaminants. However, standards or objectives for ambient VOC concentrations have yet to be established for Nunavut and Canada. Hydrogen sulphide is primarily an air contaminant of concern for oil and gas exploration projects and is therefore not a potential issue for the Project.

Acid deposition is another potential air quality effect to consider for the Project. Acid deposition primarily occurs as a result of atmospheric oxidation of sulphur dioxide to sulphate (sulphuric acid) and oxidation of nitrogen dioxide to nitrate (nitric acid). Acid deposition can be quantified as potential acid input, which is a measure of the combined input of sulphur and nitrogen derived acid species. Because the Project will use ultra low sulphur diesel fuel emissions of sulphur dioxide will be negligible; hence the potential for acid deposition derived from sulphate formation is limited.

The formation and kinetics of acid deposition associated with nitrate species are not well understood. Nitrate deposition is to some extent reversible and the behaviour of the nitrogen species on snow surfaces are not well established (Environment Canada, 2005). Because modelling predictions of nitric acid deposition rates are associated with considerable uncertainties they were not included in the air quality modelling study. The implementation of a snow chemistry sampling and analysis program would be an appropriate approach for monitoring acid deposition resulting from project activities.

3.2 Emissions Sources

The emissions estimates for the Project were based on emissions factors supplied by manufacturers, regulatory agencies and the scientific literature. Sources were categorized based on area of activity. Table 3.2-1 through Table 3.2-9 summarizes the emissions sources included in the inventory for the Project and sources for emission factors. Equipment lists were supplied by SNC Lavalin. Emission factors for the stationary and mobile sources are included in Appendix 1.

Table 3.2-1
Construction Equipment Based at the Port Site

Equipment	Hp	Number of Vehicles/Vessels	Emission Factor Source
Mobile Crane – 150 T	350	1	(US EPA, 2004)
Mobile Crane – 50 T	200	1	(US EPA, 2004)
Fuel Tanker	450	1	(US EPA, 2004)
Service Truck	285	2	(US EPA, 2004)
15 Passenger Van	285	2	(US EPA, 2004)

(continued)

Table 3.2-1
Construction Equipment Based at the Port Site (completed)

Equipment	Hp	Number of Vehicles/Vessels	Emission Factor Source
38 Passenger Bus Passenger Van	385	2	(US EPA, 2004)
Drill	170	1	(US EPA, 2004)
Air Trac Compressor	125	4	(US EPA, 2004)
Tank Drill	260	1	(US EPA, 2004)
Dozer - D10	580	2	(US EPA, 2004)
Dozer - D9	410	2	(US EPA, 2004)
Dozer - D8	310	1	(Manufacturer's Data)
Front End Loader - CAT 988H	501	3	(Manufacturer's Data)
Front End Loader - CAT 992G	800	2	(US EPA, 2004)
Grader - CAT 14 H	220	1	(US EPA, 2004)
Grader - CAT 16 H	265	1	(US EPA, 2004)
Off Highway Trucks CAT 777	938	7	(US EPA, 2004)
Off Highway Trucks CAT 769	485	2	(US EPA, 2004)
100 tonne Float and Tractor	300	1	(US EPA, 2004)
Mobile Crushing and Screening Plant	300	1	(US EPA, 2004)
Cement + Portable Plant	200	1	(US EPA, 2004)
Agitator Trucks	475	2	(US EPA, 2004)
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)

Table 3.2-2
Maintenance Equipment Based at the Port Site

Equipment	Hp	Number of Vehicles/Vessels	Emission Factor Source
Fuel Truck	300	2	(US EPA, 2004)
Dozer - D8	310	1	(Manufacturer's Data)
Boat and Outboard Engine	15	1	(US EPA, 2004)
Front End Loader - CAT 988H	501	3	(Manufacturer's Data)
Container Handler - 52,000 lb Fork Lift	360	1	(US EPA, 2004)
Fork Lift (5 tonne)	211	1	(US EPA, 2004)
HIAB Flat Bed Utility Truck, 2 tonne	245	1	(US EPA, 2004)
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)
Sand Truck/Snow Plow	365	2	(US EPA, 2004)
Grader - 14 G	220	2	(Manufacturer's Data)
Tandem Dump Truck - 20 tonne	360	2	(US EPA, 2004)
Water Truck	305	2	(US EPA, 2004)
Mechanic's Service Truck	285	1	(US EPA, 2004)
Low-Bed Tractor and Trailer	350	1	(US EPA, 2004)
Crew Cab Truck	285	2	(US EPA, 2004)
Industrial Ambulance Vehicle	300	1	(US EPA, 2004)
Fire Snuffer Truck	300	1	(US EPA, 2004)
12 Passenger Van	285	2	(US EPA, 2004)

Table 3.2-3
Construction Equipment Based at the Contwoyto Camp

Equipment	Hp	Number of Vehicles/Vessels	Emission Factor Source
Mobile Crane - 50 T	200	1	(US EPA, 2004)
Fuel Tanker	450	1	(US EPA, 2004)
Fuel Truck	300	2	(US EPA, 2004)
15 Passenger Van	285	2	(US EPA, 2004)
38 Passenger Bus Passenger Van	385	1	(US EPA, 2004)
Air Trac Compressor	125	4	(US EPA, 2004)
Tank Drill	260	1	(US EPA, 2004)
Dozer - D10	580	2	(US EPA, 2004)
Dozer - D9	410	2	(US EPA, 2004)
Dozer - D8	310	2	(Manufacturer's Data)
Front End Loader - CAT 988H	501	1	(Manufacturer's Data)
Front End Loader - CAT 992G	800	2	(US EPA, 2004)
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)
Grader - CAT 16 H	265	1	(US EPA, 2004)
Off Highway Trucks CAT 777	938	7	(US EPA, 2004)
Off Highway Trucks CAT 769	485	2	(US EPA, 2004)
100 tonne Float and Tractor	300	1	(US EPA, 2004)
Mobile Crushing and Screening Plant	300	1	(US EPA, 2004)
Cement + Portable Plant	200	1	(US EPA, 2004)
Agitator Trucks	475	2	(US EPA, 2004)

Table 3.2-4
Maintenance Equipment Based at the Contwoyto Camp

Equipment	Hp	Number of Vehicles/Vessels	Emission Factor Source
Service Truck	285	2	(US EPA, 2004)
Grader - CAT 14 H	220	1	(US EPA, 2004)
Dozer - D6 Wide Path	310	1	(Manufacturer's Data)
Water Truck	305	2	(US EPA, 2004)
Crew Cab Truck	285	2	(US EPA, 2004)
Boat and Outboard Engine	15	1	(US EPA, 2004)
Ferry	n/a	n/a	n/a

Table 3.2-5
Primary Truck Fleet for BIPR Project

Truck Type	Hp	Number of Trucks		Emission Factor Source
		Prospective Users	Future Users	
90 tonne B-train (Bulk Cargo)	475	0	70	(US EPA, 2004)
45 tonne B-train (General Cargo)	410	15	30	(US EPA, 2004)
35 tonne B-train (Fuel)	410	60	105	(US EPA, 2004)

Table 3.2-6
Airstrip Emissions

Source	Emission Factor Source
Portable lighting plant	(US EPA, 1995, Section 3.3)
Twin Otter – Approach, Taxi-in/out, Take-off	(US EPA, 1999)

Table 3.2-7
Stationary Emissions

Equipment	Emission Factor Source
4 CAT 3412 Gensets	(Manufacturer's Data)
Incinerator	(US EPA, 1995, Section 2.1)

Note: includes only gensets operated at the Bathurst Inlet Port site.

Table 3.2-8
Ship Emissions

	Hp	Emission Factor Source
Marine Vessel Emissions		
Underway		
50,000 DWT Cargo Vessel (Main Engine at 75% Load)	11,000	(Transport Canada, 2006)
50,000 DWT Cargo Vessel (Auxiliary Engine at 13% Load)	520	(Transport Canada, 2006)
Manoeuvring		
50,000 DWT Cargo Vessel (Main Engine at 8% Load)	11,000	(Transport Canada, 2006)
50,000 DWT Cargo Vessel (Auxiliary Engine at 45% Load)	520	(Transport Canada, 2006)
Dockside		
50,000 DWT Cargo Vessel (Auxiliary Engine at 67% Load)	520	(Transport Canada, 2006)

Table 3.2-9
Estimated Emissions from ANFO Detonation

Species	Emission Factor
CO	(US EPA, 1995, Section 13.3)
NO_x	(US EPA, 1995, Section 13.3)
SO_2	(US EPA, 1995, Section 13.3)

Ultra low-sulphur diesel fuel (less than 15 ppm sulphur) will be used for equipment and trucks operating at the Project site. Information about emissions factors for mobile equipment was primarily obtained from US EPA (2004). When available, emission factors published by equipment manufacturers were used.

3.3 Fugitive Dust Emissions

The construction and operation of the Project will result in emissions of fugitive dust from travelling vehicles, blasting, grading, loading, hauling, and other activities. Fugitive dust emissions are classified based on the aerodynamic diameter of the emitted particles.

Emissions of fugitive dust can affect air quality by contributing to ambient concentrations of TSP and $PM_{2.5}$. Elevated concentrations of ambient particulate matter have been associated with respiratory and cardio-vascular ailments. In addition, fugitive dust emitted from a road or industrial facility can settle on surrounding vegetation or waterbodies where it could affect plants or water quality (Lippmann *et al.*, 2003).

Particulate matter is ubiquitous, being emitted from both natural and anthropogenic sources. The fine fraction of particulate matter ($PM_{2.5}$) and its precursor gases originate typically from combustion processes such as motor vehicles, industrial processes, and wild fires. In contrast, the coarse fraction (particles greater than 10 μm) is associated with mechanical processes, such as wind erosion or mechanical disturbance of crustal materials. Measurements of ambient concentrations of TSP and $PM_{2.5}$ do not normally distinguish between different types of particulate matter (mineral, soot, salts, *etc*.) but report the total concentrations.

Producing reliable estimates of fugitive emissions from unpaved roads and industrial facilities is problematic because of the large uncertainties associated with existing emissions factors. Emissions factors from Section 13.2.2 of US EPA (2004) are commonly used to calculate emissions estimates for unpaved roads. For vehicles travelling on an unpaved industrial road, the fugitive dust emissions are a function of the road surface silt content and the mean vehicle weight. Because the road for the Project has not yet been constructed, the surface silt content is unknown. Typical values for surface silt content can be used to estimate emissions. However, the surface silt content for unpaved roads can vary by one to two orders of magnitude and as a result the emissions estimates are uncertain. A quality rating of “D” (where “A” is best and “E” is worst) is assigned to emissions factors calculated for unpaved roads using estimated silt values.

The emissions factors for unpaved roads can be adjusted to account for the reduction in fugitive dust emissions on rainy days. Fugitive dust emissions are assumed to be negligible if the daily precipitation is at least 0.254 mm (0.10 in). However, similar adjustment factors are not available for snow-covered roads. Because the Bathurst Inlet/Contwoyto road will be operational during the winter the potential snow cover will influence the fugitive emissions from the road. The lack of data concerning fugitive dust emissions from snow-covered roads contribute to the uncertainties associated with the calculated emissions.

Emissions from activities such as blasting, hauling, loading, grading, or bulldozing can be estimated based on factors published in Section 11.9 of US EPA (2004). However, the emission factors have quality ratings of “E” or “D” if applied to the Project and should therefore be considered to be highly uncertain.

Emissions of TSP and $PM_{2.5}$ were included in the CALPUFF modelling study for the road from Bathurst Inlet to Contwoyto (Table 3.3-1). The modelling results for ambient TSP and $PM_{2.5}$ concentrations along the road are intended to provide an order-of-magnitude estimate of expected maximum concentrations and to provide information about the expected concentration gradients with distance from the road. Thus, the results do not represent the most probable concentrations but possible concentrations based on the specified assumptions.

Estimates of fugitive dust from activities at the port site were considered too uncertain to include in the CALPUFF modelling scenarios. Instead, the potential zone of influence of TSP, $PM_{2.5}$, and dustfall determined for the Bathurst Inlet road was assumed to provide some indication of the expected zone of influence for the Bathurst Inlet port facility. Implementation of a fugitive dust management plan and ongoing monitoring would help ensure that fugitive dust emissions are minimized.

Table 3.3-1
Order of Magnitude Estimate of Fugitive Dust Emissions from the Bathurst Inlet Road

	English Units (lb/VMT)	Metric Units (g/VKT)	Corrected for Road Watering and Natural Mitigation (50% control efficiency assumed) (g/VKT)
TSP	11	3,000	1,500
$PM_{2.5}$	0.47	130	66

Notes: Emissions estimates were based on US EPA (1995, Section 13.2.2).
VMT – vehicle miles travelled.
VKT – vehicle kilometres travelled.

4. MODELLING METHODOLOGY

4. Modelling Methodology

4.1 Model Selection

The air dispersion model CALPUFF was chosen for the BIPR modelling study. CALPUFF is a generalized Gaussian non-steady-state air quality modelling system for regulatory use. The United States Environmental Protection Agency (US EPA) has promulgated the use of CALPUFF for long range dispersion model studies and for near field studies on a case-by-case basis (US EPA, 2003). CALPUFF offers considerable flexibility with respect to meteorological, geo-physical and emissions inputs. The model accepts observed surface or upper air meteorological data, meso-scale meteorological model data, or a combination of observed and model data. Several routines are available for extrapolating or merging observed and model meteorological data. The model allows for constant, time-varying or conditional emissions from point, line, area or volume sources (Scire *et al.*, 2000).

4.2 Model Implementation

Because of limited site-specific meteorological data and non-existing upper air data the CALPUFF model was used in “ISC3-mode,” where a 2-dimensional wind field based on a single surface meteorological station provided the meteorological field for the dispersion modelling. This mode of implementation is a simplistic representation of the wind and meteorological fields used for the dispersion modelling, but was the best available approach given the available data.

During the arctic winter the meteorological conditions often results in very stable boundary layer conditions. Stable boundary layer conditions result in less dispersion of emitted air contaminants and, as a result, relatively high ambient contaminant concentrations. The road from Bathurst Inlet to Contwoyto is planned to operate every year from January to April. The port would be receiving cargo during the open water season, which is expected to last from mid-July to October. The majority of Project activities would occur during the winter when conditions for dispersion air contaminants are least favourable. Air quality data collected in the Northwest Territories shows that maximum ambient air contaminant concentrations are generally recorded during the winter months (Government of the NWT, 2006). Therefore, the CALPUFF model was run only for the road operating season (January to April) because maximum air contaminant concentrations will occur during this period.

Each CALPUFF scenario was run using hourly time steps for a total of 8 months, which included the meteorology data for months of January through April of 2002 and 2003. The meteorological data for the two years was included in a single file to facilitate post processing of the modelling results. Chemical conversion of SO_2, NO and NO_2 were not used in the modelling scenarios.

Several assumptions were used in the modelling study to ensure that predicted concentrations of air contaminants would reflect a reasonably worst-case scenario. Many of the emissions sources for the Project would not be active 24 hours a day but it was assumed that estimated maximum emissions occurred throughout the modelling period (January to April). In other words, it was assumed that all equipment was continuously operational throughout the modelling period, 24 hours a day. This assumption was made to ensure that maximum emissions would coincide with the meteorological conditions that were least ideal for dispersion. While this approach may result in reasonable estimates of maximum hourly ambient air contaminant concentrations, the predicted 24-hour or run-time average concentrations are overestimated.

Details about input data and the model implementation are described in the following sections. The settings used for input groups 2, 8, 9 and 12 in the CALPUFF input file, which controls the execution of the model, are shown in Appendix 2.

4.3 Model Domains

Two modelling domains selected for the Bathurst Inlet port site and road section are shown on Figure 4.3-1. The grid resolution for the modelling domains was 1.0 km by 1.0 km.

The extent of the road from Bathurst Inlet to Contwoyto made it unpractical to include the entire road in the CALPUFF model. The road section included in the modelling domain was selected arbitrarily and was assumed to be representative of a typical road section; that is, it was assumed that the model predictions of gradients of air contaminant concentrations with distance from the road section would be indicative of the air contaminant concentrations along the entire road.

The sizes of the modelling domain were established such that the majority of air contaminant species would approach background concentrations within the modelling domains. For species with predicted maximum concentrations that were well above background concentrations it was ensured that areas of potential exceedances of standards and objectives were well within the modelling domains.

4.4 Meteorological Input Data

Air dispersion models require input of meteorological data to generate a model meteorological field from which air dispersion characteristics are calculated. Site specific or local observed surface and upper air meteorological data are preferred as model inputs. Typically, hourly records of various meteorological parameters are required. For screening-level air dispersion modelling site specific or local meteorological data is not required. Rather, generalized meteorological data covering a wide range of atmospheric conditions are used as model inputs. For projects located in remote regions local or regional meteorological data is often limited or unavailable, particularly upper air data (BC MOE, 2005).

An automated meteorological station was installed near the Project site in late August 2001. The station was installed in an open area that is not targeted for future development. Climatic parameters monitored are relative humidity, rain precipitation, snow accumulation, incoming global short-wave solar radiation, air temperature and wind speed and direction. Meteorological data were collected by the station from August 2001 to July 2003 when wildlife damaged the temperature and relative humidity probe; all other sensor operated without interruption until

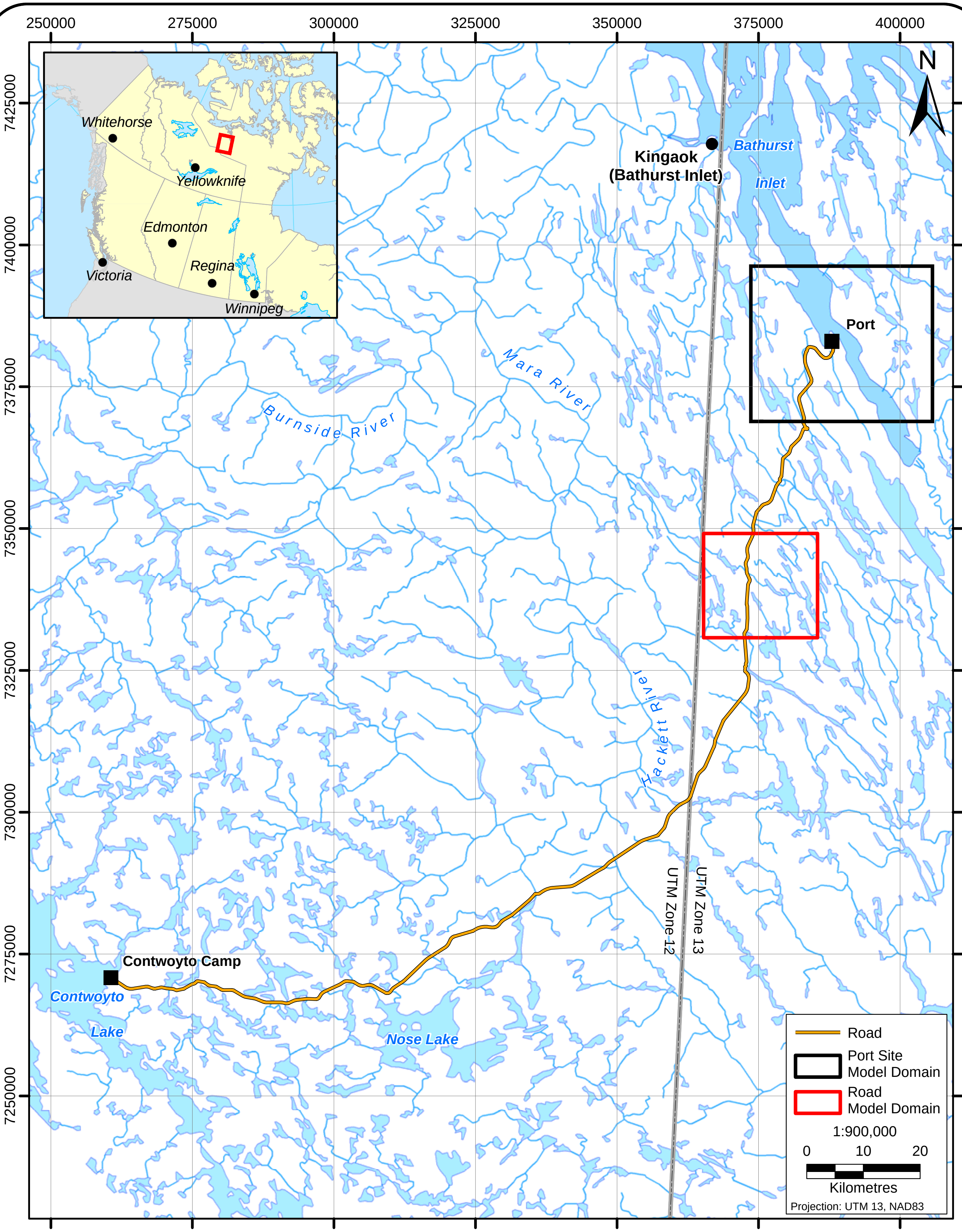

FIGURE 4.3-1

Port Site and Road Domains for the Air Quality Modelling Study

the Bathurst Inlet Port and Road Project

Rescan

August 2004, when a bear destroyed the datalogger enclosure and wiring. A detailed description of the Bathurst Inlet meteorology station is available in the meteorological baseline report (Rescan, 2007).

Running the CALPUFF model in ISC3-mode (using a 2-dimensional wind field) for dispersion modelling that includes dry deposition of particulate matter requires the following meteorological input data:

- wind direction (deg.);
- wind speed (m/s);
- temperature (K);
- Pasquill-Gifford stability class ('A' through 'F');
- mixing height (m);
- friction velocity (m/s);
- Monin-Obukhov length (m);
- surface roughness length (m); and
- upper air data is not required.

4.4.1 Wind and Stability Data

Hourly records of wind speed/direction and temperature data were available from the meteorological station that operated near the port site between 2001 and 2003 (Rescan, 2007). As described in Section 4.2, the modelling scenarios included the months of January to April in the modelling scenarios. Figure 4.4-1 shows wind roses produced from on-site wind speed and direction data (10 m) collected between January to April 2002 and 2003. Northwesterly winds were predominant during the months of January through April in 2002 and 2003.

Hourly on-site records of the standard deviation for wind directions were used to estimate Pasquill-Gifford stability classes using the σ_A method as described in US EPA (2000). The σ_A method is a turbulence-based method which uses the standard deviation of the wind direction in combination with the scalar mean wind speed. The method used was appropriate for data collected at 10 m and an assumed roughness length of 15 cm.

4.4.2 Mixing Heights

Site-specific records of mixing heights were not available and site-specific meteorological data were insufficient for calculating reliable estimates of mixing heights. Therefore, historical regional mixing height data were used as surrogates. Figure 4.4-2 shows monthly mean afternoon mixing heights recorded at several stations located in Nunavut and Northwest Territories between 1965 and 1969 (Fisheries and Environment Canada, 1977). Table 4.4-1 shows the World Meteorological Organization station numbers, distance, and direction from Bathurst inlet for the historic mixing height stations. The nearest station is Kugluktuk (formerly Coppermine) located

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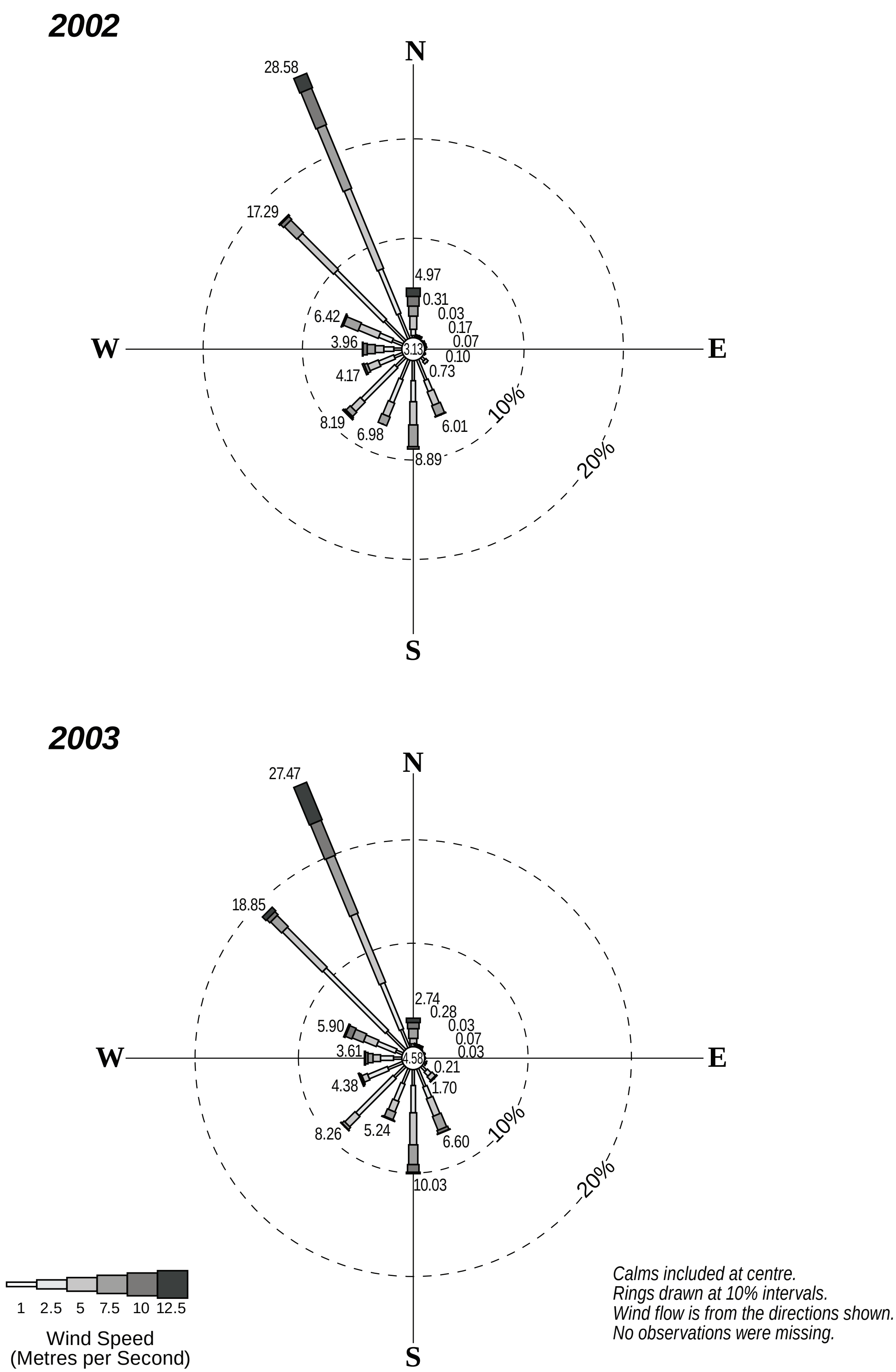
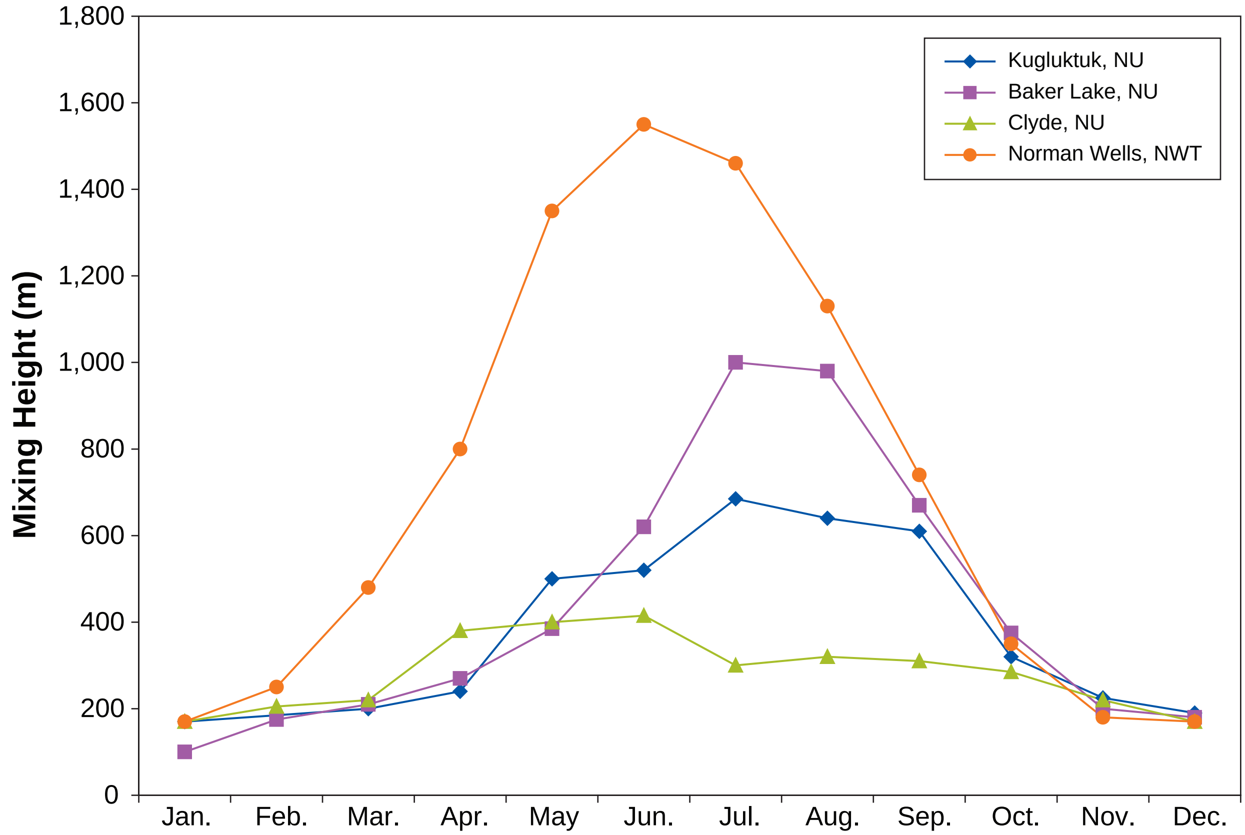


the BATHURST INLET PORT AND ROAD PROJECT

Wind Roses for Bathurst Inlet Port Site (January 1 to April 30)

FIGURE 4-4-1

Rescan™



Source: Fisheries and Environment Canada, 1977.

the BATHURST INLET PORT AND ROAD PROJECT

Monthly Mean Afternoon Mixing Heights (1965 to 1969)

FIGURE 4.4-2

Rescan

Table 4.4-1
Mixing Height Stations

Station	World Meteorological Organization Number	Distance from Bathurst Inlet (km)	Direction
Kugluktuk, NU	72938	318	Northwest
Baker Lake, NU	72926	606	East-southeast
Clyde, NU	74090	750	East-southeast
Norman Wells, NWT	74043	840	West

approximately 318 km northwest of Bathurst Inlet. The Kugluktuk station is situated on the south shore of the Coronation Gulf. Therefore, the climatic conditions can be expected to be similar to the Bathurst Inlet site, which likewise is situated in close proximity to a large body of water and at a similar latitude.

Mixing heights are in part determined by the input of solar energy into the atmosphere. The effect of solar radiation on the mixing heights can be seen by the gradual increase in mixing heights for all stations in the summer months followed by a decrease as fall and winter approaches (Figure 4.4-2). When mixing heights are low, atmospheric dispersion conditions are generally poor. Therefore, the maximum air contaminant concentrations can be expected to occur during the winter months in the Arctic. Because air emissions associated with the Project also are highest during the winter months, only the operating period for the road from Bathurst Inlet to Contwoyto (January 1 to April 30) was included in the modelling study.

Mixing heights can be associated with large diurnal variation. Nighttime mixing heights are typically shallow because of the limited input of solar energy to the atmosphere. Following sunset, air heated near the earth's surface rises, which results in an increase in the depth of the mixing layer. However, during the dark arctic winters, the sun only appears on the horizon for a few hours daily, if at all. Therefore, the diurnal variability in mixing heights may not be as pronounced as the variability in mixing heights at more southern latitudes.

The recorded monthly mean afternoon mixing heights were assumed to represent the mean maximum mixing heights at the stations shown in Table 4.4-1. As a result, actual mixing heights could be considerably less than the recorded monthly mean mixing heights. Because the objective of an air quality modelling study is to produce predictions of maximum contaminant concentrations, it was assumed that the mixing height was 80 m for the entire winters of 2002 and 2003, based on the data shown in Figure 4.4-2. Although conservative, this assumption ensured that a reasonable worst-case scenario was used with respect to atmospheric dispersion conditions. Therefore, modelling results can also be assumed to represent a reasonable worst-case scenario.

4.4.3 Other Meteorological Inputs

For the BIPR air quality modelling study hourly friction velocities were assumed to be 10% of the 10 m wind speeds. Monin-Obukhov lengths were estimated based on stability class following the method of Golder (1972). The uncertainty associated with estimates of friction velocity and Monin-Obukhov lengths are not expected to produce large errors in the internal deposition velocity calculations in CALPUFF. Particles larger than 10 µm are dominated by gravitational settling effects, while gaseous species are deposited by Brownian diffusion. Therefore, the gravitational settling term will dominate the calculation for deposition velocity in CALPUFF (Scire *et al.*, 2000). For the Project, deposition of fugitive dust from the road could affect plants and lichen in areas in proximity to the road. Assessments of the potential zone of influence of fugitive dust from the BIPR road were discussed in Section 3.3.

4.5 Model Emissions

The emissions sources for the Project (Tables 3.2-1 through 3.2-9) were implemented in CALPUFF as point, line, and area sources. Table 4.5-1 shows the attributes assigned to the three types of emission sources. Emission factors used for individual sources are shown in Appendix 1. Overall emissions for the different modelling scenarios are presented in Section 5.1.

Table 4.5-1
Implementation of Emissions Sources in CALPUFF

Domain	Type of Equipment	Reference	Source Type in CALPUFF	Attributes
Port Facility	Construction and Maintenance Equipment	Table 3.2-1 and Table 3.2-2	Area Source	Size: 6.0 ha Release Height: 3 m Initial Sigma: 4 m
Port Facility	Portable Lighting System and Aircrafts	Table 3.2-6	Area Source	Size: 7.0 ha Release Height: 4 m Initial Sigma: 5 m
Port Facility	Generator Sets	Table 3.2-7	Point Source	Stack Height: 32 m Diameter: 0.203 m Temperature: 725 K Exit Velocity: 111 m/s
Port Facility	Incinerator	Table 3.2-7	Point Source	Stack Height: 10 m Diameter: 0.25 m Temperature: 700 K Exit Velocity: 8.4 m/s
Port Facility	Truck Fleet	Table 3.2-5	Line Source	Length: 20.2 km Release Height: 3 m
Road	Truck Fleet	Table 3.2-5	Line Source	Length: 22.8 km Release Height: 3 m

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5. MODELLING RESULTS

5. Modelling Results

5.1 CALPUFF Scenario Runs

The CALPUFF scenario runs were devised to predict potential maximum 1-hour, 8-hour, 24-hour, and runtime average air contaminant concentrations for activities associated with construction and operation of the Project. The runtime average concentrations are the average concentrations predicted by the model using maximum hourly emissions and meteorological data for the months of January through April of 2002 and 2003 (8 months total). Therefore, the average runtime concentrations are considerable higher than average annual concentrations. However, the average runtime concentrations can provide conservative order-of-magnitude estimate of annual average concentrations, which can serve as a basis of comparison with ambient air quality standards and objectives.

Three CALPUFF scenario runs were completed for the BIPR air quality effects assessment:

1. road domain – operation;
2. port domain – construction phase; and
3. port domain – operation.

Construction of the road from Bathurst Inlet to Contwoyto is projected to last 2.5 years and the estimated operational life of the road is 20 years. The road will be constructed in two sections with one heading starting from Contwoyto Camp and the other from Bathurst Inlet. Road construction will be supported by mobile camps that will follow the two headings. A total of 40 quarries will be excavated along the road to supply fill and aggregate for the road. Because of the transient nature of the road construction, air emissions from construction equipment and quarries will be limited to a few months for each location. Therefore, a scenario considering construction of the road was not included in the air quality modelling study. Once the road is operational, air emissions will be relatively continuous during the operating season from January to April.

Decommissioning the road would involve the removal of bridges and some re-contouring of some disturbed areas. Air emissions associated with decommissioning of the road would be less than emissions associated with the construction and operation of the road and was therefore not considered in the air quality modelling study.

5.1.1 Road Domain – Operation

Approximately 7,000 truck loads will be required annually by the prospective road users. In addition, a smaller fleet of maintenance and support vehicles will be using the road throughout the year (see Table 3.2-2 and Table 3.2-4). Thus, over a four-month operating season an average of 5 truckloads will pass a road section every hour assuming that trucks are operating 24 hours a day. Trucks travelling south will generally be loaded and trucks travelling north will generally be empty. Truck traffic will not be evenly distributed over the entire season on an hourly basis because of operational constraints and because trucks will travel the road in convoys.

For the modelling scenarios for the road domain it was assumed that 12 trucks would pass a road section every hour for the duration of the operating season. Emissions from maintenance and service trucks were assumed to be included in this estimate. Although estimates of hourly maximum concentrations likely are reasonable using this approach the runtime emissions and concentration predictions are overestimated by a factor of 2.4.

Table 5.1-1 shows the hourly emissions used for the road domain scenario. The emissions were calculated using the emission factors listed in Appendix 1.

Table 5.1-1
Emissions for the Road Operation Scenario

	SO_2 (g/s)	NO_x (g/s)	CO (g/s)	Exhaust $PM_{2.5}$ (g/s)	Fugitive Dust		
					PM2.5 (g/s)	PM10 (g/s)	TSP (g/s)
Road to Contwoyto[a]	0.031	17	1.1	0.23	5.2	33	114

[a]Emissions from the 22.8 km section of the road included in the model domain.

5.1.2 Port Domain

Two scenarios were completed for the Port domain: Port construction and Port Operation. Tables 5.1-2 and 5.1-3 show the overall emissions estimates used for the two scenarios. For the scenarios, it was assumed that all equipment associated with the construction and operation of the port (see Section 3.2) were operating 24 hours a day throughout the modelling runs. Analogous to the road operation scenario, this assumption was made to ensure reasonable estimates of hourly maximum concentrations, while recognizing that 24-hour and run-time concentrations would be over-predicted.

Table 5.1-2
Emissions for the Port Construction Scenario

	SO_2 (g/s)	NOx (g/s)	CO (g/s)	Exhaust $PM_{2.5}$ (g/s)
Point Sources				
Generator Sets	0.0069	15	4.5	0.24
Incinerator	0.0013	0.0014	0.00017	0.0065
Line Sources				
Road to Contwoyto[a]	0.028	15	0.39	0.20
Area Sources				
Port area	0.026	18	6.5	1.1
Airstrip	0.021	0.58	0.36	0.0033
Domain Emissions Total	0.084	49	12	1.6

[a]Emissions from the 20.2 km section of the road included in the model domain.

Table 5.1-3
Emissions for the Port Operation Scenario

	SO_2 (g/s)	NOx (g/s)	CO (g/s)	Exhaust $PM_{2.5}$ (g/s)
Point Sources				
Generator Sets	0.0069	15	4.5	0.24
Incinerator	0.0013	0.0014	0.00017	0.0065
Line Sources				
Road to Contwoyto[a]	0.028	15	0.39	0.20
Area Sources				
Port area	0.011	6.7	2.8	0.43
Airstrip	0.021	0.58	0.36	0.0033
Domain Emissions Total	0.069	37	8.0	0.89

[1]**Emissions from the 20.2 km section of the road included in the model domain.**

Point sources for the two scenarios included generator sets and incinerators. Line sources included emissions from haul trucks and maintenance vehicles. Area sources included emissions from all mobile construction equipment listed in Table 3.2-1 and Table 3.2-2.

5.2 Results

5.2.1 Road Domain – Operation

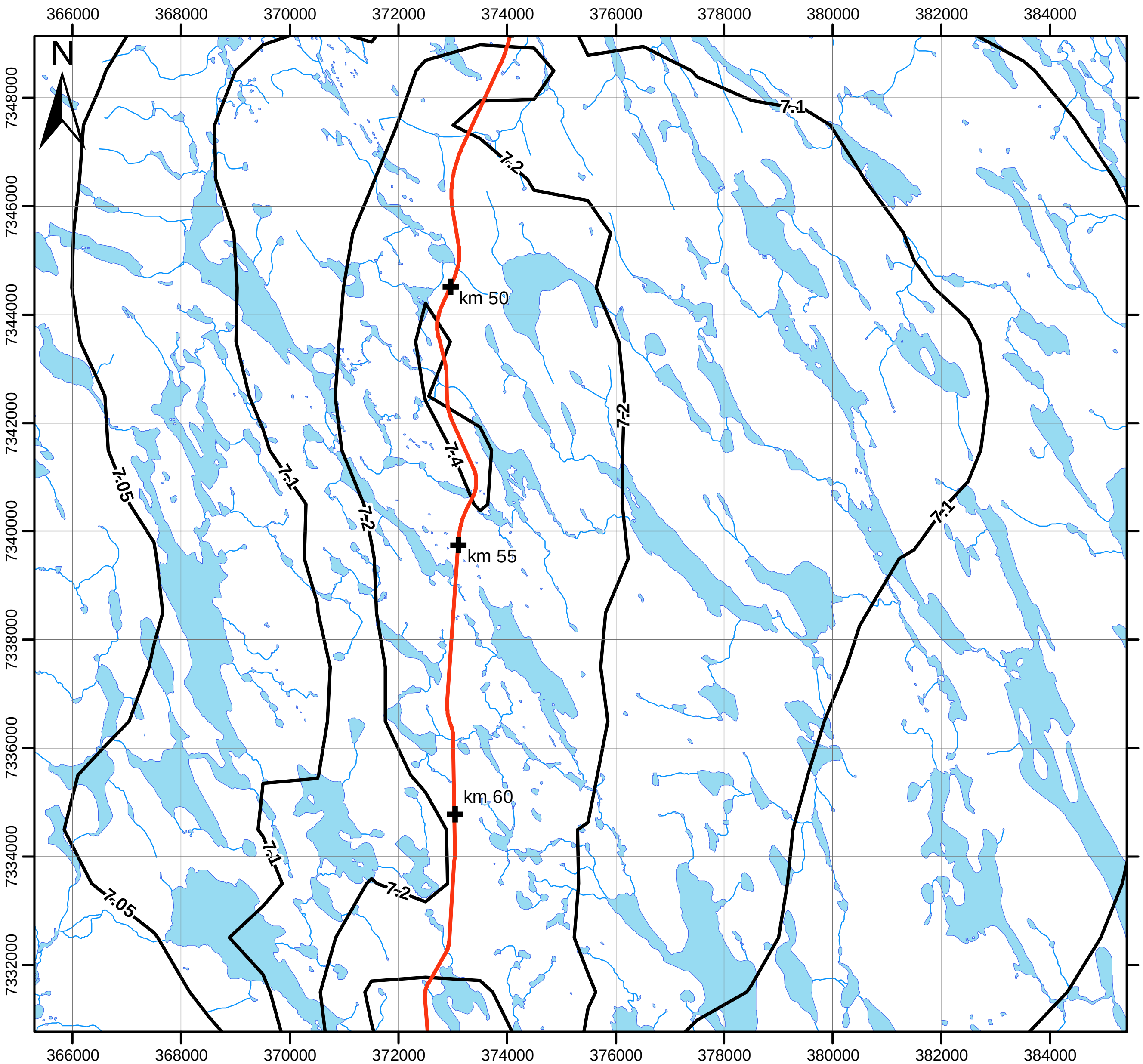
Predicted maximum 1-hour, 24-hour and run-time average SO_2 concentrations for the road operation scenario were 7.6 µg/m^3, 7.1 µg/m^3 and 7.0 µg/m^3, respectively, which is well below Nunavut's air quality standards of 450 µg/m^3, 150 µg/m^3 and 30 µg/m^3. Figures 5.2-1, 5.2-2 and 5.2-3 show SO_2 concentration isopleths for the modelling domain. The use of ultra low sulphur diesel fuel (15 ppm sulphur) for mobile and stationary diesel equipment for the Project is the main explanation for the low predicted ambient SO_2 concentrations.

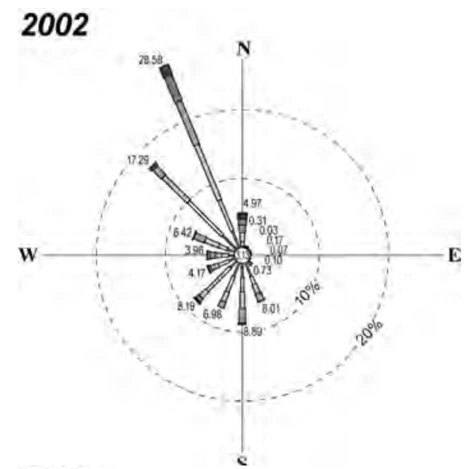
In CALPUFF, NO_2 emissions are modelled as NOx emissions. NOx from internal combustion sources is mainly comprised of NO gas (~90%) with approximately 5% to 10% NO_2 and smaller quantities of other oxides of nitrogen. In the atmosphere, ozone readily oxidizes NO to NO_2. Predicted maximum concentrations of NO_2 can be estimated from NOx concentrations by using the ozone limiting method (BC MOE, 2005). The ozone limiting method is applied as follows:

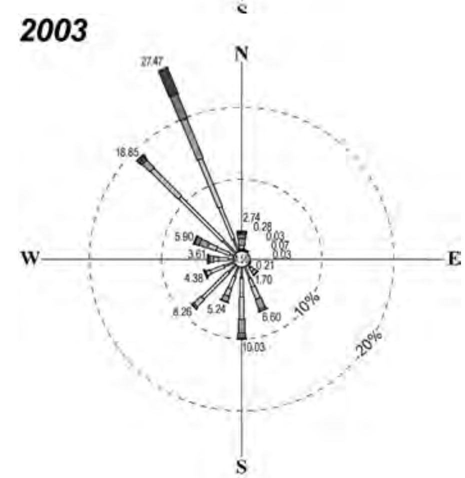
$$NO_2 \text{ conc.} = 0.10 \cdot NOx \text{ conc.} + \text{the lesser of } (O_3 \text{ conc. OR } 0.90 \cdot NOx) + \text{background } NO_2 \text{ conc.}$$

When model predictions of maximum NOx concentrations are higher than applicable NO_2 objectives the ozone limiting method is employed to provide a refined estimate of predicted NO_2 concentrations that are then compared to the objectives (BC MOE, 2005).

Figures 5.2-4, 5.2-5 and 5.2-6 show that predicted maximum 1-hour, 24-hour and runtime NO_2 concentrations are 310 µg/m^3, 46 µg/m^3 and 16 µg/m^3, which are below the NAAQOs of 400







Predicted Maximum 1-hour SO_2 Concentration (µg/m³)

Road

Notes:
Assumed background concentration: 7 µg/m³ (5 ppb)
Maximum concentration: 7.6 µg/m³
Nunavut Ambient Air Quality Guideline: 450 µg/m³

1:120,000

0 2.5 5

Kilometres

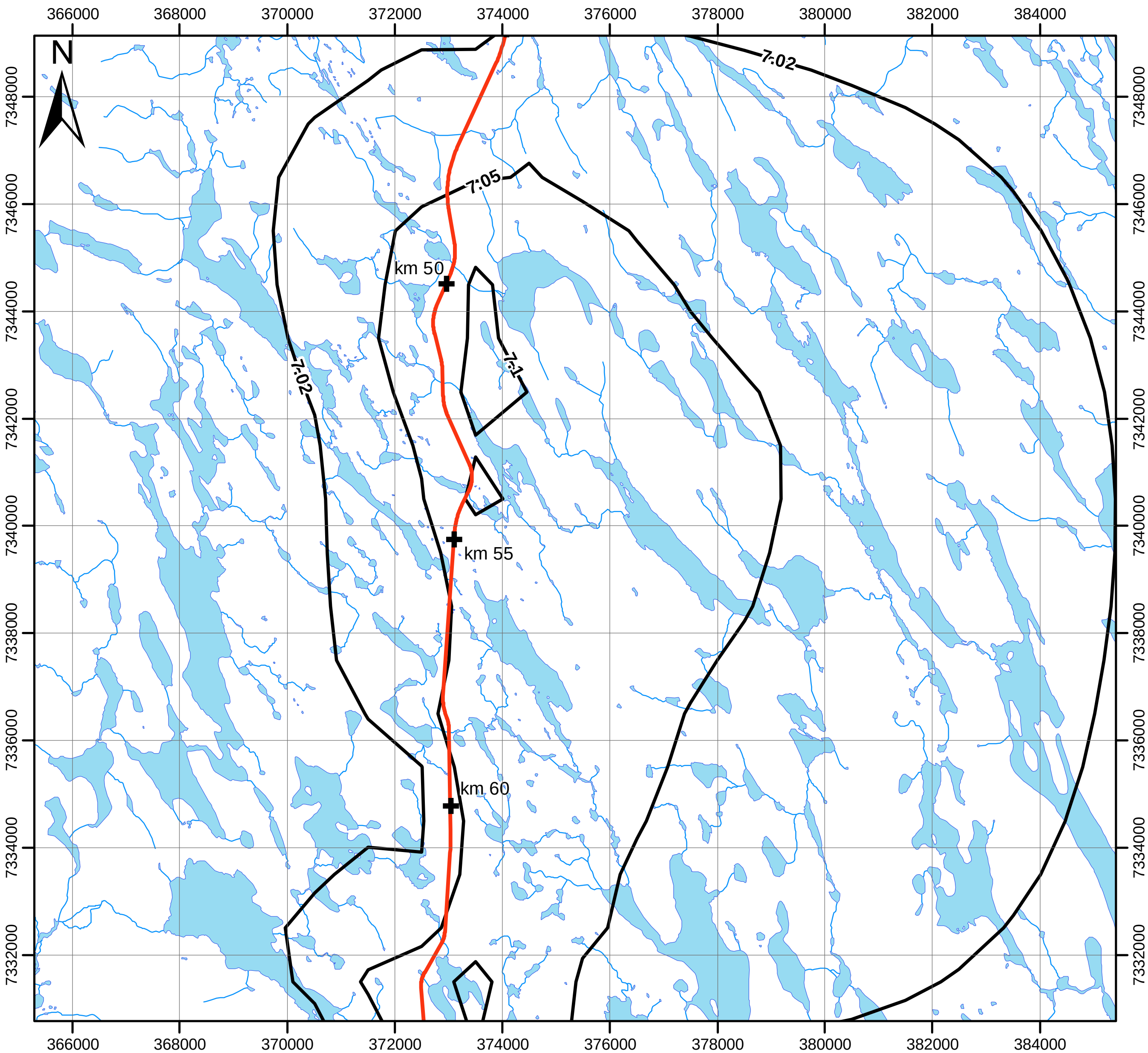
Projection: UTM13, NAD83

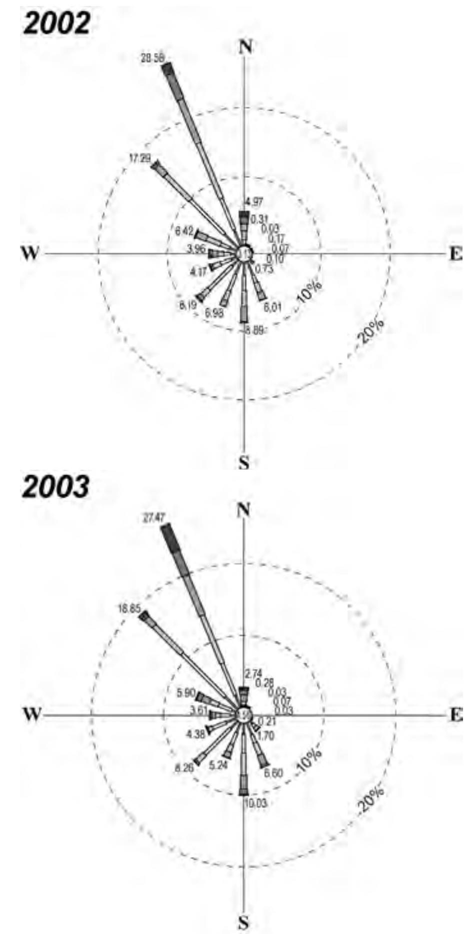
FIGURE 5.2-1

the Bathurst Inlet Port and Road Project

Predicted Maximum 1-hour SO_2 Concentrations (µg/m³) for the Road Operation Scenario

Rescan





Predicted Maximum 24-hour SO_2 Concentration (µg/m³)

Road

Notes:
Assumed background concentration: 7 µg/m³ (5 ppb)
Maximum concentration: 7.2 µg/m³
Nunavut Ambient Air Quality Guideline: 150 µg/m³

1:120,000

0 2.5 5

Kilometres

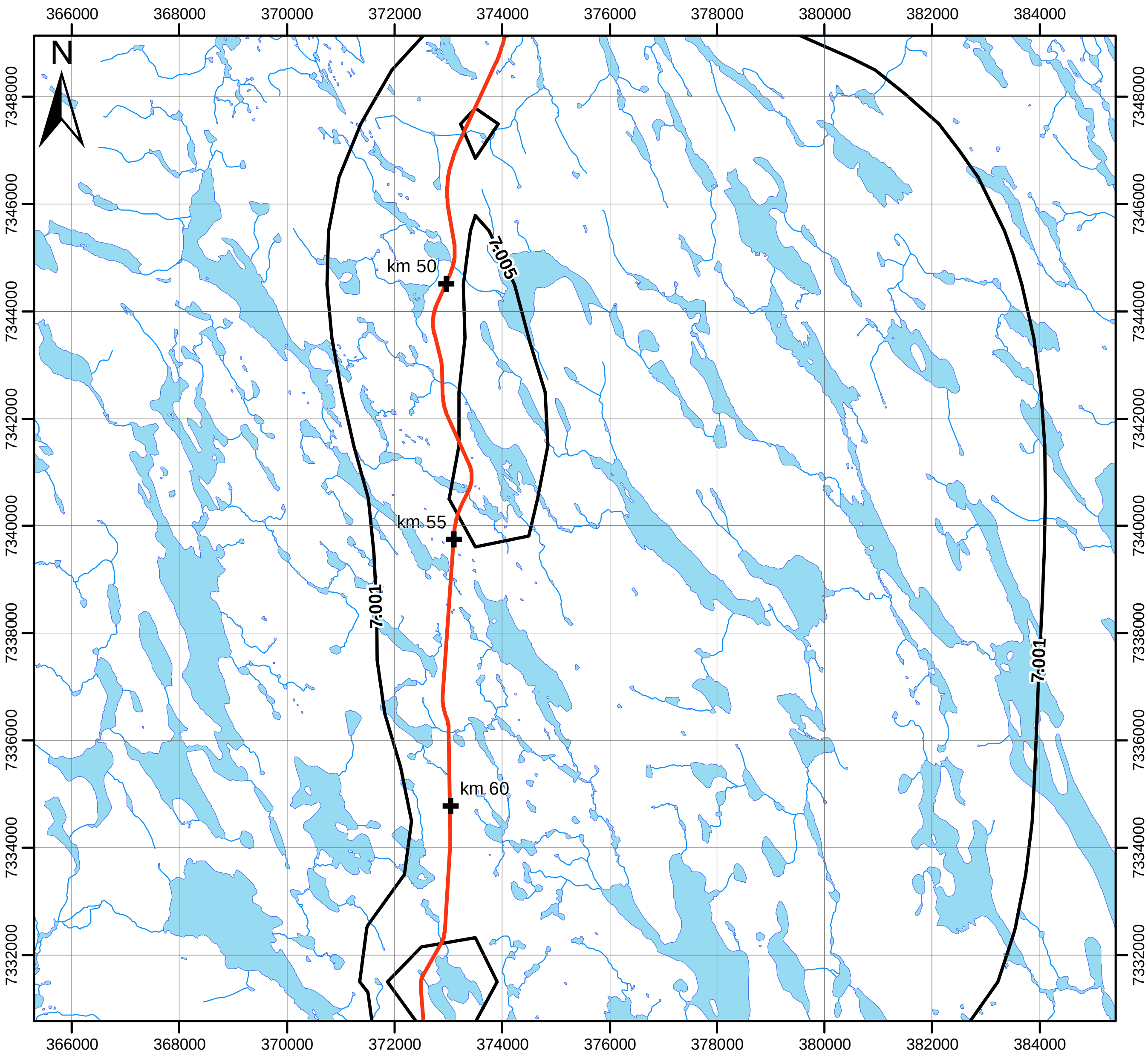
Projection: UTM13, NAD83

FIGURE 5.2-2

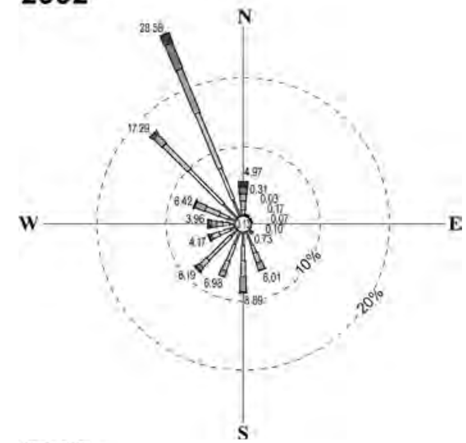
the BATHURST INLET PORT AND ROAD PROJECT

Predicted Maximum 24-hour SO_2 Concentrations (µg/m³) for the Road Operation Scenario

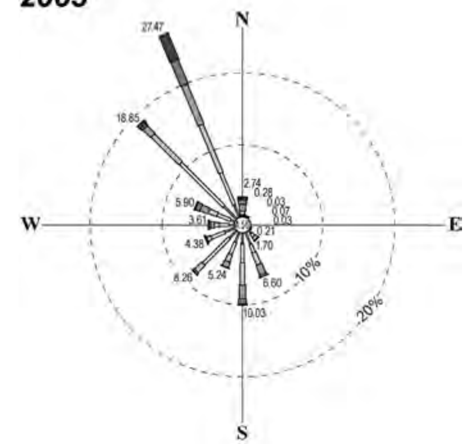
Rescan™



2002



2003



Predicted Average Runtime SO_2 Concentration ($\mu g/m^3$)

Road

Notes:
Assumed background concentration: 7 $\mu g/m^3$ (5 ppb)
Maximum concentration: 7.01 $\mu g/m^3$
Nunavut Ambient Air Quality Guideline: 30 $\mu g/m^3$

1:120,000

0 2.5 5

Kilometres

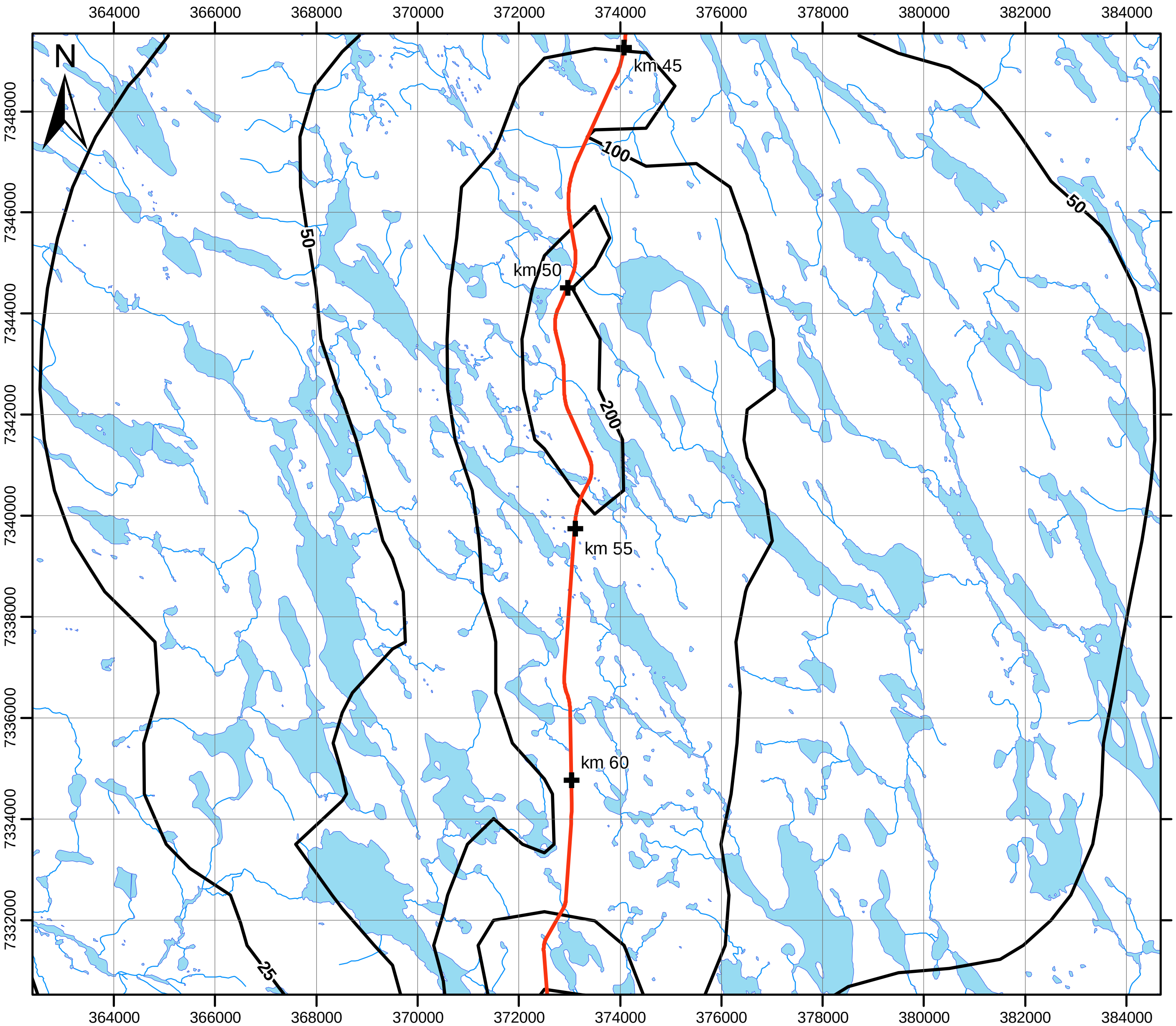
Projection: UTM13, NAD83

the Bathurst Inlet Port and Road Project

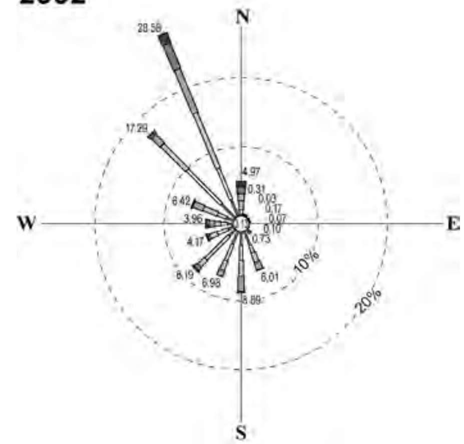
FIGURE 5.2-3

Predicted Average Runtime SO_2 Concentrations ($\mu g/m^3$) for the Road Operation Scenario

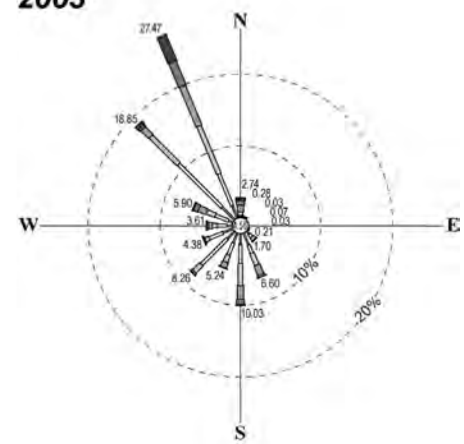
Rescan™



2002



2003



Predicted Maximum 1-hour NO_2 Concentration ($\mu g/m^3$)

All-weather Road

Notes:
The Ozone Limiting Method was not applied
Assumed background concentration: 9.4 $\mu g/m^3$ (5 ppb)
Maximum concentration: 320 $\mu g/m^3$
NAAQO: 400 $\mu g/m^3$ (maximum acceptable)

1:125,000

0 2.5 5

Kilometres

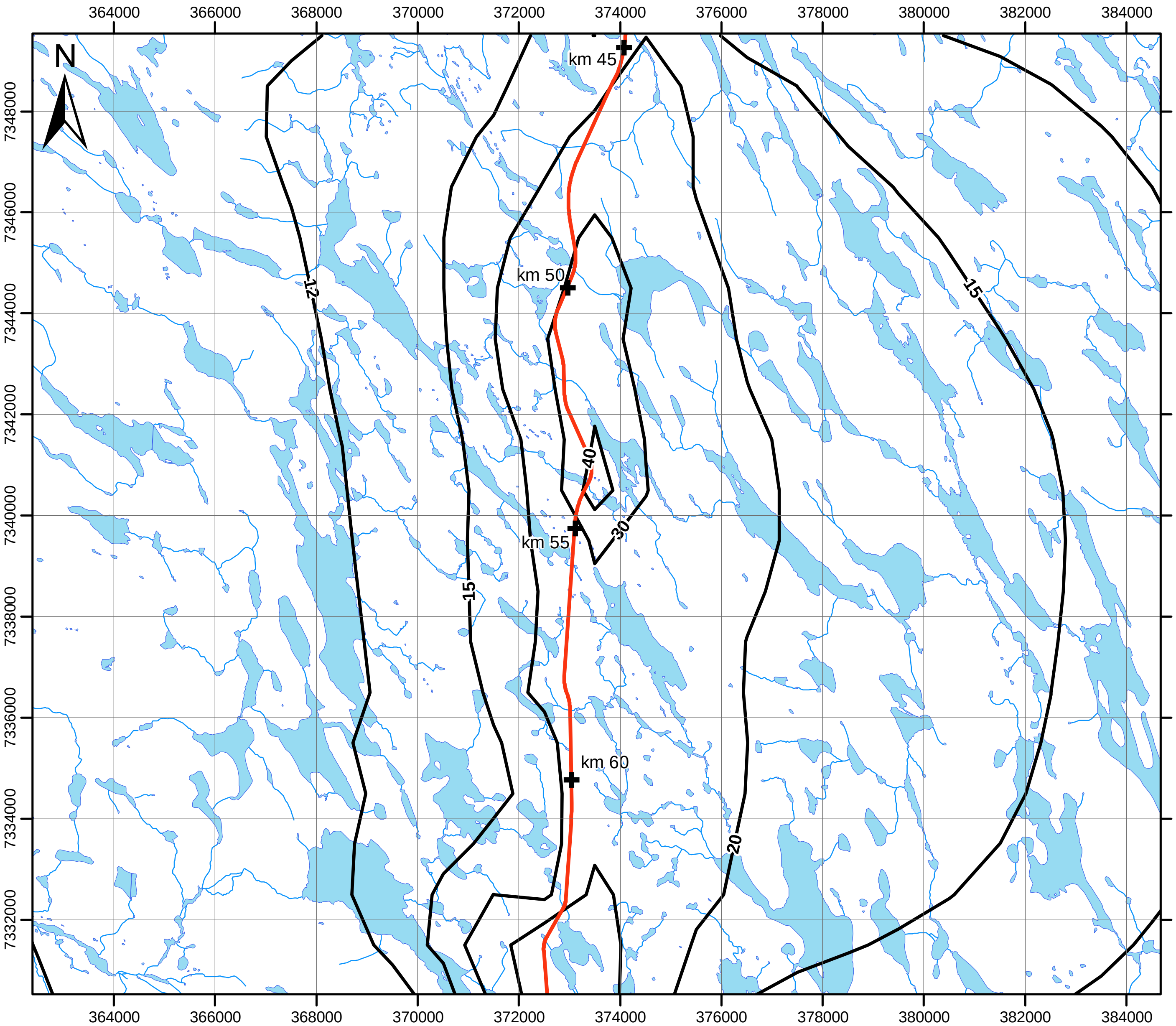
Projection: UTM13, NAD83

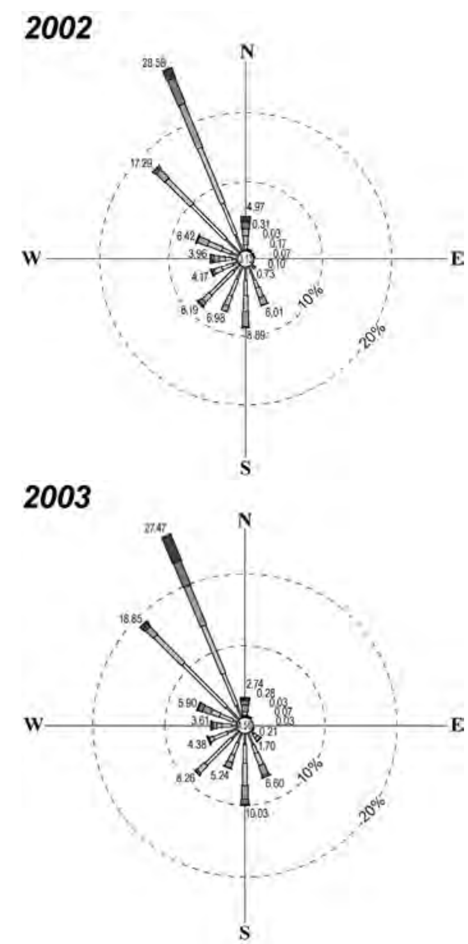
FIGURE 5.2-4

the Bathurst Inlet Port and Road Project

Predicted Maximum 1-hour NO_2 Concentrations ($\mu g/m^3$) for the Road Operation Scenario

Rescan™





Predicted Maximum 24-hour NO_2 Concentration (µg/m^3)

Road

Notes:
The Ozone Limiting Method was not applied
Assumed background concentration: 9.4 µg/m^3(5 ppb)
Maximum concentration: 46 µg/m^3
NAAQO: 200 µg/m^3 (maximum acceptable)

1:125,000

0 2.5 5

Kilometres

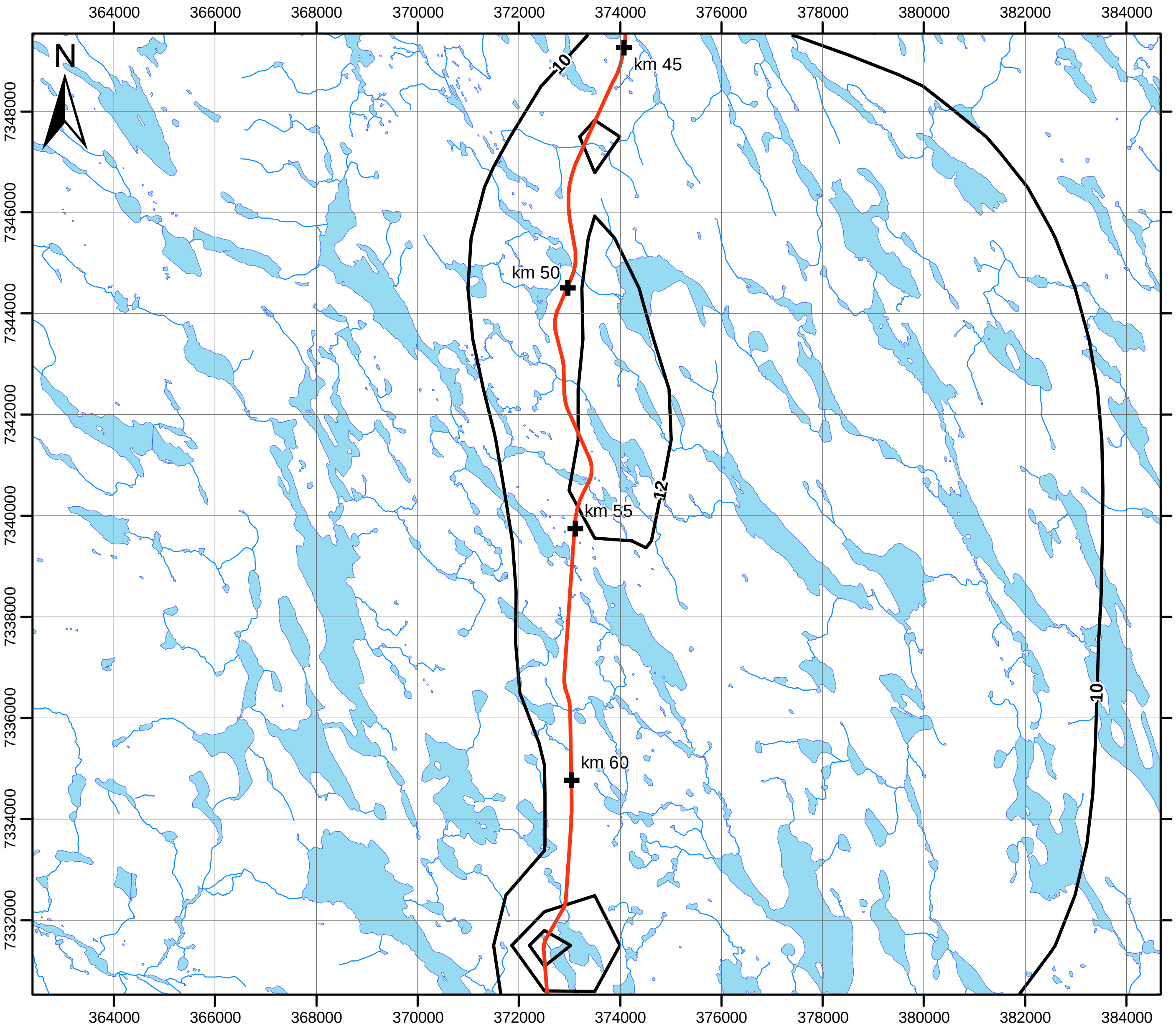
Projection: UTM13, NAD83

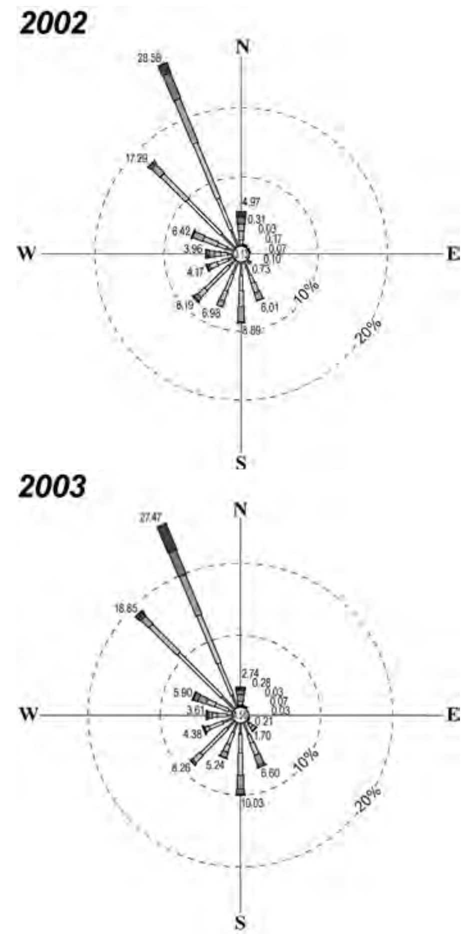
FIGURE 5.2-5

Predicted Maximum 24-hour NO_2 Concentrations (µg/m^3) for the Road Operation Scenario

the Bathurst Inlet Port and Road Project

Rescan™





Predicted Average Runtime NO_2 Concentration (µg/m^3)

Road

Notes:
The Ozone Limiting Method was not applied
Assumed background concentration: 9.4 µg/m^3(5 ppb)
Maximum concentration: 16 µg/m^3
NAAQO: 60 µg/m^3 (maximum acceptable)

1:125,000

0 2.5 5

Kilometres

Projection: UTM13, NAD83

FIGURE 5.2-6

the Bathurst Inlet Port and Road Project

Predicted Average Runtime NO_2 Concentrations (µg/m^3) for the Road Operation Scenario

Rescan™

µg/m^3, 200 µg/m^3 (maximum acceptable) and 60 µg/m^3 (maximum desirable) when NO_2 concentrations are estimated as predicted NO_x concentrations. Therefore, NO_2 concentrations along the Bathurst Inlet road are not expected to exceed national objectives for ambient NO_2 concentrations.

Predicted 1-hour and 8-hour ambient carbon monoxide concentrations for the road operation scenario were 220 µg/m^3 and 160 µg/m^3 which are far below the NAAQOs of 15,000 and 6,000, respectively.

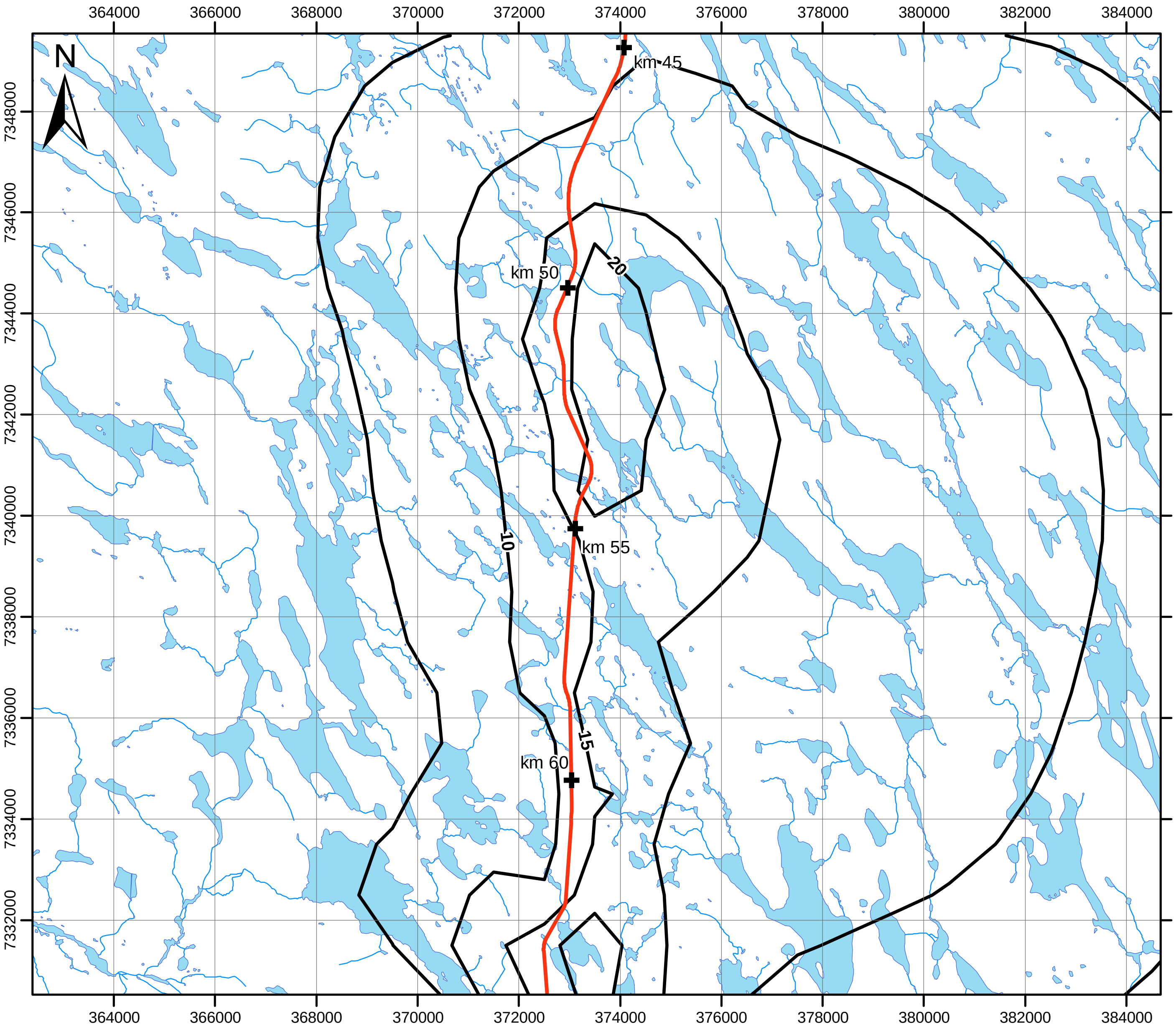
Maximum 24-hour $PM_{2.5}$ concentrations for the Road Operation Scenario are shown in Figure 5.2-7. Predicted maximum 24-hour and runtime TSP concentrations are shown in Figures 5.2-8 and 5.2-9. Figure 5.2-10 shows the model predictions of runtime dustfall for the road operation scenario. As discussed in Section 3.3, the model predictions of $PM_{2.5}$ and TSP concentrations as well as predictions for dustfall are associated with considerable uncertainty because of inherent uncertainties associated with emissions estimates. The concentration isopleths shown on Figures 5.2-7 through 5.2-10 should be viewed as possible scenarios rather than as likely scenarios.

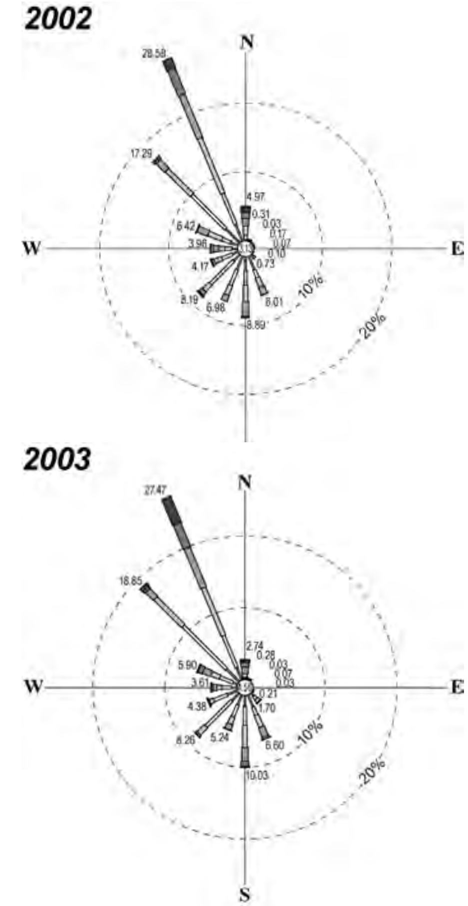
As indicated by the modelling results, ambient concentrations of $PM_{2.5}$ and TSP close to the road could potentially exceed the Nunavut guideline and the Canada Wide Standard for TSP and $PM_{2.5}$, respectively. However, concentrations would decrease sharply with distance from the road and the elevated concentrations would be highly localized near the centreline of the road. The exact zone of influence can only be established through monitoring programs. Fugitive dust emissions can be managed through the implementation of an adaptive management plan. An adaptive management plan would contain different levels of mitigation strategies that could be initiated if certain thresholds of dustfall or ambient particulate matter concentrations were reached.

5.2.2 Port Domain

Predicted maximum 1-hour, 24-hour, and runtime average SO_2 concentrations for the port construction and operation are shown in Table 5.2-1. Figures 5.2-11 and 5.2-12 show the predicted maximum 1-hour SO_2 concentrations for the port construction and operation scenarios, respectively. All concentrations are well below Nunavut's standards for ambient SO_2. As mentioned, the use of ultra low sulphur diesel fuel (15 ppm sulphur) for mobile and stationary diesel equipment for the Project is the main explanation for the low predicted ambient SO_2 concentrations.

Table 5.2-2 shows predicted maximum 1-hour, 24-hour, and runtime average NO_2 concentrations for the port construction and operation scenarios. Figures 5.2-13 through 5.2-18 show the corresponding NO_2 concentration isopleths for the averaging times listed in Table 5.2-2. Because predicted NOx concentrations exceeded the NAAQOs for NO_2, the ozone limiting method was used to obtain refined estimates of the predicted NO_2 concentrations.





Predicted Maximum 24-hour $PM_{2.5}$ Concentration ($\mu g/m^3$)

Road

Notes:
Assumed background concentration: 5.0 $\mu g/m^3$
Maximum concentration: 24 $\mu g/m^3$
Canada Wide Standard: 30 $\mu g/m^3$ (98th Percentile over 3 years)

1:125,000

0 2.5 5

Kilometres

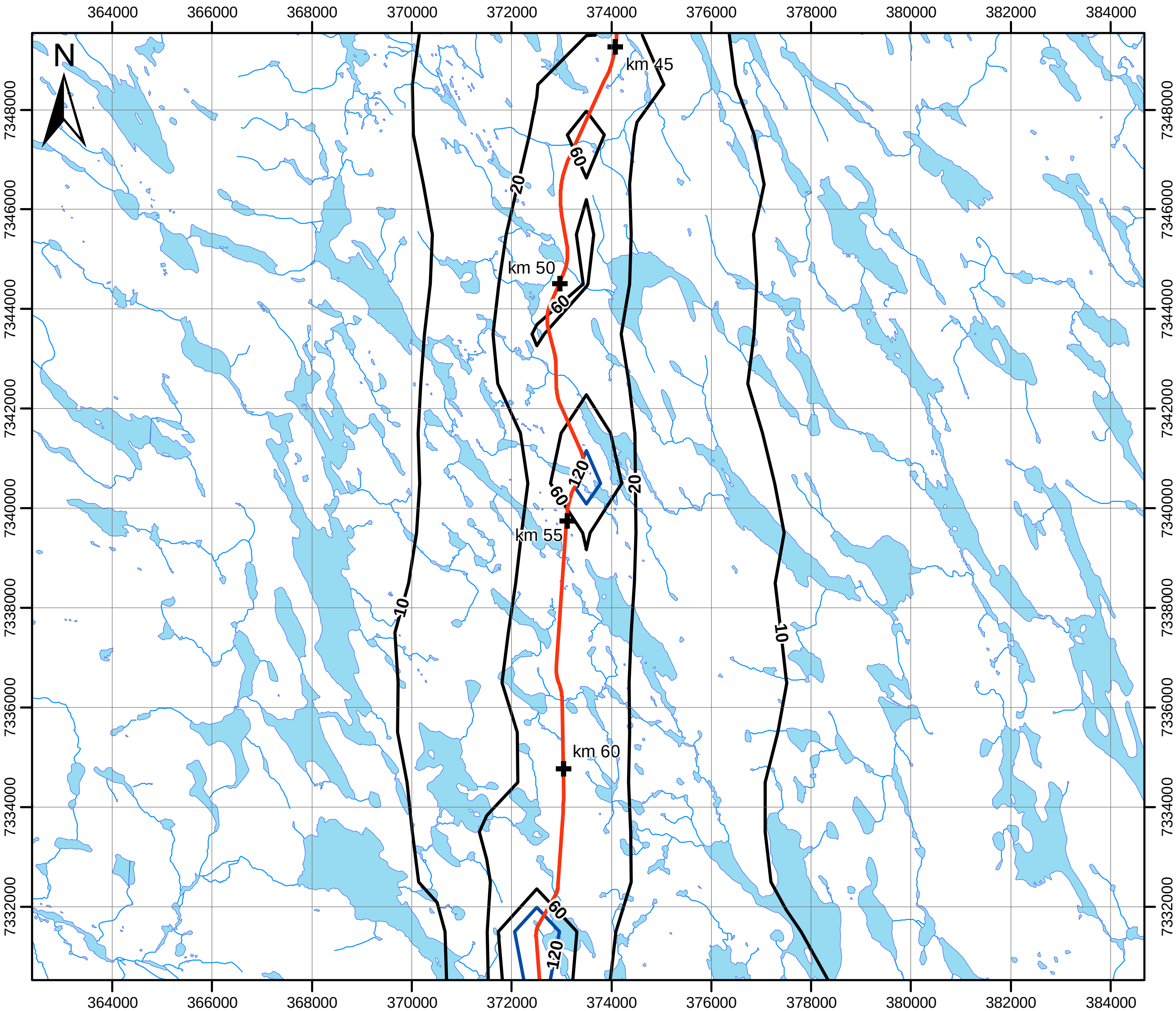
Projection: UTM13, NAD83

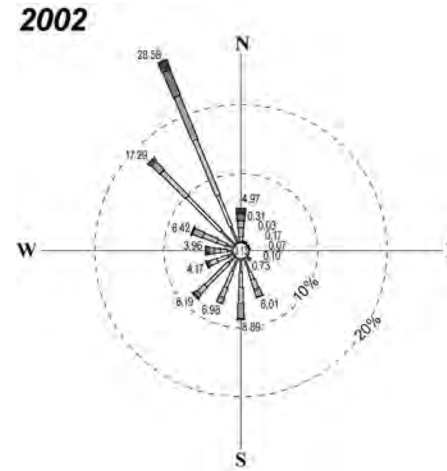
FIGURE 5.2-7

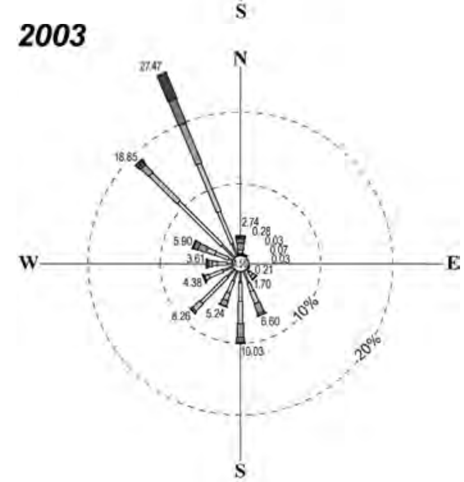
Predicted Maximum 24-hour $PM_{2.5}$ Concentrations ($\mu g/m^3$) for the Road Operation Scenario

the Bathurst Inlet Port and Road Project

Rescan™







- Predicted Maximum 24-hour TSP Concentration (μg/m³)
- Nunavut Ambient Air Quality Guideline Value
- Road

Notes:
Assumed background concentration: 7.5 μg/m³
Maximum concentration: 199 μg/m³
Nunavut Ambient Air Quality Guideline: 120 μg/m³

1:125,000

0 2.5 5

Kilometres

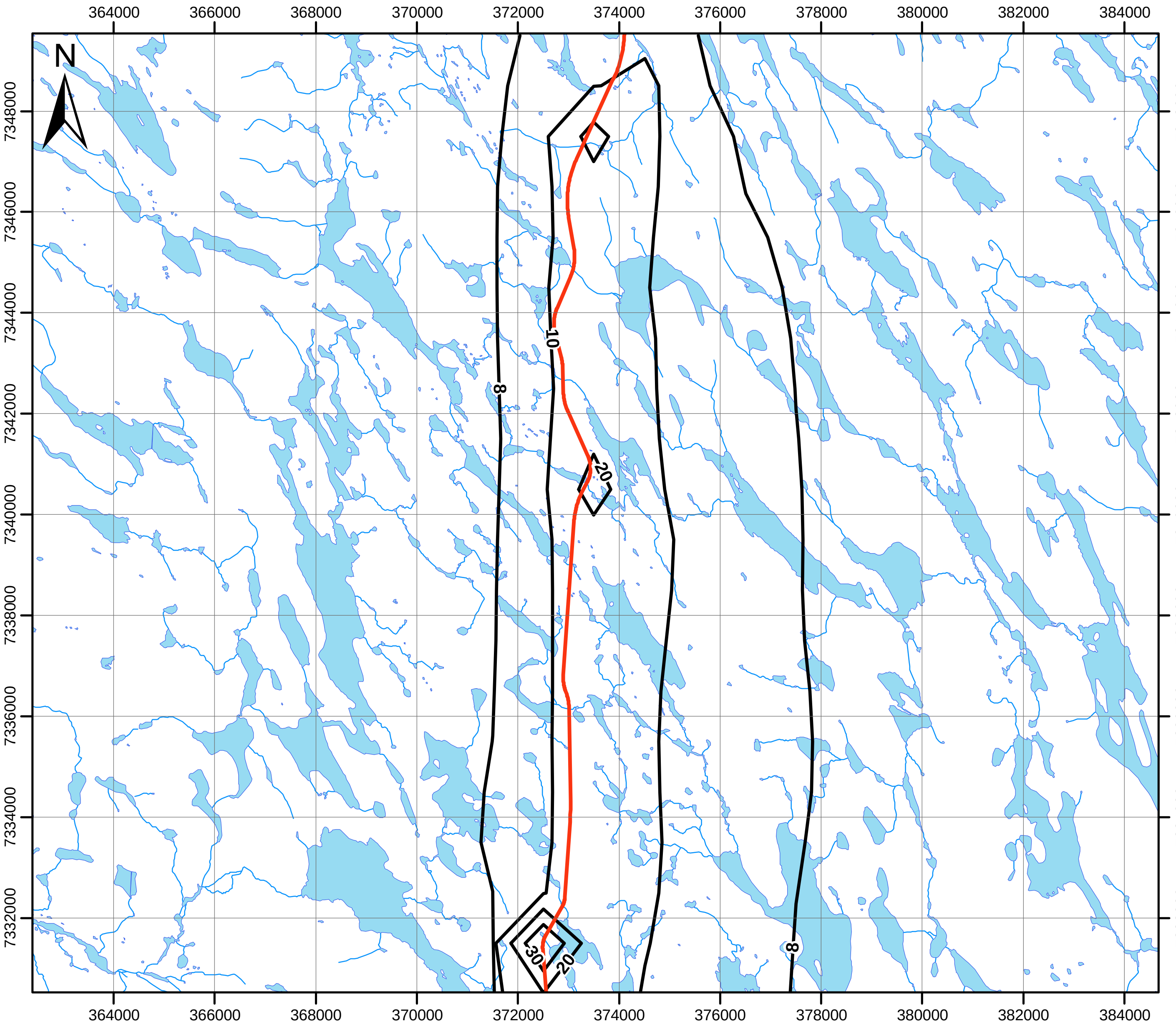
Projection: UTM13, NAD83

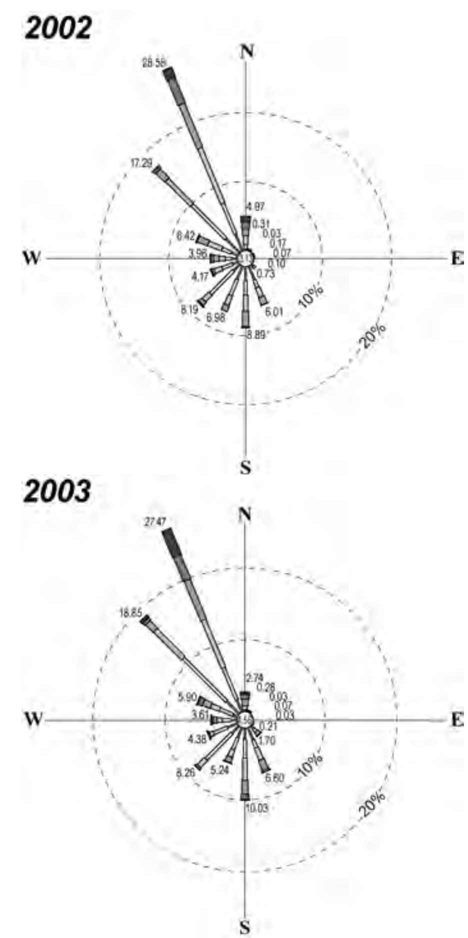
FIGURE 5.2-8

the Bathurst Inlet Port and Road Project

Predicted Maximum 24-hour TSP Concentrations (μg/m³) for the Road Operation Scenario

Rescan™





Predicted Average Runtime TSP Concentration (µg/m³)

All-weather Road

Notes:
Assumed background concentration: 7.5 µg/m³
Maximum concentration: 42 µg/m³
Nunavut Ambient Air Quality Guideline: 60 µg/m³

1:125,000

0 2.5 5

Kilometres

Projection: UTM13, NAD83

FIGURE 5.2-9

The Bathurst Inlet Port and Road Project

Predicted Average Runtime TSP Concentrations (ug/m³) for the Road Operation Scenario

Rescan™

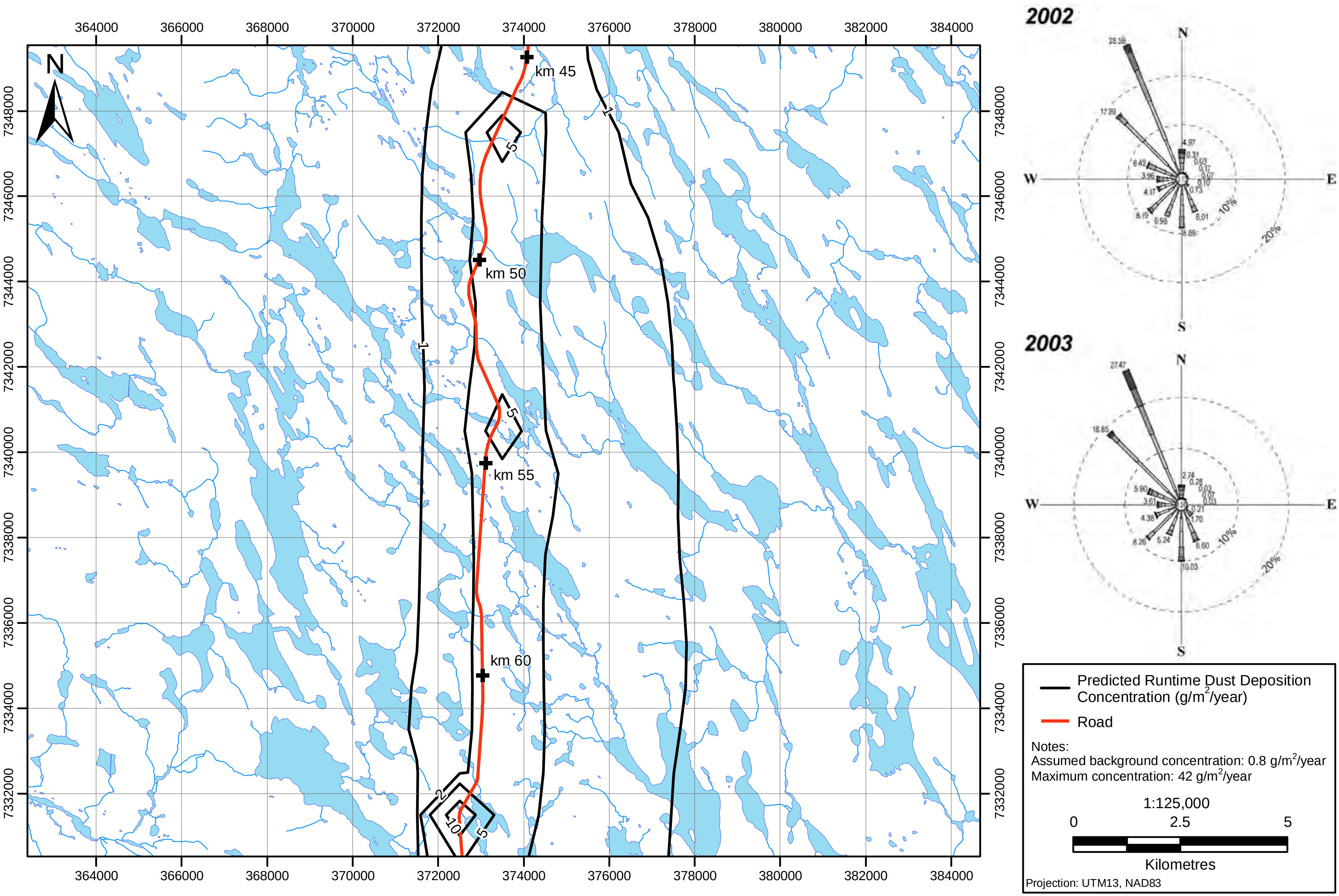


FIGURE 5.2-10

Predicted Runtime Dust Deposition Concentration (g/m^2/year) for the Road Operation Scenario

the Bathurst Inlet Port and Road Project

Rescan

Table 5.2-1
Predicted SO_2 Concentrations for the Port Construction and Operation Scenarios

Air Contaminant	Averaging Time	Unit	Assumed Background Concentration	Port Construction	Port Operation
SO_2	1-hour	μg/m^3	7.0	19	12
	24-hour	μg/m^3	7.0	10	8.6
	Runtime	μg/m^3	7.0	7.3	7.1

The modelling results show that maximum 1-hour and 24-hour NO_2 concentrations could potentially exceed the maximum acceptable NAAQOs for NO_2, but would be of the same order as the maximum tolerable NAAQOs. Exceedances of the maximum acceptable NAAQOs for maximum 1-hour and 24-hour NO2 concentrations occurred within 1.5 km and 1 km of the emissions sources, respectively.

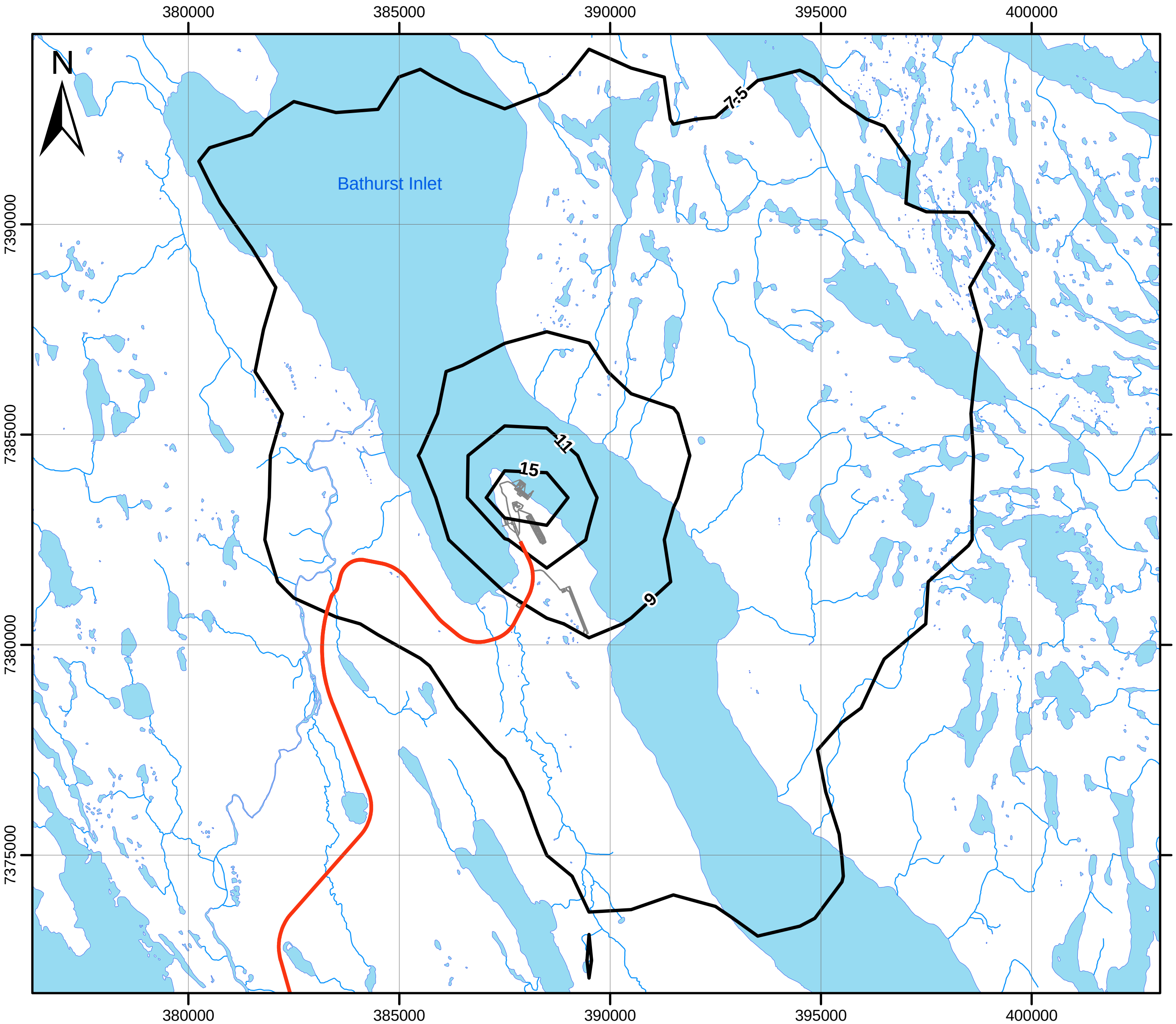
Although the runtime NO_2 concentrations for the two scenarios approach the maximum acceptable NAAQO for annual average NO_2 concentrations the annual average NO_2 concentrations are not expected to exceed the NAAQO. Predicted annual average NO_2 concentration can be estimated from the runtime average concentrations by computing a weighed average of expected concentrations including the eight months of the year when project activities are minimal. Thus, average annual NO_2 concentrations can be expected to be approximately three times lower than predicted runtime concentrations.

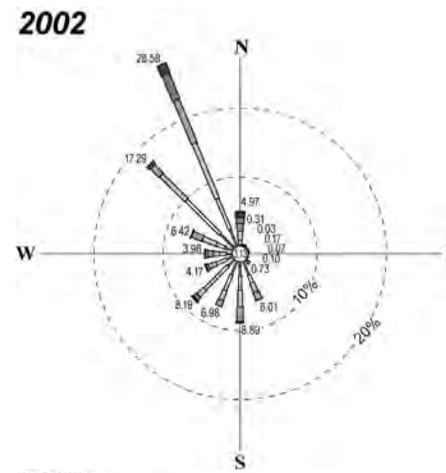
Predicted 1-hour ambient carbon monoxide concentrations for the port construction and operation scenarios were 2990 μg/m^3 and 1350 μg/m^3, respectively, which are well below the NAAQO for CO of 15,000 μg/m^3. 8-hour average concentrations for the two scenarios were 1578 μg/m^3 and 777 μg/m^3, respectively, which are also well below the NAAQO of 6,000 μg/m^3.

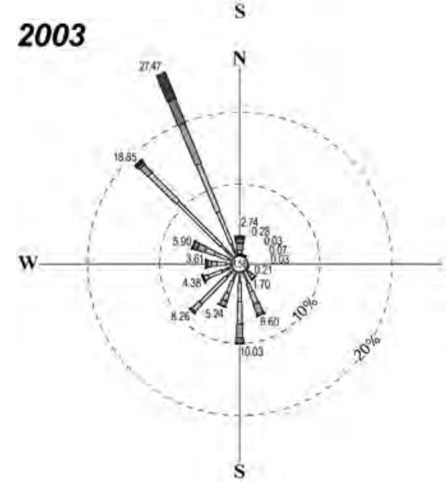
Table 5.2-2
Predicted NO_2 Concentrations for the Port Construction and Operation Scenarios

Air Contaminant	Averaging Time	Unit	Assumed Background Concentration	Port Construction	Port Operation
NO_2	1-hour	μg/m^3	9.4	889[a]	374[a]
	24-hour	μg/m^3	9.4	310[a]	162[a]
	Runtime	μg/m^3	9.4	92[a]	78[a]

[a]Ozone limiting method was used.







Predicted Maximum 1-hour SO_2 Concentration (µg/m³)

Road

Port Infrastructure

Notes:

Assumed background concentration: 7 µg/m³

Maximum concentration: 19 µg/m³

Nunavut Ambient Air Quality Guideline: 450 µg/m³

1:150,000

0 2.5 5

Kilometres

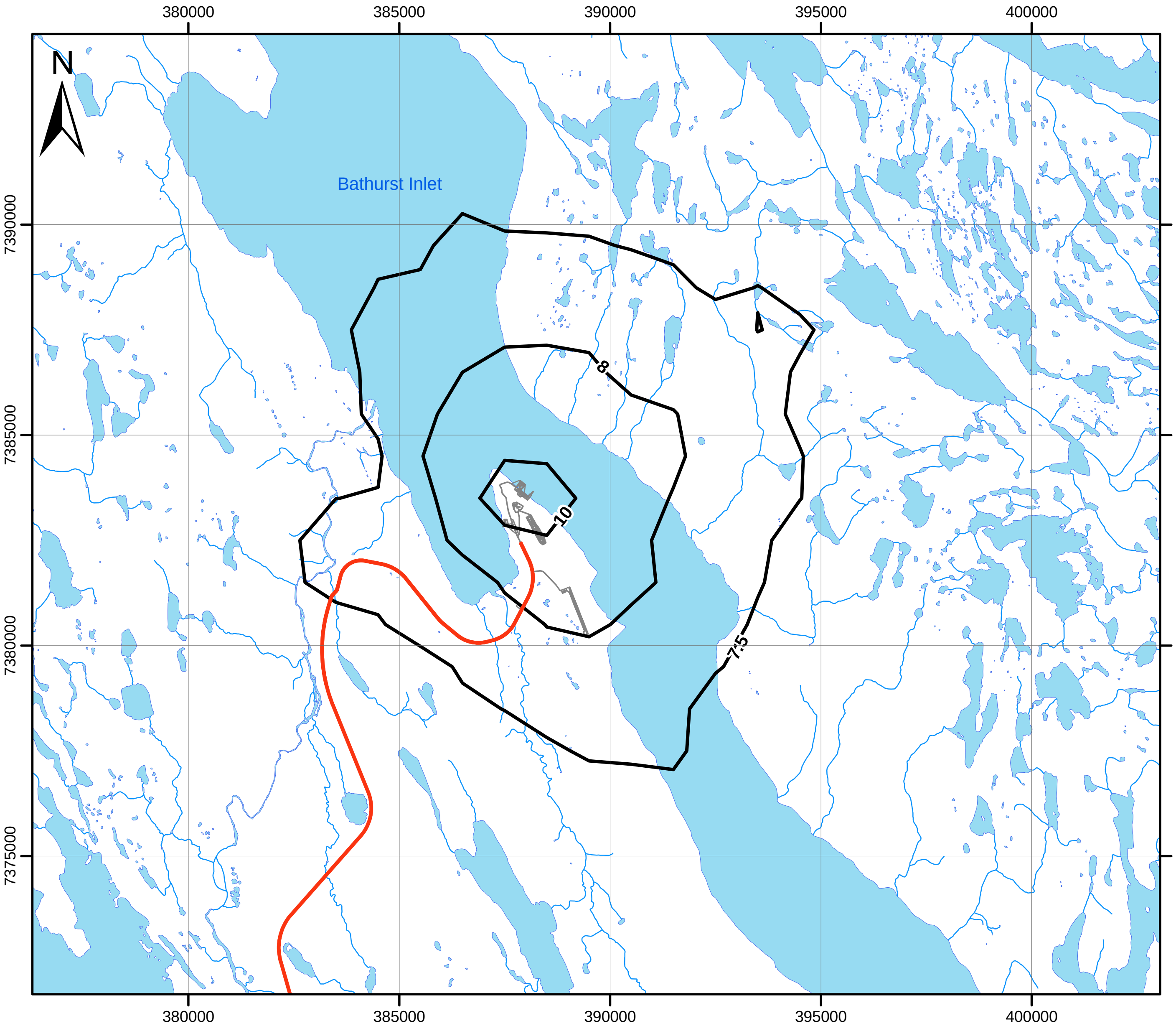
Projection: UTM13, NAD83

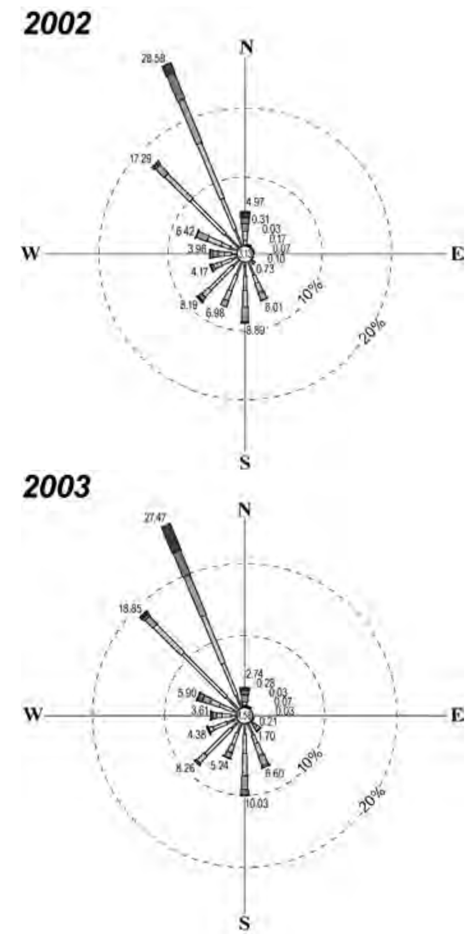
FIGURE 5.2-11

Predicted Maximum 1-hour SO_2 Concentrations (µg/m³) for the Port Construction Scenario

the Bathurst Inlet Port and Road Project

Rescan™





Predicted Maximum 1-hour SO_2 Concentration ($\mu g/m^3$)

Road

Port Infrastructure

Notes:
Assumed background concentration: 7 $\mu g/m^3$ (5 ppb)
Maximum concentration: 12 $\mu g/m^3$
Nunavut Ambient Air Quality Guideline: 450 $\mu g/m^3$

1:150,000

0 2.5 5

Kilometres

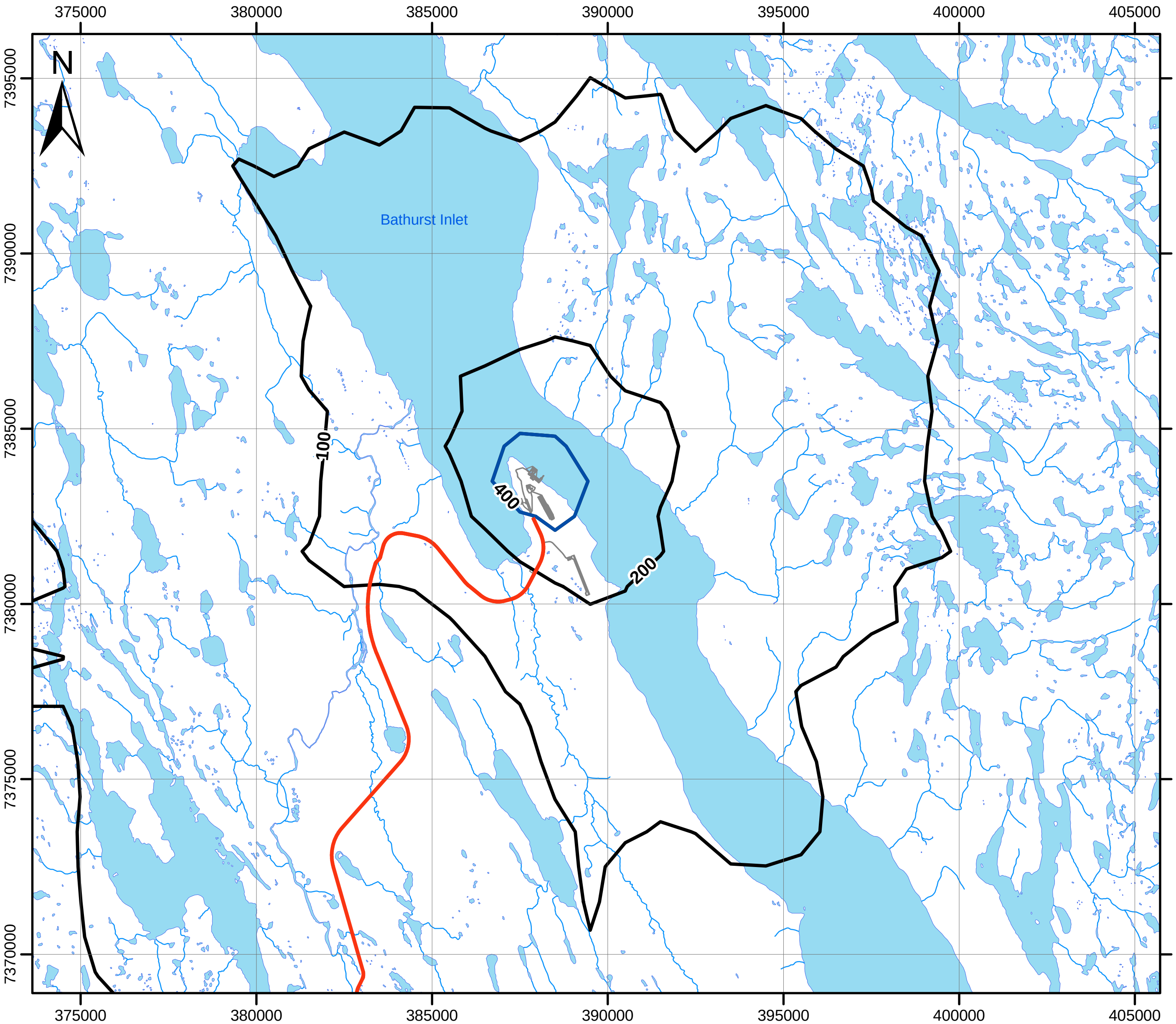
Projection: UTM13, NAD83

FIGURE 5.2-12

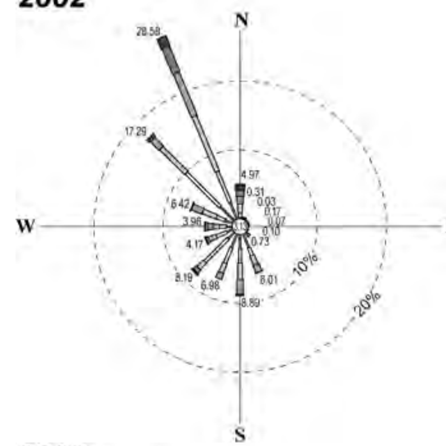
the Bathurst Inlet Port and Road Project

Predicted Maximum 1-hour SO_2 Concentrations ($\mu g/m^3$) for the Port Operation Scenario

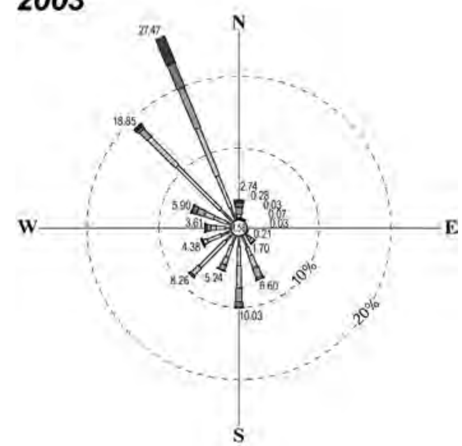
Rescan



2002



2003



Predicted Maximum 1-hour NO_2 Concentration ($\mu g/m^3$)
Maximum Acceptable NAAQO
Road
Port Infrastructure

Notes:
Ozone Limiting Method was applied
Assumed background concentration: 9.4 $\mu g/m^3$ (5 ppb)
Maximum concentration: 889 $\mu g/m^3$
NAAQO: 400 $\mu g/m^3$ (maximum acceptable),
1,000 (Maximum tolerable)

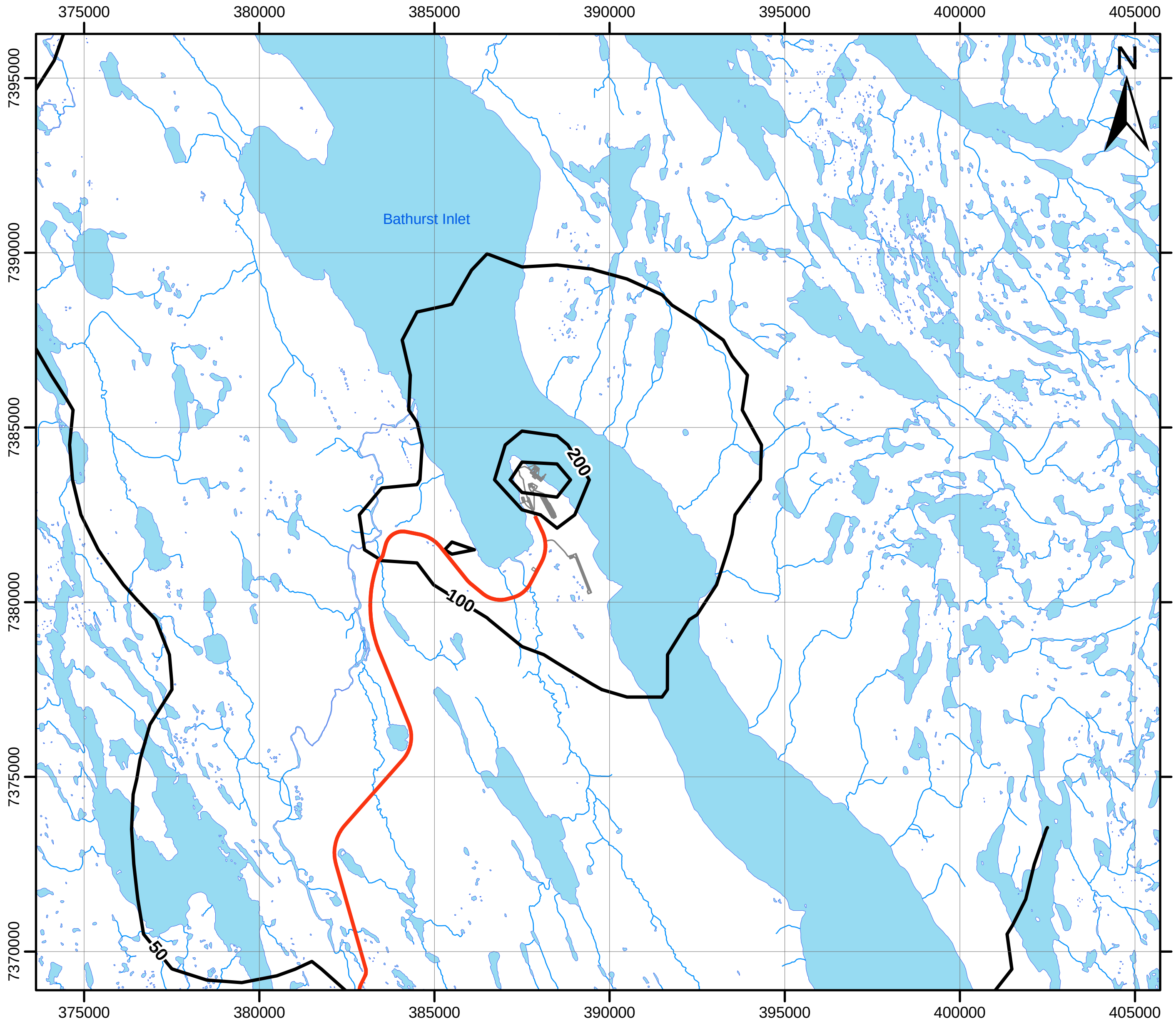
1:180,000
0 2.5 5
Kilometres
Projection: UTM13, NAD83

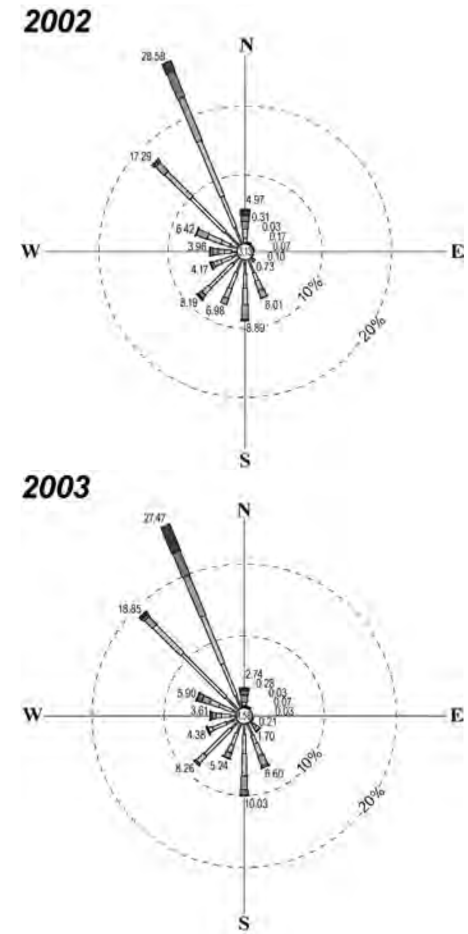
FIGURE 5.2-13

the Bathurst Inlet Port and Road Project

Predicted Maximum 1-hour NO_2 Concentrations ($\mu g/m^3$) for the Port Construction Scenario

Rescan™





Predicted Maximum 1-hour NO_2 Concentration (µg/m³)
Road
Port Infrastructure

Notes:
Ozone Limiting Method was applied
Assumed background concentration: 9.4 µg/m³(5 ppb)
Maximum concentration: 374 µg/m³
NAAQO: 400 µg/m³ (maximum acceptable)

1:180,000
0 2.5 5
Kilometres
Projection: UTM13, NAD83

FIGURE 5.2-14

the Bathurst Inlet Port and Road Project

Predicted Maximum 1-hour NO_2 Concentrations (µg/m³) for the Port Operation Scenario

Rescan™

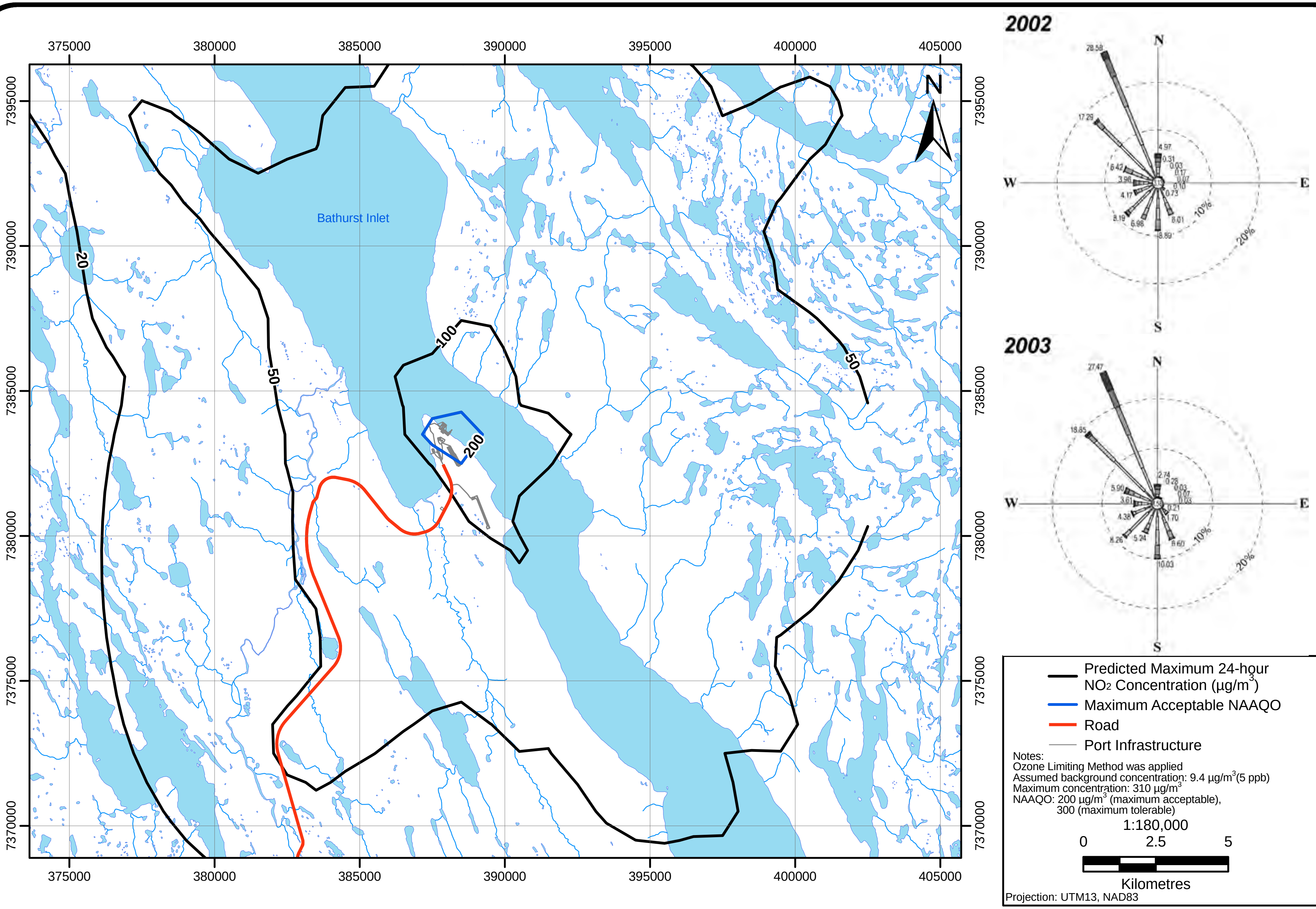
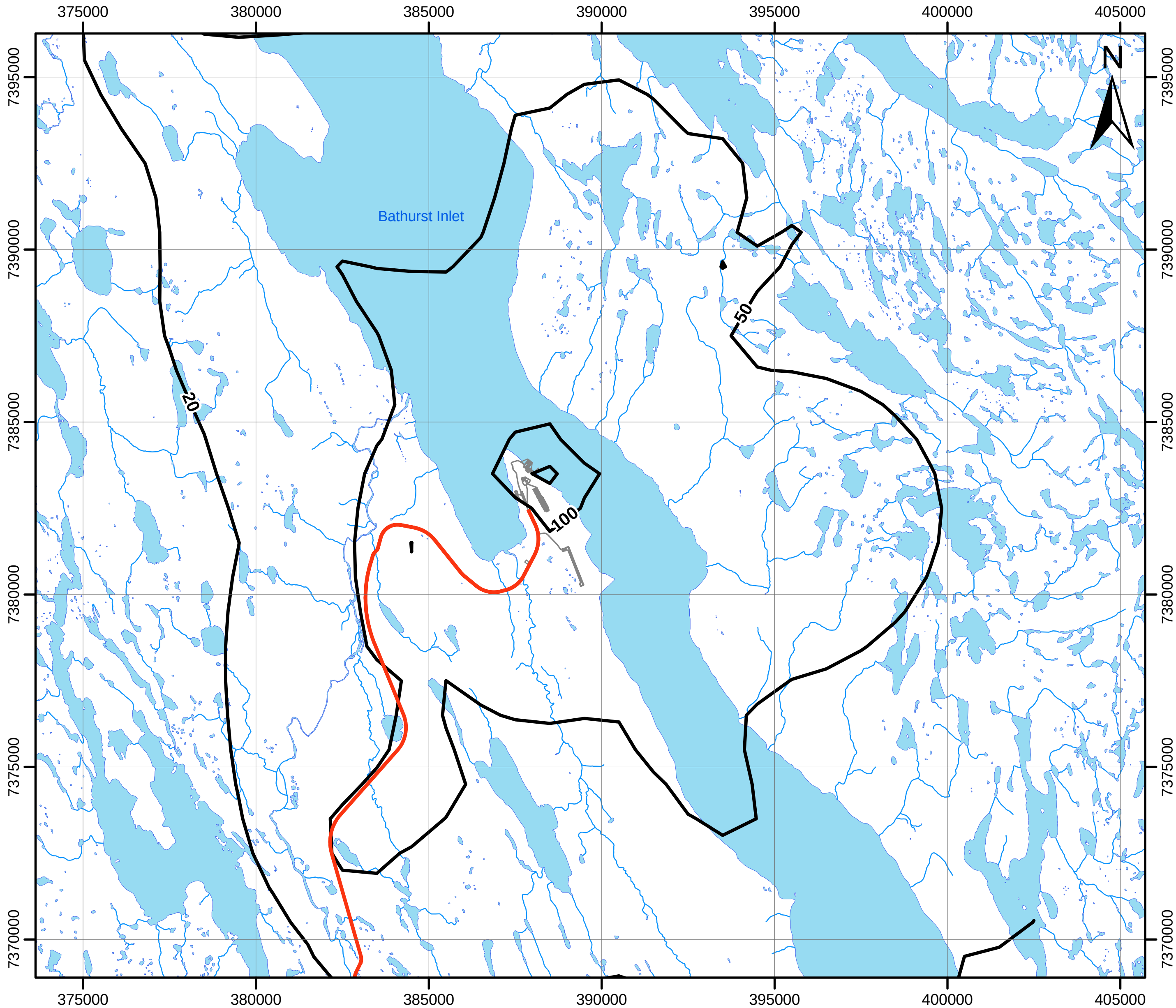


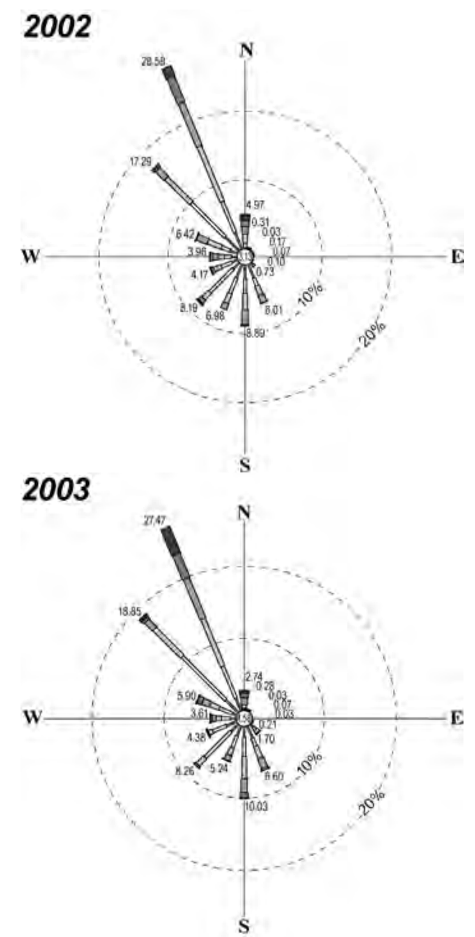
FIGURE 5.2-15

the BATHURST INLET PORT AND ROAD PROJECT

Predicted Maximum 24-hour NO_2 Concentrations ($\mu g/m^3$) for the Port Construction Scenario

Rescan™





— Predicted Maximum 24-hour NO_2 Concentration (µg/m^3)
— Road
— Port Infrastructure

Notes:
Ozone Limiting Method was applied
Assumed background concentration: 9.4 µg/m^3(5 ppb)
Maximum concentration: 162 µg/m^3
NAAQO: 200 µg/m^3 (maximum acceptable)

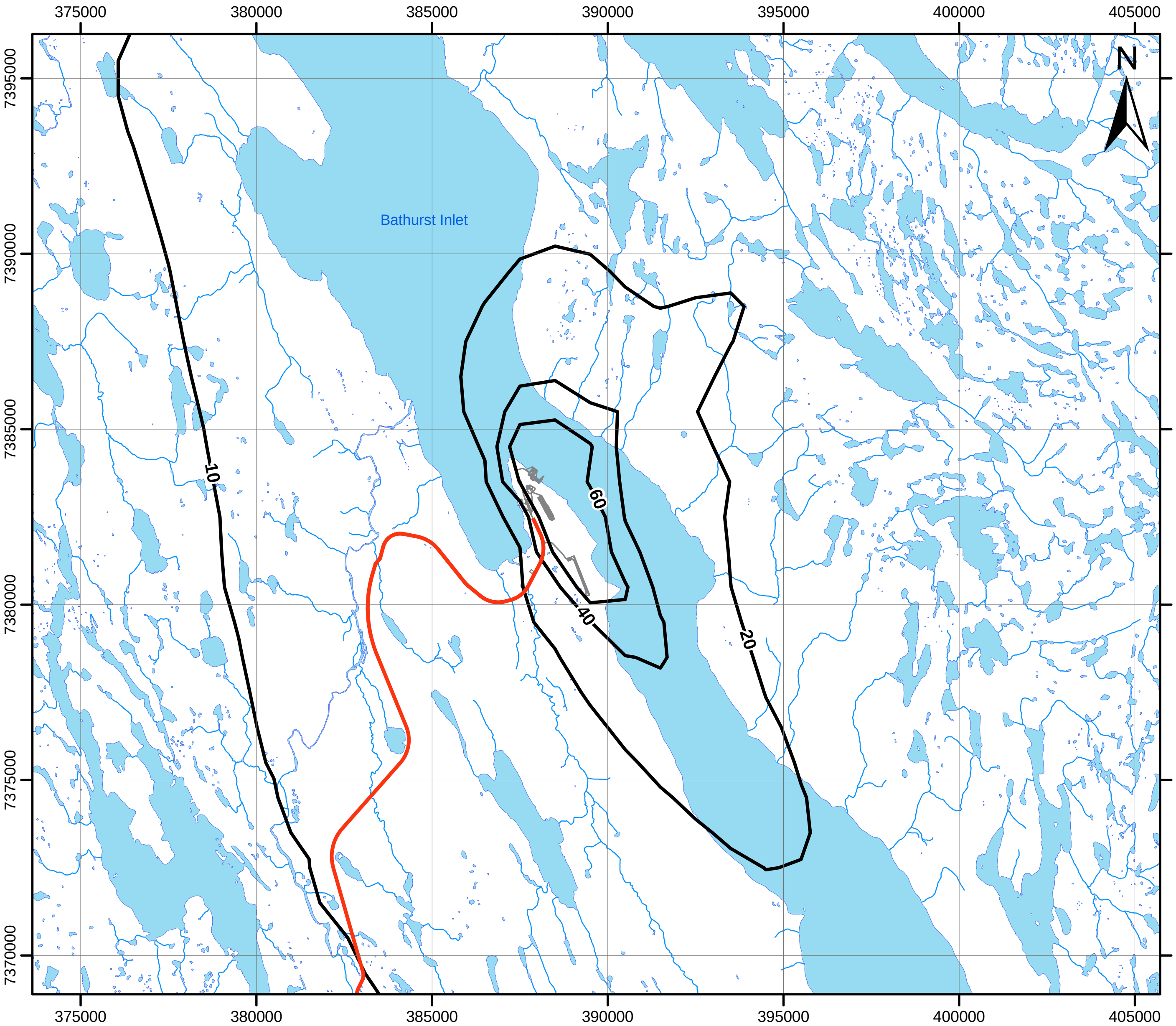
1:180,000
0 2.5 5
Kilometres
Projection: UTM13, NAD83

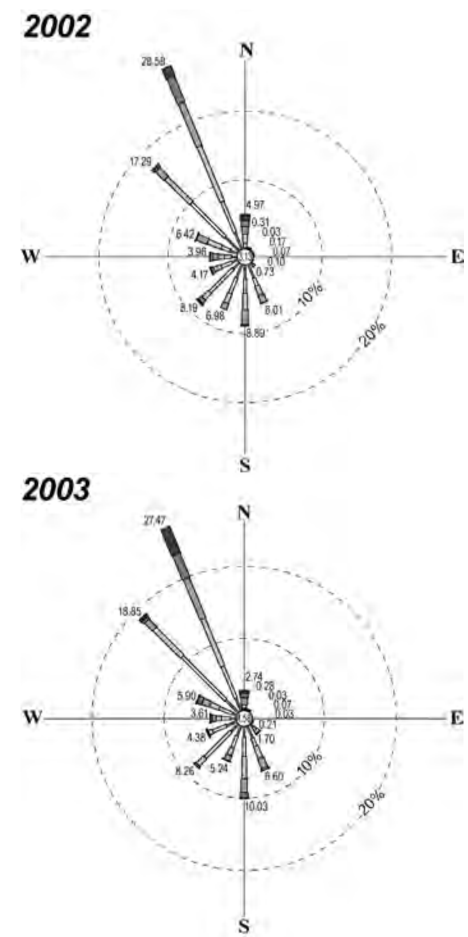
FIGURE 5.2-16

the Bathurst Inlet Port and Road Project

Predicted Maximum 24-hour NO_2 Concentrations (µg/m^3) for the Port Operation Scenario

Rescan™





Predicted Average Runtime NO2 Concentration (µg/m3)

Road

Port Infrastructure

Notes:
Ozone Limiting Method was applied
Assumed background concentration: 9.4 µg/m^3(5 ppb)
Maximum concentration: 92 µg/m^3
NAAQO (annual average): 60 µg/m^3 (maximum desirable), 300 (maximum acceptable)

1:180,000

0 2.5 5

Kilometres

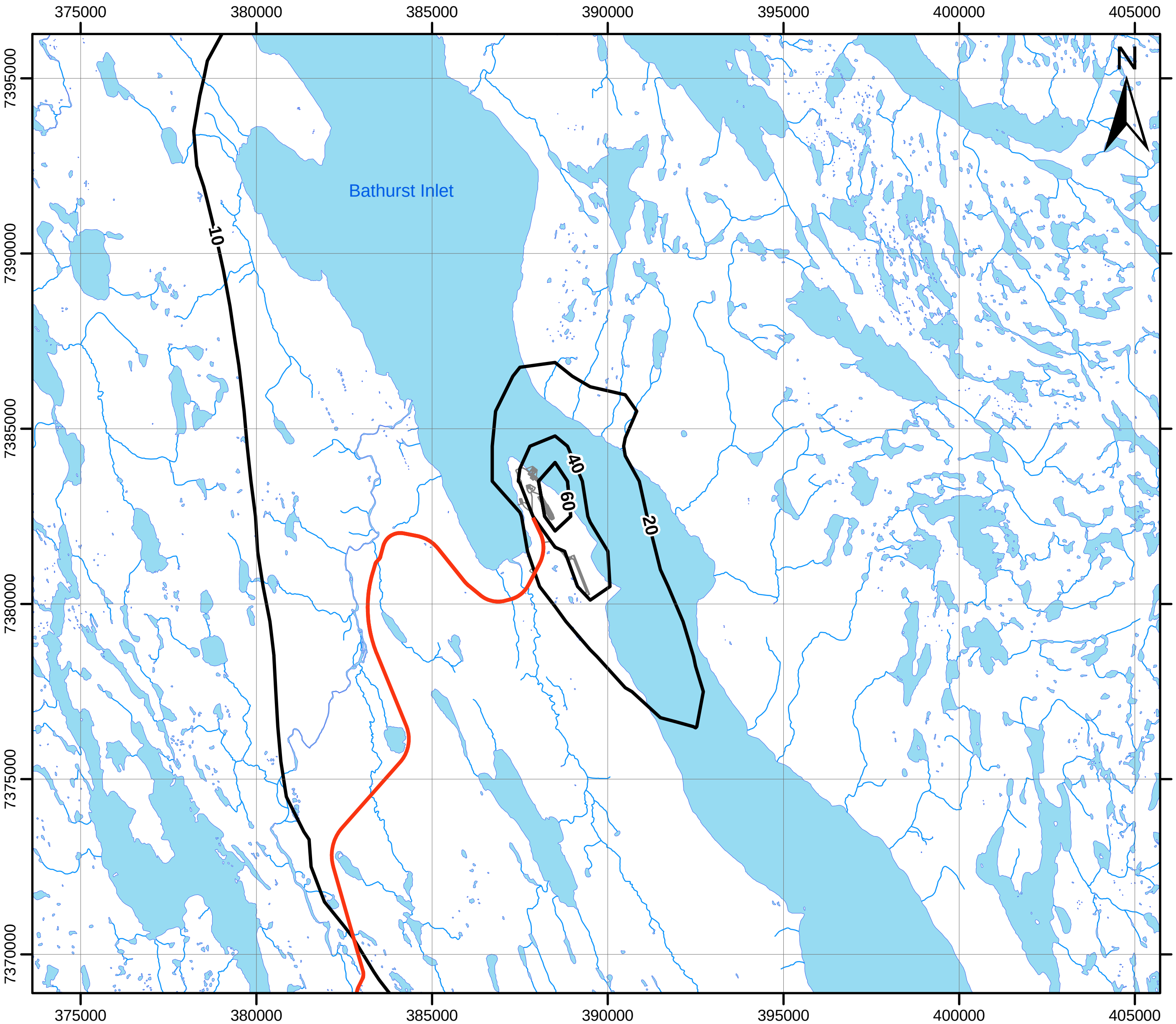
Projection: UTM13, NAD83

FIGURE 5.2-17

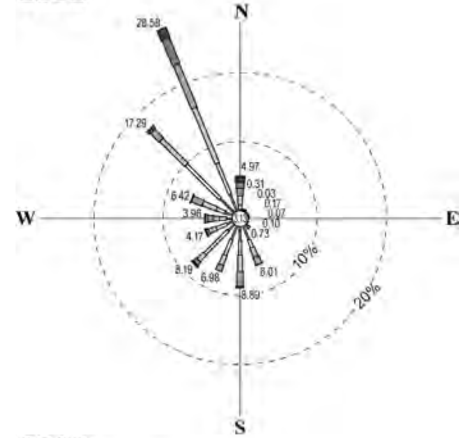
Predicted Average Runtime NO_2 Concentrations (µg/m^3) for the Port Construction Scenario

the Bathurst Inlet Port and Road Project

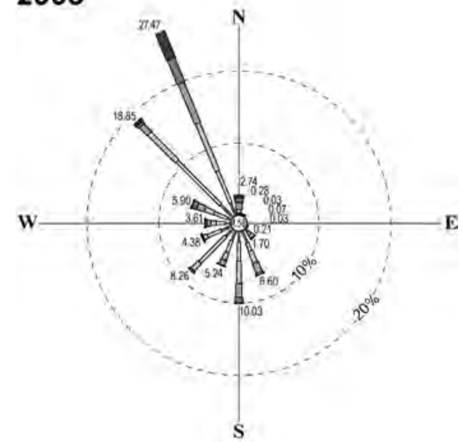
Rescan™



2002



2003



Predicted Average Runtime NO_2 Concentration (µg/m^3)

Road

Port Infrastructure

Notes:
Ozone Limiting Method was applied
Assumed background concentration: 9.4 µg/m^3(5 ppb)
Maximum concentration: 78 µg/m^3
NAAQO (annual average): 60 µg/m^3 (maximum desirable), 100 (maximum acceptable)

1:180,000

0 2.5 5

Kilometres

Projection: UTM13, NAD83

FIGURE 5.2-18

the Bathurst Inlet Port and Road Project

Predicted Average Runtime NO_2 Concentrations (µg/m^3) for the Port Operation Scenario

Rescan™

6. CONCLUSIONS

6. Conclusions

The air quality modelling study for the Project included an evaluation of potential air quality effects associated with operation of the road from Bathurst Inlet to Contwoyto as well as construction and operation of the proposed port facility at Bathurst Inlet. Table 6-1 summarizes the results of the scenario runs.

Table 6-1
Predicted Maximum Air Contaminant Concentrations Resulting from BIPR Project Activities

Air Contaminant	Averaging Time	Units	Assumed Background Concentration	Road Operation	Port Construction	Port Operation
SO_2	1-hour	µg/m^3	7.0	7.6	19	12
	24-hour	µg/m^3	7.0	7.2	10	8.6
	Runtime	µg/m^3	7.0	7.0	7.3	7.1
NO_2	1-hour	µg/m^3	9.4	320[a]	**889[b]**	374[b]
	24-hour	µg/m^3	9.4	46[a]	**310[b]**	162[b]
	Runtime	µg/m^3	9.4	16[a]	92[b]	78[b]
CO	1-hour	µg/m^3	100	220	2,990	1350
	8-hour	µg/m^3	100	160	1,578	777
TSP	24-hour	µg/m^3	7.5	**199**	-	-
	Runtime	µg/m^3	7.5	42	-	-
$PM_{2.5}$	24-hour	µg/m^3	5.0	24	-	-
Dustfall	Runtime	g/m^2	0.8	15	-	-

Notes:
Numbers in bold indicate potential exceedance of lowest applicable territorial or national ambient air quality standards or objectives.
[a]Ozone limiting method was not used.
[b]Ozone limiting method was used.

Maximum 1-hour, 24-hour and average runtime SO_2 concentrations are predicted to be well below Nunavut's ambient air quality standards. The low rates of SO_2 emissions and resulting ambient concentrations can be attributed to the use of ultra low sulphur diesel fuel for equipment used at the Project.

Predicted maximum 1-hour and 24-hour NO_2 concentrations for the port construction scenario exceeded the maximum acceptable NAAQOs, but were of the same order as the maximum tolerable NAAQOs. Annual average NO_2 concentrations for both construction and operation of the port facility are not expected to exceed the NAAQO for annual average NO_2. Also, predicted NO_2 concentrations resulting from project activities during the operation of the port facility did not exceed the NAAQOs for NO_2.

Predicted maximum 1-hour and 8-hour carbon monoxide concentrations were well below the corresponding NAAQOs.

Maximum TSP and $PM_{2.5}$ concentrations and dustfall concentrations are difficult to predict because of the inherent uncertainties associated with the emissions estimates. The modelling results suggest that there may be localized exceedances of the Nunavut's standard for ambient 24-hour or annual average TSP, or the Canada Wide Standard for 24-hour $PM_{2.5}$ in areas near the road. However, such exceedances are likely to be highly localized, near the centreline of the unpaved road.

A potential measurable zone of influence for dustfall cannot be determined through a modelling study because of the uncertainties associated with fugitive dust emissions estimates. Implementation of a monitoring program along with a comprehensive adaptive management plan would ensure that fugitive dust emissions remain at an acceptable level.

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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APPENDIX 1
EMISSIONS FACTORS FOR THE BIPR PROJECT

Appendix 1
Emissions Factors for the BIPR Project

Table 1 - Construction Equipment Based at the Bathurst Inlet Port Site

Equipment	hp	Number of Vehicles/Vessels	Emission Factor Source	SCC Number	Estimated Emissions per Unit: Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Mobile Crane - 150 T	350	1	(US EPA, 2004)	2270002045	0.00048	0.24	0.082	52	0.014
Mobile Crane - 50 T	200	1	(US EPA, 2004)	2270002045	0.00027	0.12	0.042	30	0.0081
Fuel Tanker	450	1	(US EPA, 2004)	2270002051	0.00060	0.33	0.16	66	0.027
Service Truck	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.091	42	0.017
15 Passenger Van	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.091	42	0.017
38 Passenger Bus Passenger Van	385	2	(US EPA, 2004)	2270002051	0.00051	0.28	0.14	57	0.023
Drill	170	1	(US EPA, 2004)	2270002033	0.00023	0.12	0.035	25	0.0069
Air Trac Compressor	125	4	(US EPA, 2004)	2270002033	0.00017	0.059	0.026	18	0.0051
Tank Drill	260	1	(US EPA, 2004)	2270002033	0.00036	0.18	0.054	38	0.011
Dozer - D10	580	2	(US EPA, 2004)	2270002069	0.00078	0.42	0.21	86	0.034
Dozer - D9	410	2	(US EPA, 2004)	2270002069	0.00054	0.3	0.15	60	0.024
Dozer - D8	310	1	(Manufacturer's Data)	-	0.00042	0.24	0.16	46	0.0086
Front End Loader - CAT 988H	501	3	(Manufacturer's Data)	-	0.00066	0.35	0.12	74	0.02
Front End Loader - CAT 992G	800	2	(US EPA, 2004)	2270002066	0.0013	1.1	0.44	120	0.099
Grader - CAT 14 H	220	1	(US EPA, 2004)	2270002048	0.00030	0.27	0.07	32	0.0089
Grader - CAT 16 H	265	1	(US EPA, 2004)	2270002048	0.00036	0.33	0.084	39	0.016
Off Highway Trucks CAT 777	938	7	(US EPA, 2004)	2270002051	0.0013	1.1	0.30	140	0.049
Off Highway Trucks CAT 769	485	2	(US EPA, 2004)	2270002051	0.00066	0.35	0.17	72	0.029
100 tonne Float and Tractor	300	1	(US EPA, 2004)	2270002051	0.00039	0.22	0.095	44	0.018
Mobile Crushing and Screening Plant	300	1	(US EPA, 2004)	2270002054	0.00039	0.21	0.062	44	0.012
Cement + Portable Plant	200	1	(US EPA, 2004)	2270002054	0.00027	0.14	0.042	30	0.0081
Agitator Trucks	475	2	(US EPA, 2004)	2270002051	0.00063	0.34	0.17	70	0.028
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)	-	0.00045	0.6	0.077	51	0.0058

All engines were assumed to be Tier 3 engines.

Diesel fuel was assumed to contain 15 ppm of sulphur.

SO_2 emissions calculated from: SO_2 (g/hr) = diesel consumption (kg/hr)*0.01*0.05%S*2 (g SO_2/gS).

CO_2 emissions calculated as: CO_2 (g/hr) = diesel consumption (kg/hr)*0.87 (C content of diesel)*(44/12) (g CO_2/g C).

Table 2 - Maintenance Equipment Based at the Bathurst Inlet Port Site

Equipment	hp	Number of Vehicles/Vessels	Emission Factor Source	SCC Number	Estimated Emissions per Unit: Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Fuel Truck	300	2	(US EPA, 2004)	2270002051	0.00039	0.22	0.095	44	0.018
Dozer - D8	310	1	(Manufacturer's Data)	-	0.00042	0.24	0.16	46	0.0086
Boat and Outboard Engine	15	1	(US EPA, 2004)	-	0.00002	0.01	0.009	2.2	0.0011
Front End Loader - CAT 988H	501	3	(Manufacturer's Data)	-	0.00066	0.35	0.12	74	0.02
Container Handler - 52,000 lb Fork Lift	360	1	(US EPA, 2004)	2270003020	0.00048	0.26	0.13	53	0.021
Fork Lift (5 tonne)	211	1	(US EPA, 2004)	2270003020	0.00029	0.15	0.067	31	0.013
HIAB Flat Bed Utility Truck, 2 tonne	245	1	(US EPA, 2004)	2270002051	0.00033	0.18	0.088	36	0.015
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)	-	0.00045	0.6	0.077	51	0.0058
Sand Truck/Snow Plow	365	2	(US EPA, 2004)	2270002051	0.00048	0.26	0.13	54	0.022
Grader - 14 G	220	2	(Manufacturer's Data)	-	0.00030	0.26	0.049	32	0.0043
Tandem Dump Truck - 20 tonne	360	2	(US EPA, 2004)	2270002051	0.00048	0.26	0.13	53	0.021
Water Truck	305	2	(US EPA, 2004)	2270002051	0.00042	0.22	0.11	45	0.018
Mechanic's Service Truck	285	1	(US EPA, 2004)	2270002051	0.00039	0.21	0.1	42	0.017
Low-Bed Tractor and Trailer	350	1	(US EPA, 2004)	2270002051	0.00048	0.25	0.13	52	0.021
Crew Cab Truck	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.1	42	0.017
Industrial Ambulance Vehicle	300	1	(US EPA, 2004)	2270002051	0.00039	0.22	0.11	44	0.018
Fire Snuffer Truck	300	1	(US EPA, 2004)	2270002051	0.00039	0.22	0.11	44	0.018
12 Passenger Van	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.1	42	0.017

All engines were assumed to be Tier 3 engines.

(continued)

Diesel fuel was assumed to contain 15 ppm of sulphur.

SO_2 emissions calculated from: SO_2 (g/hr) = diesel consumption (kg/hr)*0.01*0.05%S*2 (g SO_2/gS).

CO_2 emissions calculated as: CO_2 (g/hr) = diesel consumption (kg/hr)*0.87 (C content of diesel)*(44/12) (g CO_2/g C).

Appendix 1
Emissions Factors for the BIPR Project (continued)

Table 3 - Construction Equipment Based at the Contwoyto Camp

Equipment	hp	Number of Vehicles/Vessels	Emission Factor Source	SCC Number	Estimated Emissions per Unit: Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Mobile Crane - 50 T	200	1	(US EPA, 2004)	2270002045	0.00027	0.14	0.042	30	0.0081
Fuel Tanker	450	1	(US EPA, 2004)	2270002051	0.00060	0.33	0.16	66	0.027
Fuel Truck	300	2	(US EPA, 2004)	2270002051	0.00039	0.22	0.095	44	0.018
15 Passenger Van	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.091	42	0.017
38 Passenger Bus Passenger Van	385	1	(US EPA, 2004)	2270002051	0.00051	0.28	0.14	57	0.023
Air Trac Compressor	125	4	(US EPA, 2004)	2270002033	0.00017	0.14	0.026	18	0.0051
Tank Drill	260	1	(US EPA, 2004)	2270002033	0.00036	0.18	0.054	38	0.011
Dozer - D10	580	2	(US EPA, 2004)	2270002069	0.00078	0.42	0.21	86	0.034
Dozer - D9	410	2	(US EPA, 2004)	2270002069	0.00054	0.3	0.15	60	0.024
Dozer - D8	310	2	(Manufacturer's Data)	-	0.00042	0.24	0.16	46	0.0086
Front End Loader - CAT 988H	501	1	(Manufacturer's Data)	-	0.00066	0.35	0.12	74	0.02
Front End Loader - CAT 992G	800	2	(US EPA, 2004)	2270002066	0.00126	1.1	0.44	120	0.099
Excavator - CAT 345 BL	345	1	(Manufacturer's Data)	-	0.00045	0.6	0.077	51	0.0058
Grader - CAT 16 H	265	1	(US EPA, 2004)	2270002048	0.00036	0.33	0.084	39	0.016
Off Highway Trucks CAT 777	938	7	(US EPA, 2004)	2270002051	0.00126	1.1	0.3	140	0.049
Off Highway Trucks CAT 769	485	2	(US EPA, 2004)	2270002051	0.00066	0.35	0.17	72	0.029
100 tonne Float and Tractor	300	1	(US EPA, 2004)	2270002051	0.00039	0.22	0.095	44	0.018
Mobile Crushing and Screening Plant	300	1	(US EPA, 2004)	2270002054	0.00039	0.21	0.062	44	0.012
Cement + Portable Plant	200	1	(US EPA, 2004)	2270002054	0.00027	0.14	0.042	30	0.0081
Agitator Trucks	475	2	(US EPA, 2004)	2270002051	0.00063	0.34	0.17	70	0.028

All engines were assumed to be Tier 3 engines.
Diesel fuel was assumed to contain 15 ppm of sulphur.
SO_2 emissions calculated from: SO_2 (g/hr) = diesel consumption (kg/hr)*0.01*0.05%S*2 (g SO_2/gS).
CO_2 emissions calculated as: CO_2 (g/hr) = diesel consumption (kg/hr)*0.87 (C content of diesel)*(44/12) (g CO_2/g C).

Table 4 - Maintenance Equipment Based at the Contwoyto Camp

Equipment	hp	Number of Vehicles/Vessels	Emission Factor Source	SCC Number	Estimated Emissions per Unit: Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Service Truck	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.091	42	0.017
Grader - CAT 14 H	220	1	(US EPA, 2004)	2270002048	0.00030	0.27	0.07	32	0.0089
Dozer - D6 Wide Path	310	1	(Manufacturer's Data)	-	0.00042	0.24	0.16	46	0.0086
Water Truck	305	2	(US EPA, 2004)	2270002051	0.00042	0.22	0.11	45	0.018
Crew Cab Truck	285	2	(US EPA, 2004)	2270002051	0.00039	0.21	0.1	42	0.017
Boat and Outboard Engine	15	1	(US EPA, 2004)	-	0.000020	0.01	0.009	2.2	0.0011
Ferry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

All engines were assumed to be Tier 3 engines.
Diesel fuel was assumed to contain 15 ppm of sulphur.
SO_2 emissions calculated from: SO_2 (g/hr) = diesel consumption (kg/hr)*0.01*0.05%S*2 (g SO_2/gS).
CO_2 emissions calculated as: CO_2 (g/hr) = diesel consumption (kg/hr)*0.87 (C content of diesel)*(44/12) (g CO_2/g C).

Table 5 - Primary Truck Fleet for BIPR Project

Truck Type	hp	Number of Trucks - Possible Users	Number of Trucks - Potential Users	Emission Factor Source	SCC Number	Estimated Emissions per Unit: Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)
90 tonne B-train (Bulk Cargo)	475	0	70	(US EPA, 2004)	2270002051	0.00063	0.34	0.17	70
45 tonne B-train (General Cargo)	410	15	30	(US EPA, 2004)	2270002051	0.00054	0.3	0.15	60
35 tonne B-train (Fuel)	410	60	105	(US EPA, 2004)	2270002051	0.00054	0.3	0.15	60

All engines were assumed to be Tier 3 engines.
Diesel fuel was assumed to contain 15 ppm of sulphur.
SO_2 emissions calculated from: SO_2 (g/hr) = diesel consumption (kg/hr)*0.01*0.05%S*2 (g SO_2/gS).
CO_2 emissions calculated as: CO_2 (g/hr) = diesel consumption (kg/hr)*0.87 (C content of diesel)*(44/12) (g CO_2/g C).

Table 6 - Airstrip Emissions

Source	Emission Factor Source	Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Portable lighting plant	(US EPA, 1995, Section 3.3)	0.000095	0.048	0.0034	1.8	0.0033
Twin Otter - Approach	(US EPA, 1999)	0.00006	0.039	0.014	0.32	n/a
Twin Otter - Taxi-in/Taxi-out	(US EPA, 1999)	0.00031	0.098	0.34	1.5	n/a
Twin Otter - Take-off	(US EPA, 1999)	0.00019	0.40	0.0046	1.2	n/a

Note: Portable lighting plant from US EPA (1995, Section 3.3).

(continued)

Appendix 1
Emissions Factors for the BIPR Project (completed)

Table 7 - Stationary Emissions

Equipment	Emission Factor Source	SCC Number	Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
4 CAT 3412 Gensets	(Manufacturer's Data)	n/a	0.0070	15	4.5	0.75	0.24
Incinerator	(US EPA, 1995, Section 2.1)	n/a	0.0013	0.0014	0.00017	0.73	0.0065

Genset emissions based on manufacturers data.

238.7 diesel per hour at 70% load (890 kW).

Table 8 - Ship Emissions

			Estimated Emissions per Ship				
	hp	Emission Factor Source	Exhaust SO_2 (g/s)	Exhaust NO_x (g/s)	Exhaust CO (g/s)	Exhaust CO_2 (g/s)	Exhaust $PM_{2.5}$ (g/s)
Marine Vessel Emissions							
Underway							
50,000 DWT Cargo Vessel (Main Engine at 75% Load)	11000	(Transport Canada, 2006)	18	32	0.83	1040	2.50
50,000 DWT Cargo Vessel (Auxiliary Engine at 13% Load)	520	(Transport Canada, 2006)	0.17	0.21	0.013	10	0.014
Manoeuvering							
50,000 DWT Cargo Vessel (Main Engine at 8% Load)	11000	(Transport Canada, 2006)	1.9	3.4	0.089	111	0.27
50,000 DWT Cargo Vessel (Auxiliary Engine at 45% Load)	520	(Transport Canada, 2006)	0.60	0.71	0.044	35	0.048
Dockside							
50,000 DWT Cargo Vessel (Auxiliary Engine at 67% Load)	520	(Transport Canada, 2006)	0.89	1.1	0.065	52	0.072

Notes: Ships were assumed to use heavy fuel oil with 2.7% sulphur.

Table 9 - Estimated Emissions from ANFO Detonation

Species	Emission Factor[A] g/kg ANFO
CO	34
NOx	8.0
SO_2	1.0

[A] US EPA (1995, Section 13.3).

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APPENDIX 2
CALPUFF INPUT FILE

Rescan™

Appendix 2 – CALPUFF Input File

```
PARAMETER SETTING USED FOR THE BATHURST INLET PORT AND ROAD PROJECT
AIR QUALITY MODELLING STUDY.

-------------------------------------------------------------
INPUT GROUPS 2, 8, 9 AND 12 OF THE CALPUFF MODEL CONTROL FILE
-------------------------------------------------------------


-------------------------------------------------------------------------------
INPUT GROUP: 2 -- Technical options
-------------------------------------------------------------------------------

! MGAUSS    = 1           !  Control variable determining the vertical distr...
! MCTADJ    = 3           !  Terrain adjustment method
! MCTSG     = 0           !  CALPUFF subgrid scale complex terrain module (C...
! MSLUG     = 0           !  Near-field puffs are modeled as elongated 'slugs'
! MTRANS    = 1           !  Transitional plume rise modeled
! MTIP      = 1           !  Stack tip downwash modeled
! MBDW      = 2           !  Building downwash method
! MSHEAR    = 0           !  Vertical wind shear above stack top modeled in ...
! MSPLIT    = 0           !  Puff splitting allowed
! MCHEM     = 0           !  Chemical mechanism flag
! MAQCHEM   = 0           !  Aqueous phase transformation modeled
! MWET      = 0           !  Wet removal modeled
! MDRY      = 1           !  Dry deposition modeled
! MDISP     = 2           !  Method used to compute the horizontal and verti...
! MTURBVW   = 3           !  Sigma-v/sigma-theta, sigma-w measurements used
! MDISP2    = 3           !  Back-up method used to compute dispersion when ...
! MROUGH    = 0           !  PG ay and az adjusted for surface roughness
! MPARTL    = 1           !  Partial plume penetration of elevated inversion
! MTINV     = 0           !  Strength of temperature inversion provided in P...
! MPDF      = 1           !  Probability Distribution Function method used f...
! MSGTIBL   = 0           !  Subgrid scale TIBL module used for shoreline
! MBCON     = 0           !  Boundary conditions (concentration) modeled
! MFOG      = 0           !  Configure for FOG Model output
! MREG      = 0           !  Check options for regulatory values
! END !

-------------------------------------------------------------------------------
INPUT GROUP: 8 -- Size parameters for dry deposition of particles
-------------------------------------------------------------------------------

                 Geometric mass   Geometric std.
                 mean diameter    deviation
  Species        (microns)        (microns)
  ------------   ---------------  ---------------
! PM2A5       =              1,               2 !
! TSP         =             10,               4 !
! END !

-------------------------------------------------------------------------------
INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
-------------------------------------------------------------------------------

! RCUTR     = 30          !  Reference cuticle resistance
! RGR       = 10          !  Reference ground resistance
! REACTR    = 8           !  Reference pollutant reactivity
! NINT      = 9           !  Number of particle-size intervals
! IVEG      = 1           !  Vegetation state in unirrigated areas
! END !
```

```
--------------------------------------------------------------------------------
INPUT GROUP: 12 -- Misc. dispersion and computational parameters
--------------------------------------------------------------------------------

! SYTDEP    = 550          !  Sigma-y at which Heffter curve begins
! MHFTSZ    = 0            !  Use Heffter equation for sigma-z
! JSUP      = 5            !  Stability class above PBL
! CONK1     = 0.01         !  Vertical dispersion constant for stable conditions
! CONK2     = 0.1          !  Vertical dispersion constant for neutral/unstab...
! TBD       = 0.5          !  Factor for determining transition-point from Sc...
! IURB1     = 81           !  Beginning urban land use category
! IURB2     = 82           !  Ending urban land use category
! ILANDUIN  = 80           !  Land use category for modeling domain
! Z0IN      = 0.2          !  Roughness length for modeling domain
! XLAIIN    = 0            !  Leaf area index for modeling domain
! ELEVIN    = 345          !  Elevation above sea level
! XLATIN    = 66.23408     !  Latitude of station
! XLONIN    = 107.6632     !  Longitude of station
! ANEMHT    = 10           !  Anemometer height
! ISIGMAV   = 1            !  Form of lateral turbulence data in CTDM profile...
! IMIXCTDM  = 0            !  Choice of mixing heights
! XMXLEN    = 1            !  Maximum length of an emitted slug
! XSAMLEN   = 1            !  Maximum travel distance of a slug or puff
! MXNEW     = 99           !  Maximum number of puffs or slugs released
! MXSAM     = 99           !  Maximum number of sampling steps
! NCOUNT    = 2            !  Number of iterations used when computing the tr...
! SYMIN     = 1            !  Minimum sigma-y a new puff or slug
! SZMIN     = 1            !  Minimum sigma-z a new puff or slug
! SVMIN     = 0.50, 0.50, 0.50, 0.50, 0.50, 0.50 !  Minimum turbulence sigma-v
! SWMIN     = 0.20, 0.12, 0.08, 0.06, 0.03, 0.016 !  Minimum turbulence sigma-w
! CDIV      = 0, 0         !  Divergence criterion for dw/dz in met cell
! WSCALM    = 0.5          !  Minimum wind speed allowed for non-calm conditions
! XMAXZI    = 3000         !  Maximum mixing height
! XMINZI    = 50           !  Minimum mixing height
! SL2PF     = 10           !  Slug-to-puff transition criterion factor
! WSCAT     = 1.54, 3.09, 5.14, 8.23, 10.8 !  Upper bounds for first 5 wind ...
! PLX0      = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !  Wind speed profile power...
! PTG0      = 0.020, 0.035 !  Potential temperature gradient for stability c...
! PPC       = 0.5, 0.5, 0.5, 0.5, 0.35, 0.35 !  Default plume path coefficients
! NSPLIT    = 3            !  Number of puffs from split (vertical)
! ZISPLIT   = 100          !  Split allowed if last mix height > (vertical)
! ROLDMAX   = 0.25         !  Split allowed if mix height ratio < (vertical)
! IRESPLIT  = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0,
0, 0 !
! NSPLITH   = 5            !  Number of puffs from split (horizontal)
! SYSPLITH  = 1            !  Split allowed if sigma-y > (horizontal)
! SHSPLITH  = 2            !  Split allowed if puff elongation rate > (horizo...
! CNSPLITH  = 0.0000001    !  Split allowed if peak concentration > (horizontal)
! EPSSLUG   = 0.0001       !  Fractional convergence criterion for numerical ...
! EPSAREA   = 0.000001     !  Fractional convergence criterion for numerical ...
! DSRISE    = 1            !  Trajectory step length for numerical rise integ...
! END !

--------------------------------------------------------------------------------
```

Appendix B-5
Meteorology Baseline Study, 2001-2002

Author: **Rescan Environmental Services Ltd.**
Date: **January 2003**

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the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project

Nunavut, Canada

Meteorology Baseline Study, 2001 - 2002

Prepared by:

Rescan™ Environmental Services Ltd.
Vancouver, British Columbia

January 2003

EXECUTIVE SUMMARY

Executive Summary

Ambient air is a principal component of the natural ecosystem and of paramount importance for the health of humans, wildlife and vegetation. The meteorology baseline study began with the commissioning of an automated meteorological station near the proposed Port site at Bathurst Inlet in late August 2001. The purpose of the meteorology baseline study was to collect data required to support the Project design and the potential future environmental impact assessment (EIA). The EIA will review the potential environmental effects from the Project's air emissions and provide a basis for the effects analysis on valued ecosystem components (VECs), as appropriate.

This report presents the baseline meteorological data that was collected at the Bathurst Inlet automated station between August 22, 2001 and August 7, 2002. The Bathurst data is compared with data from regional meteorological stations operated by Environment Canada (Meteorological Services of Canada –MSC) at Lupin Airport, Kugluktuk (Coppermine) Airport, and Cambridge Bay Airport. The Bathurst data was also compared with data from an automated station at the Hope Bay Joint Venture, Boston Site and an historical station that operated near the Bathurst Inlet community from February 1958 to August 1962.

The air temperature recorded at the Bathurst Inlet automated station during August 2001 to August 2002 was warmer than Cambridge Bay, Lupin and Kugluktuk (Coppermine). This was consistent with historical meteorological data from Bathurst Inlet (February 1958 to August 1962). Average air temperature in the Mackenzie District was above normal during autumn 2001 and winter 2001/2002, colder that normal for spring 2002 and near normal for summer 2002.

Precipitation in the Mackenzie District was above normal for autumn 2001, below normal for winter 2001/2002 and slightly above normal for spring 2002. Summer 2002 was the 6th wettest summer on record for the Mackenzie District, but this trend was not recorded at the Bathurst Inlet Port and Road Project meteorological station because the period of record ended in the first week of August 2002. The total precipitation recorded at the Bathurst Inlet station for the available period of record, 349 days, was 273 mm. Slightly less than one half of the 349 day total precipitation was from snow-water-equivalent (SWE).

The most common wind direction and speed at the Bathurst automated station was from the northwest (29% of time) and between 5.0 and 7.5 m/s (28%), respectively. Calm winds (hourly average wind speed of less than 1 m/s) occurred approximately 3% of the time. These wind patterns are determined mainly by regional weather patterns and the local topography and elevation.

Solar radiation recorded at the Bathurst Project automated meteorology station indicated that the total incoming direct and diffuse short wave radiation peaked out at approximately 650 W/m^2 in July. The monthly average solar radiation values decreased progressively towards autumn and

winter. During July there were almost 24 hours of sunlight and during January there were almost 24 hours of darkness. The mean number of hours of bright sunshine expected at the Bathurst Inlet site is 1,680 hours per year.

Arctic inversions are a phenomenon where there is an increase in air temperature with elevation. This differs from normal tropospheric conditions in which temperature decreases with elevation from surface. The presence of Arctic inversions is closely related to the snow and ice surfaces that exist in the Arctic regions. Arctic inversions create a high potential for poor air quality due to long durations of calm or light winds and the persistent Arctic inversion. Based on historical data the frequency of occurrence for surface based inversions at the Bathurst Inlet site is approximately 67% during December to May at 1100 GMT. During June to November the frequency of surface based inversions at 1100 GMT falls to approximately 43%. Surface based inversions at the Bathurst site at 2300 GMT have roughly the same frequency as 1100 GMT except the frequency decreases substantially to 21% from March to November.

The phenomenon of ice fog and blowing snow is important for the Bathurst Inlet Port and Road Project because of its potential for disrupting both air and ground transport. Based on data from regional stations (Cambridge Bay Airport and Kugluktuk (Coppermine) Airport) the total number of days per year with fog, ice fog or freezing fog was between 28 and 54. The total number of days per year with blowing snow was between 48 and 77. Therefore, based on this regional data the Bathurst Inlet site would be expected to have limited visibility caused by either fog, ice fog, freezing fog or blowing snow between 76 and 131 days per year.

Because it is solar powered, the Bathurst Project meteorological station continues to operate and is collecting meteorological data around the clock. The station will be serviced the next time there is a site visit that enables a crew to access the station. At that time the station will be inspected and the storage module will be swapped out. Calibration and maintenance are recommended for the station's sensors during summer 2003 to ensure representative data collection. A recommended maintenance schedule and equipment service record have been established for this purpose.

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Meteorology Baseline Study, 2001-2002

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1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road Project (the Project) is located in the Kitikmeot region of Nunavut (Figure 1-1). The proposed Port is located on the west side of Bathurst Inlet (66°33'N and 107°31'W), about 40 km south of the community of Bathurst Inlet. The proposed all-weather road will be in two sections: from Bathurst Inlet to Contwoyto Lake, a distance of 211 km, and from Lupin Mine to Izok Lake Property, a distance of 79 km. Izok Lake is a zinc-copper deposit owned by Inmet Mining Corporation. A barge route up Contwoyto Lake (about 60 km) will connect the two sections in summer and an ice road across the lake will connect them in winter.

The Project will provide substantial economic benefits to the Kitikmeot region of Nunavut and to Nunavut in general. It will reduce transportation costs in the region, thereby increasing the likelihood of development of known mineral deposits and encouraging new mineral exploration. There is potential for a larger network of connecting roads in the future to access other mineral properties such as Tahera, Ulu, George, Goose Lake and Hackett River. There is also potential for connection south (via the existing Lupin winter road) to the major diamond mines in the Northwest Territories and to Yellowknife. The Project will also reduce the costs of fuel and supplies for Kitikmeot communities, and increase employment, training, business development, and taxation revenues to the Government of Nunavut.

Environmental baseline studies began at the Port Site in the summer, 2001 and continued in 2002. To date, baseline studies have been initiated for terrain, soils and vegetation mapping, wildlife and marine mammals, acid/alkaline rock drainage and geology, freshwater and marine environment, socio-economics, Traditional Knowledge, community consultations and meteorology monitoring.

Climate will have a major impact on the design, engineering, construction and maintenance of the proposed Port and Road. The climate in the region is extreme, characterized by short cool summers and long cold winters. The Project design will also have to accommodate long-term trends in climate. Overall, the trend in the region has been a gradual increase in ambient air temperatures. Those changes in air temperature will directly effect ice conditions at the Port site, and permafrost and snow conditions along the road. The ship loading and docking activities at the Port may also be affected by wind loading. The Project design will have to accommodate snow and rain conditions along the road. Precipitation will affect the size and locations of culverts and/or bridges along the road route and the requirement for snow removal during winter. Wind speed and direction will directly affect the distribution and dilution of gaseous air contaminants and fugitive dust.

The objective of the climate-monitoring program is to establish a climatic baseline for Bathurst Inlet near the Port. Data from this site will provide a baseline for optimizing Project design and for comparison with other regional climate monitoring stations.

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AI No. a16861f   Job No. 623-7   26/06/2007-12:00pm

the BATHURST INLET PORT AND ROAD PROJECT

FIGURE 1-1

Bathurst Inlet Proposed Port Location and Proposed All-Weather Road Route

The purpose of this baseline meteorology report is to compile and summarize almost one year of data collected by the Bathurst automated meteorological station between August 2001 and August 2002. This report includes a description of methods used to collect the meteorological data and compares the Bathurst station data to data from regional meteorological stations operated by Environment Canada (Meteorological Services of Canada – MSC) or private industry. Graphs and tables are used to present the data and the trends are discussed. The Bathurst data are compared with data from regional stations at Lupin, Kugluktuk (Coppermine) and Cambridge Bay. Data from a privately owned meteorological station at the Hope Bay Belt Exploration Project, Boston site, are also used for comparison. Historical data from an Environment Canada meteorological station at Bathurst Inlet community (Station no. 2300550) that operated from February 1958 to August 1962 are also used for comparison.

2. METHODS

2. Methods

The climate-monitoring program began in late August 2001 with the installation of an automated meteorological station at the proposed Port site (Plates 2.1-1, 2.1-2 and 2.1-3). The station uses an automatic datalogger to record measurements of climatological elements following a set program. The Campbell Scientific CR10X datalogger was used to process and record measurements in metric units. The storage module for the datalogger was retrieved periodically by an operator to download the data.

The design of the automated meteorological station at the Port was based on guidelines published by Environment Canada (AES, 1992). These guidelines provide direction for properly siting the meteorological station, documenting the station, data standards and recommended system requirements (*i.e.*, system components, environmental factors, shelter(s), tower, lightning protection, grounding and power supply). AES (1992) also provides direction for maintenance and calibration of sensors, and quality assurance of data.

Additional guidelines for the proper siting of the tower and individual sensors were provided by World Meteorological Organisation (WMO, 1983), United States Environmental Protection Agency (US EPA, 1987, 1989) and the American Association of State Climatologists (AASC, 1985).

Plate 2.1-1 The Bathurst Inlet meteorological station was commissioned on August 22, 2001. The station is located on a ridge above the proposed port site at an elevation of 170 meters above sea level. The sensors and solar panel are visible in this photograph.

Plate 2.1-2 The white fiberglass box for the CR10X datalogger and the 12 plate Gill radiation shield for the temperature and relative humidity probe are shown in this photograph. Bathurst Inlet is visible in the background of the photo.

The climatic variables monitored at the Bathurst Inlet Port site were relative humidity, rain precipitation, snow accumulation, incoming global short-wave solar radiation, air temperature and wind speed and direction.

Relative humidity is the ratio, expressed as a percentage, of the amount of water vapour actually present in the air to the amount of water vapour that would be present if the air was saturated at the same temperature and pressure.

Precipitation is defined as the liquid or solid products of the condensation of water vapour falling from the clouds or deposited from the air on the ground. The total amount of precipitation that reaches the ground in a stated period is expressed as the depth to which it would cover, in a liquid form, on a horizontal projection of the earth's surface. Snowfall is also expressed by the depth of fresh snow covering an even horizontal surface. Rainfall intensity and snow depth data recorded by the climatological station may be used in developing structural design criteria for the Road and Port.

Solar radiation is the electromagnetic energy of the sun. Ninety seven percent of this energy is confined to the spectral range 0.29 to 3.0 microns, which is referred to as short-wave radiation. Part of the extraterrestrial solar radiation penetrates through the earth's atmosphere to the earth's surface, while part of it is scattered and/or absorbed by the gas molecules, aerosol particles, cloud droplets and cloud crystals in the atmosphere. Global short-wave radiation data are useful to document the hours of daylight and darkness and the intensity of short-wave solar radiation.

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Plate 2.1-3 The Bathurst Inlet meteorological station was visited on April 25, 2002. The 30 Watt solar panel and the cross arm for the SR50 Sonic Ranger (monitors snow depth) are clearly visible about one quarter of the way up the tower. The RM Young 05305 wind monitor can be seen at the top of the tower

The automated meteorological station was installed at the Port site on August 22, 2001, in an open area that is not targeted for future development, such as development of bulk fuel storage facility (*i.e.*, tank farm), camp, bulk storage area, shops, concentrate storage or ammonium nitrate storage. The station was installed at a fair distance from the proposed road to avoid dust accumulation on the instruments.

A Vaisala HMP45CF temperature and relative humidity probe was used to monitor air temperature and relative humidity. Air temperature was monitored at a height of approximately 1.5 m above ground. The air temperature sensor was properly ventilated and protected from direct solar radiation by a screened shelter or radiation shield and located over a surface representative of the general area. The probe was protected from direct solar radiation using a 12-plate Gill radiation shield. The unit was installed in an area where snow could not accumulate around the sensor. It was mounted at a height of 1.5 m above the maximum snow depth (AES, 1992). The Campbell Scientific CR10X data-logger records hourly average air temperatures along with the daily maximum and minimum air temperatures in degrees Centigrade. The operating range for the HMP45CF sensor is –55 to +50ºC. The resolution for the air temperature data is 0.1ºC.

Hourly average values for relative humidity were recorded by the CR10X. The resolution for the relative humidity data is 1%. The accuracy of the HMP45CF probe will be periodically checked with a sling psychrometer. A psychrometer consists of a dry and wet bulb pair of thermometers; the measurements from which are used to compute the vapour pressure, relative humidity and dew point temperature.

Three different instruments could be used to measure precipitation at the Port site. A manual rain gauge could provide the daily total accumulation of liquid precipitation. It could be monitored when there are people working at the Port site. The manual rain gauge should be installed in close proximity to the climatological autostation when work is being done in the area. Unfortunately the Bathurst Port site was not occupied from August 2001 to present therefore no manual rain gauge data was available.

Data from the manual rain gauge would provide verification for the total rainfall data collected by the Texas Electronics Model TE525M tipping bucket rain gauge (TBRG) which is connected to the CR10X. This instrument automatically records rain when it is occurring. Hourly and daily total rainfall were recorded in mm. Rainfall intensity is the measure of rainfall per unit of time. The Bathurst station automatically monitors the one-minute rainfall intensity using the TBRG. The TBRG was mounted on a level, well-drained surface. The sides of hills were avoided. The TBRG was mounted close to the ground and was removed from surrounding obstructions a minimum of 4 times the height of the obstruction (AES, 1992). The resolution for the TBRG is 0.1 mm.

A Campbell Scientific Model SR50 Sonic Ranger monitors the total depth of the snow pack on the ground. The site selected for the sonic ranger was very important to obtain representative snow depth readings. The sensor was mounted at a height of 1.8 m above ground that is within the measurement range of the sensor (*i.e.*, 0.5 to 10 m). The SR50 sensor relies on an external air temperature measurement to correct the distance readings. The SR50 was mounted in close proximity to the air temperature sensor to minimize temperature errors. The sensor was mounted perpendicular to the ground to avoid slant range problems and was installed above flat ground, in the open, and free of any downwind drifting. Tall vegetation were avoided since they are "seen" and can cause signal scattering and erroneous readings at the beginning of the season. The field of view for the SR50 was cleared to bare ground (AES, 1992). The resolution for the SR50 sonic ranger is 0.1 mm, the accuracy is ±1 cm or 0.4% of distance to the target (which ever is greatest). The operating temperature for the SR50 sensor is –45 to +50ºC.

Wind speed and direction were monitored with a RM Young model 05305 wind monitor. The 05305 wind monitor is a high performance wind speed and direction sensor designed specifically for air quality measurements. The 05305 features a low starting threshold, fast response and high accuracy. It meets or exceeds the requirements recommended by the US EPA for air quality studies (US EPA, 1987, 1989). The 05305 model was selected over the 05103 model because it has higher accuracy and the wind data from the Port climatological autostation will ultimately be used for fugitive dust modelling along the road corridor.

Surface wind was measured at the international standard height of 10 m above ground. Wind in reality is a three dimensional vector quantity but surface wind is usually treated as a two dimensional quantity specified by its horizontal direction and speed. Wind direction, by convention, is the direction from which the wind is blowing and is referenced from true north. Magnetic declination is the number of degrees between true north and magnetic north. The magnetic declination for the port site (66º33’ north latitude, 107º31’ west longitude) is 19.4º east of north. The resolution for wind direction readings is ±5º. As per AES recommendations, wind direction was vector averaged over the output averaging time. The mean wind direction and standard deviation for wind directions ($\sigma(\theta)$) were recorded for every hour and the last 10 minutes of each hour. The maximum instantaneous daily wind speed and the wind direction that corresponds to that wind speed were recorded along with the time of day that it occurred. Wind speeds were recorded in m/s with a resolution of 0.28 m/s or 1 km/hr.

The LICOR Model LI200X silicon pyranometer (fixed multiplier) used at the Bathurst Port meteorology station measures global solar radiation (*i.e*,. total incoming direct and diffuse short-wave solar radiation) received from the whole dome of the sky on a horizontal surface. The silicon pyranometer was mounted on a cross arm that is attached to one of the legs for the 10 m aluminum tower. This arrangement is vibration free and the sensor was mounted approximately 1.9 m above the ground in an open area. This configuration ensured that no shadows would be cast on the sensor at any time the sun was above 5º elevation, that no bright or reflective surfaces would reflect sunlight onto the sensor and that there were no sources of radiant energy other than the sun itself (AES, 1992).

The power supply for the station consists of a 12 Volt lead acid rechargeable deep cycle marine battery (105 Amp-hour) that is recharged with a 30 Watt solar panel. The station operates independently 24 hours/day on battery power even during the months where there is no sunlight to re-charge the lead acid battery via the solar panel.

The most important component of the climatological station is the Campbell Scientific Model CR10X datalogger that operates the sensors and provide short-term data storage. Consistent with the AES Guidelines, the scan interval that the CR10X datalogger uses to interrogate the sensors is 5 seconds. The range of operating temperature for the CR10X datalogger is –55 to +50ºC. At the top of the hour, the datalogger calculates the parameter averages and maxima and minima and sends this information to the SM4M Storage Module. The Storage Module is portable and can be disconnected from the CR10X and taken back to the office for downloading to a laptop or personal computer using the Campbell Scientific PC208W version 3.3 software.

When the site is staffed the storage module (Model No. SM4M) should be extracted and downloaded once per month (it was not practical to have wildlife survey crews perform this activity on a regular basis because their fixed-wing aircraft could not land at the Port site). Otherwise, the station was configured to record data for up to 12 months without downloading. This has been a proven methodology for a climatological station installed by Rescan at the Hope Bay Belt Gold Project, north-east of Bathurst Inlet. The Bathurst Inlet storage module was downloaded twice during the 2001 to 2002 meteorology baseline study, to coincide with visits to conduct other baseline studies. If the Port site is not occupied for a long period of time (*e.g.*, several months) the meteorological station should be checked as soon as possible after the site re-opens.

Once downloaded, the data was immediately inspected to determine if the power supply and sensors were working satisfactorily. Using this strategy, large gaps in the meteorological database due to sensor malfunction or power interruption were averted. All data is kept on the server at the Rescan office in Vancouver. This network server is backed up daily. As an extra precaution the raw data was also kept on floppy diskettes and/or CD-ROM.

The data from the climatological station consists of three different arrays. The first array will contain hourly data, 24 of these arrays are recorded per day at the top of each hour. One daily summary array is recorded just after midnight. If it is raining a third array is recorded for the 1 minute rainfall intensity. Tables 2.1-1, 2.1-2 and 2.1-3 provide examples of the hourly, daily and 1 minute rainfall intensity arrays. Table 2.1.-4 summarizes the Bathurst Inlet meteorology data and the data available from the regional stations. Figure 2.1-1 and Table 2.1-5 summarize the location of the Bathurst Inlet and regional meteorological stations.

To ensure that the Bathurst Project meteorological station collects representative data, the station's sensors require periodic maintenance. Table 2.1-6 summarizes the recommended equipment maintenance and part replacement. Scheduled maintenance is recommended in the summer of 2003 for the wind monitor, temperature and relative humidity probe, pyranometer and tipping bucket rain gauge. Table 2.1-7 summarizes the equipment service record that should be used to keep track of the maintenance for the Bathurst meteorological station.

Table 2.1-1
Example of Hourly Data Array

Array ID	Year	Julian Day	Hour Minute	10 Minute Average Wind Speed (m/s)	10 Minute Average Wind Direction (deg N_T)	10 Minute Average Std. Dev. for Wind Direction (deg N_T)	Hourly Average Wind Speed (m/s)	Hourly Average Wind Direction (deg N_T)	Hourly Average Std. Dev. for Wind Direction (deg N_T)	Hourly Average Air Temperature (°C)	Hourly Average Relative Humidity (%)	Hourly Total Rain (mm)	Snow Depth for the Last Minute of the Hour (m)	Hourly Average Solar Radiation (kW/m^2)
60	2001	131	1500	5.21	340.2	15.1	5.56	330.7	16.5	-5.76	76.7	0.0	0.010	350.0

Table 2.1-2
Example of Daily Data Array

Array ID	Year	Julian Day	Hour Minute	Program Signature	Station ID	Maximum Battery Voltage (Volts)	Minimum Battery Voltage (Volts)	Program Version	Daily Maximum Instantaneous Wind Speed (m/s)	Time of Maximum Wind Speed	Direction of Maximum Wind Speed (deg N_T)	Daily Maximum One Min. Average Air Temperature (°C)	Daily Minimum One Min. Average Air Temperature (°C)	Daily Maximum 10 Minute Average Wind Speed (m/s)	Daily Total Rain (mm)
24	2001	131	2400	1117.5	620.4	12.37	12.22	1.02	13.25	1315	315.7	-3.27	-19.76	9.71	0.0

Table 2.1-3
Example of One Minute Rainfall Intensity Array

Array ID	Julian Day	Hour Minute	One Minute Rainfall Intensity (mm/minute)
121	131	1239	0.2

Table 2.1-4
Meteorology Data Available For Bathurst Inlet Region, August 2001 – August 2002

Variable	Bathurst Meteorological Station	Boston Meteorological Station	Cambridge Bay Airport Meteorological Station	Lupin Airport	Kugluktuk (Coppermine) Airport
Air Temperature	August 22, 2001 to August 7, 2002	September 12, 2001 to May 8, 2002	August 1, 2001 to August 31, 2002	August 1, 2001 to July 31, 2002	August 1, 2001 to August 31, 2002
Rain Precipitation	August 22, 2001 to August 7, 2002	September 13, 2001 to October 29, 2001	August 1, 2001 to August 31, 2002	August 1, 2001 to July 31, 2002	August 1, 2001 to August 31, 2002
Snow on Ground	August 22, 2001 to August 7, 2002	September 12, 2001 to May 8, 2002	August 1, 2001 to June 27, 2002; July1, 2002 to August 1, 2002	August 1,2001 to October 30, 2001; May 31, 2002 to July 31, 2002.	August 2001 to June 15, 2002; June 15 to August 30, 2002 with sizeable gaps.
Wind Speed and Direction	August 22, 2001 to August 7, 2002	September 12, 2001 to May 8, 2002	n/a	n/a	n/a
Solar Radiation	August 22, 2001 to August 7, 2002	September 12, 2001 to May 8, 2002	n/a	n/a	n/a
Relative Humidity	August 22, 2001 to August 7, 2002	September 12, 2001 to May 8, 2002	n/a	n/a	n/a

Table 2.1-5
Location of Bathurst Inlet and Regional Meteorology Stations

Station	Latitude (North)	Longitude (West)	Elevation (meters above sea level)
Bathurst Inlet (August 2001)	66°31’	107°34’	170
Bathurst Inlet (1958 to 1962, stations no. 2300550)	66°50’	108°01’	13
Cambridge Bay Airport (station no. 2400600)	69°06’	105°08’	27
Lupin Airport (station no. 23026HN)	65°46’	111°14’	490
Kugluktuk (Coppermine) Airport (station no. 2300902)	67°49’	115°08’	23
Hope Bay Belt Project, Boston Site	67°38’	106°23’	75

Table 2.1-6
Bathurst Inlet Port Automated Meteorological Station Recommended Equipment Maintenance and Part Replacement Summary

Model Number	Recommended Frequency of Service	Replacement Part Number	Part Number/Maintenance Action Description	Quantity of Parts Required
R.M. Young 05305 wind sensor	12-24 months	RO5124UG	Vertical shaft bearing (oil filled)	2
		RO5163PG	Flange bearing (oil filled)	2
	24-48 months	RO5133B	Potentiometer 10K Ω 0.25%	1
	48 months	RO5145C	Potentiometer mounting and coil assembly	1
Visalia HMP45C temperature and relative humidity probe	Periodically	done at site	Clean radiation shield	1
	12-24 months	HMP45C-CAL	Sensor recalibration	1
	60 months	C847	RH replacement chip	1
LI-COR L1200X silicon pyranometer	Periodically	done at site	Wipe sensor clean	1
	24 months	L1200SZ-CAL	Sensor calibration	1
Campbell Scientific CR10X datalogger	Periodically	DSC 50/2	Replacement desiccant	1
	36 months	Calibration	Calibration	1
Texas Electronics TE525M tipping bucket rain gauge	Periodically	done at site	Level and clean bucket of debris	1
	12 months	Calibration	Sensor calibration	1
Campbell Scientific SR50 Sonic Ranger	Periodically	DSC 50/2	Replacement desiccant	1

Table 2.1-7
Bathurst Inlet Port Automated Meteorological Station Equipment Service Record

Model Number	Serial Number	Purchase Date	Last Service Date	Work Done
R.M. Young 05305 wind sensor	WM34534	August 2001	N/A	Installed Aug. 22, 2001
Viasala HMP45C temperature and relative humidity probe	U0840018	August 2001	N/A	Installed Aug. 22, 2001
LI-COR LI200X silicon pyranometer	PY33536	August 2001	N/A	Installed Aug. 22, 2001
Campbell Scientific CR10X datalogger	18385	August 2001	N/A	Installed Aug. 22, 2001
Texas Electronics TE525M Tipping Bucket Rain Gauge	32257-32	August 2001	N/A	Installed Aug. 22, 2001
MSX30R 30 Watt Solar Panel	1599572	August 2001	N/A	Installed Aug. 22, 2001
Campbell Scientific SR50 Sonic Ranger	13279	August 2001	N/A	Installed Aug. 22, 2001

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FIGURE 2.1-1

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Location of Environment Canada Regional Climate Stations

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3. RESULTS

3. Results

3.1 Air temperature

The mean monthly air temperatures for the Bathurst meteorological station and the regional stations are summarized in Table 3.1-1 and Figure 3.1-1. It was not possible to calculate an annual average air temperature for the Bathurst station because less than a full year of data was collected (349 days). The highest mean monthly air temperature at Bathurst Inlet was 12.4ºC (July 2002). The lowest mean monthly air temperature recorded at Bathurst Inlet was –28.9ºC (February 2002). The highest 1 minute average air temperature recorded by the Bathurst station was 26.1ºC, on July 2, 2002. The lowest one minute average air temperature recorded by the Bathurst station was – 40.1ºC for January 19, 2002.

The air temperatures at the Bathurst station were compared to regional stations for a common 11 month period of record (September 2001 to July 2002). The 11 month average air temperature at Bathurst (–10.5ºC) was warmer than at Cambridge Bay (–16.3ºC), Lupin (–12.9ºC) and Kugluktuk (–12.4ºC). Cambridge Bay (69º6' north) is colder than Bathurst Inlet (66º33' north) and the other regional stations because it is at a higher latitude. Bathurst Inlet had warmer air temperatures than all of the regional stations for the 11 month common period of record.

Environment Canada operated a meteorological station near the community of Bathurst Inlet from March 1958 to July 1962 (53 months). The mean annual air temperature for this station over this period was –11.5ºC. This mean annual air temperature was warmer than the annual "normals" (average for 1971 to 2000) reported by the Meteorological Services of Canada (MSC) for Cambridge Bay (–14.4ºC), but colder than Lupin (–11.1ºC) and Kugluktuk (–10.6ºC). With the exception of Bathurst Inlet the average air temperature for all the meteorological stations for the 11 month common period of record were colder than normal.

Environment Canada has divided the nation into 11 climatic regions. Bathurst Inlet is located in the Mackenzie District climatic region. Temperature statistics in 2001 indicated that the Mackenzie District was warming at a greater rate (1.1ºC above normal for a 54 year period of record) than any other climate region in Canada. The warmest year on record for the Mackenzie District was 1998 (3.9ºC above normal). Average air temperatures in the Mackenzie District were above normal during autumn 2001 and winter 2001/2002 (1.8 and 2.6ºC above normal, respectively). Average air temperatures in the Mackenzie District were colder than normal for spring 2002 (2.6ºC below normal) and near normal for summer 2002. The monthly average maximum and minimum air temperatures at the Bathurst Inlet meteorological station and the regional stations are summarized in Figures 3.1-2 and 3.1-3. The mean daily air temperatures recorded at the Bathurst Inlet meteorology station are included in Appendix A.

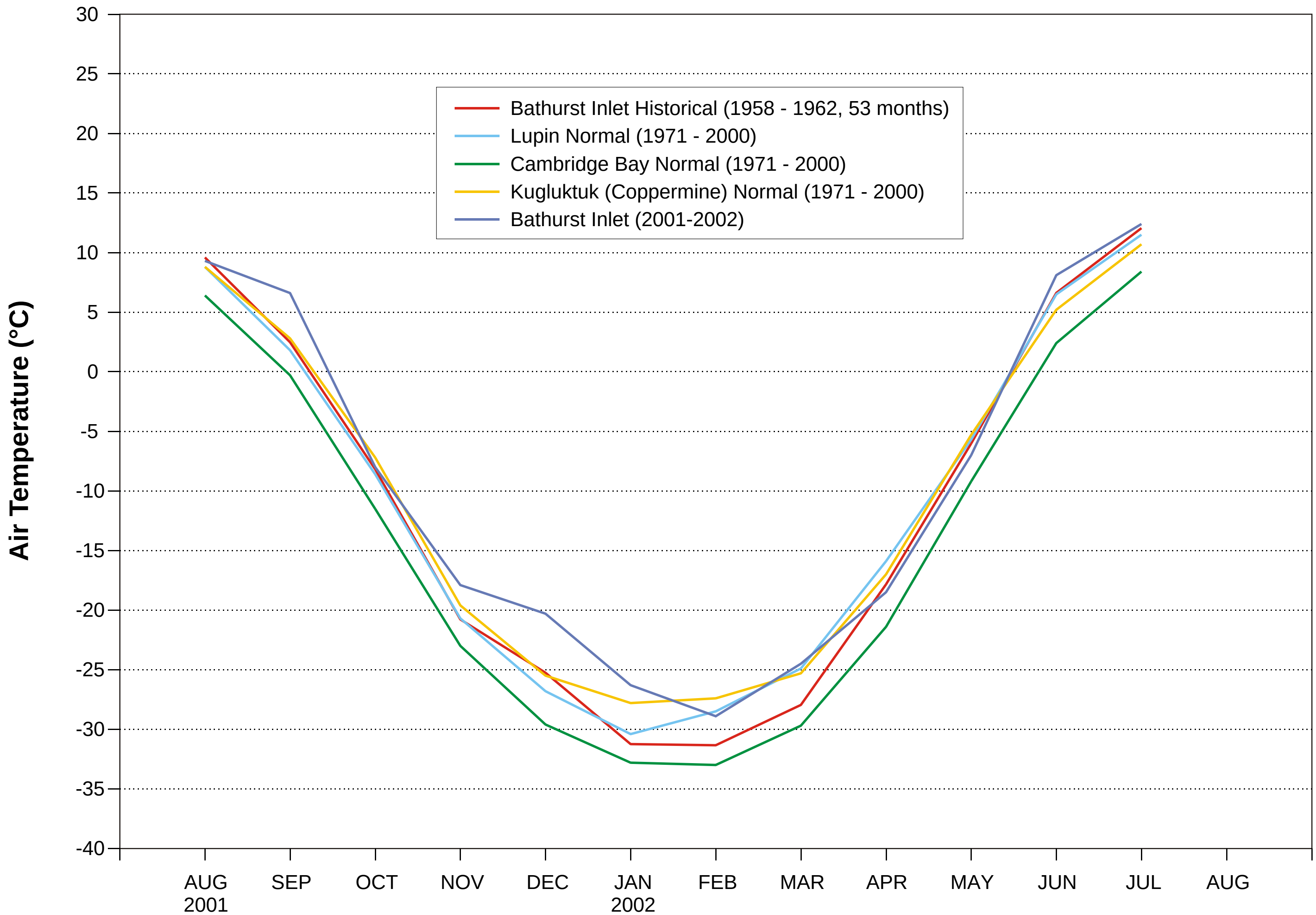
Table 3.1-1
Mean Monthly Air Temperatures (°C) at the Bathurst Inlet and Surrounding Regional Meteorological Stations

Month	Bathurst Station	Boston Station	Cambridge Bay Airport	Lupin Airport	Kugluktuk (Coppermine) Airport
August 2001	9.3[1]	n/a	6.8	8.5	8.7
September	6.6	3.7[2]	3.2	5.9	6.6
October	-8.0	-10.7	-12.5	-9.6	-7.2
November	-17.9	-19.9	-21.6	-20.5	-17.7
December	-20.3	-22.6	-23.7	-23.2	-21.2
January 2002	-26.3	-29.3	-30.7	-28.3	-28.2
February	-28.9	-32.4	-34.2	-30.1	-31.7
March	-24.5	-27.1	-29.0	-25.5	-24.1
April	-18.5	-20.7	-24.2	-19.9	-19.5
May	-7.0	-14.5[3]	-9.7	-8.4	-8.0
June	8.1[4]	n/a	3.2	7.4	5.8
July	12.4	n/a	8.2	12.0	10.5
August	11.0[5]	n/a	7.0	n/a	7.8
11 Month Average [6]	-10.5	n/a	-16.3	-12.9	-12.4
12 Month Normal	-11.5[7]	n/a	-14.4[8]	-11.1[8]	-10.6[8]

n/a = not available
1: Data available only for 10 days, August 22 to August 31, 2001.
2: Data only available for September 12 to 30, 2001.
3: Data only available from May 1 to 8, 2002.
4: Data from June 14, 17 and 18 not used in calculations as data recorded by sensor was out of range.
5: Data available only for 7 days, August 1 to August 7, 2002
6: 11 month average for the common period of complete record for all stations, September 2001 to July 2002.
7: Normals for Bathurst Station calculated from Bathurst historical data for complete months of data from March 1958 to July 1962 (53 months).
8: Canadian Climate Normals 1971-2000 from Environment Canada-Meteorological Services of Canada (MSC) website "www.msc.ec.gc.ca/climate/climate_normals/results_e.cfm"

3.2 Precipitation

Table 3.2-1 and Figure 3.2-1 summarize the total monthly precipitation recorded by the Bathurst station and the regional stations. The precipitation in the Mackenzie District was slightly above normal for autumn 2001 (+5.1%), below normal for winter 2001/2002 (-16.9%) and slightly above normal for spring 2002 (+6.1%). Summer 2002 was the 6th wettest on record for the Mackenzie District (+38%) and this trend was reflected in the records from the regional stations. However, the records from the Bathurst Inlet station end on August 7, 2002 and therefore do not indicate that it was wetter the normal for summer 2002. Appendix B contains the total daily rainfall at the Bathurst Inlet meteorological station recorded with the tipping bucket rain gauge.



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Mean Monthly Air Temperatures for Bathurst Inlet and Regional Stations

FIGURE 3.1-1

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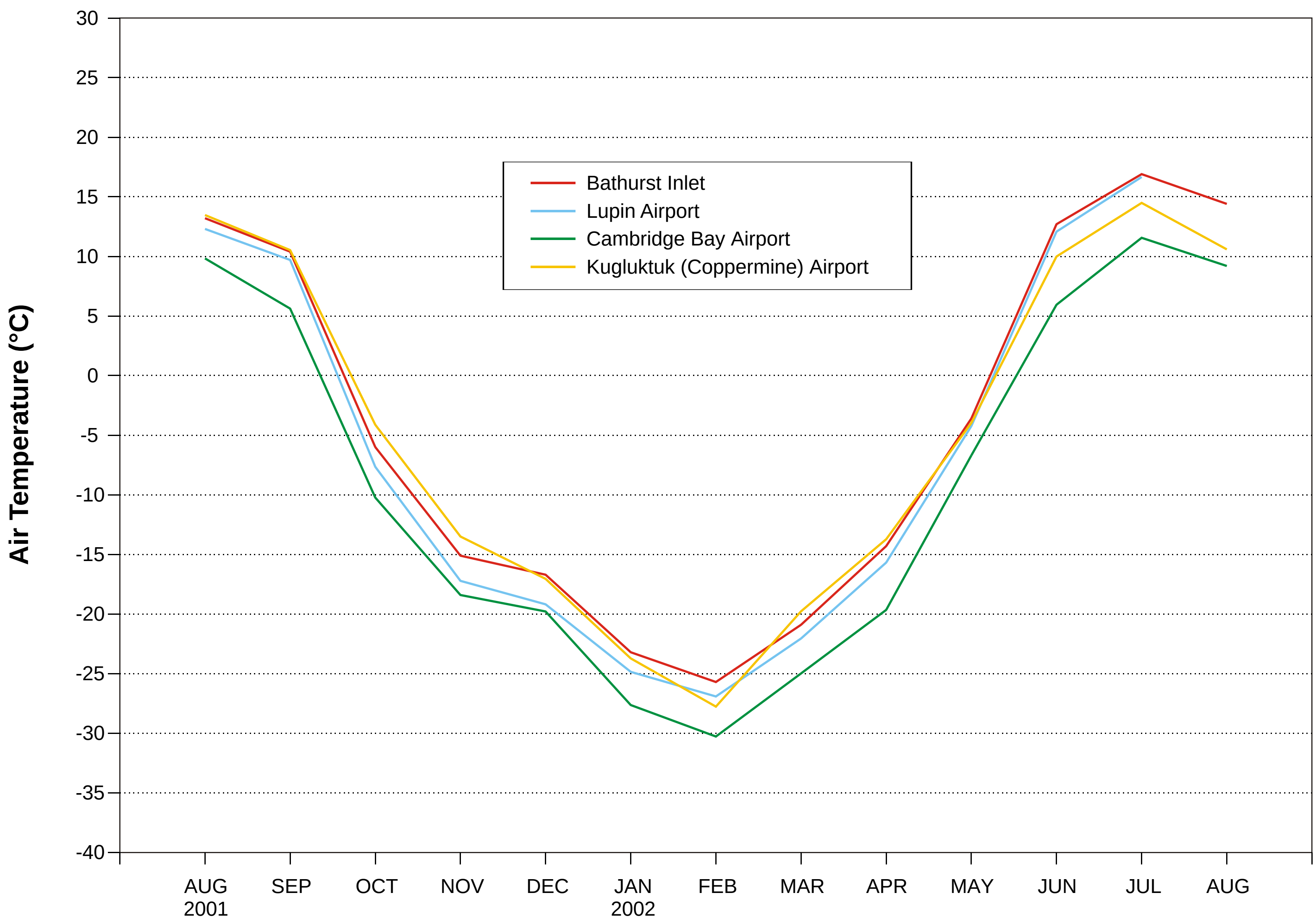

FIGURE 3.1-2

Monthly Average Maximum Air Temperatures for Bathurst Inlet and Regional Stations

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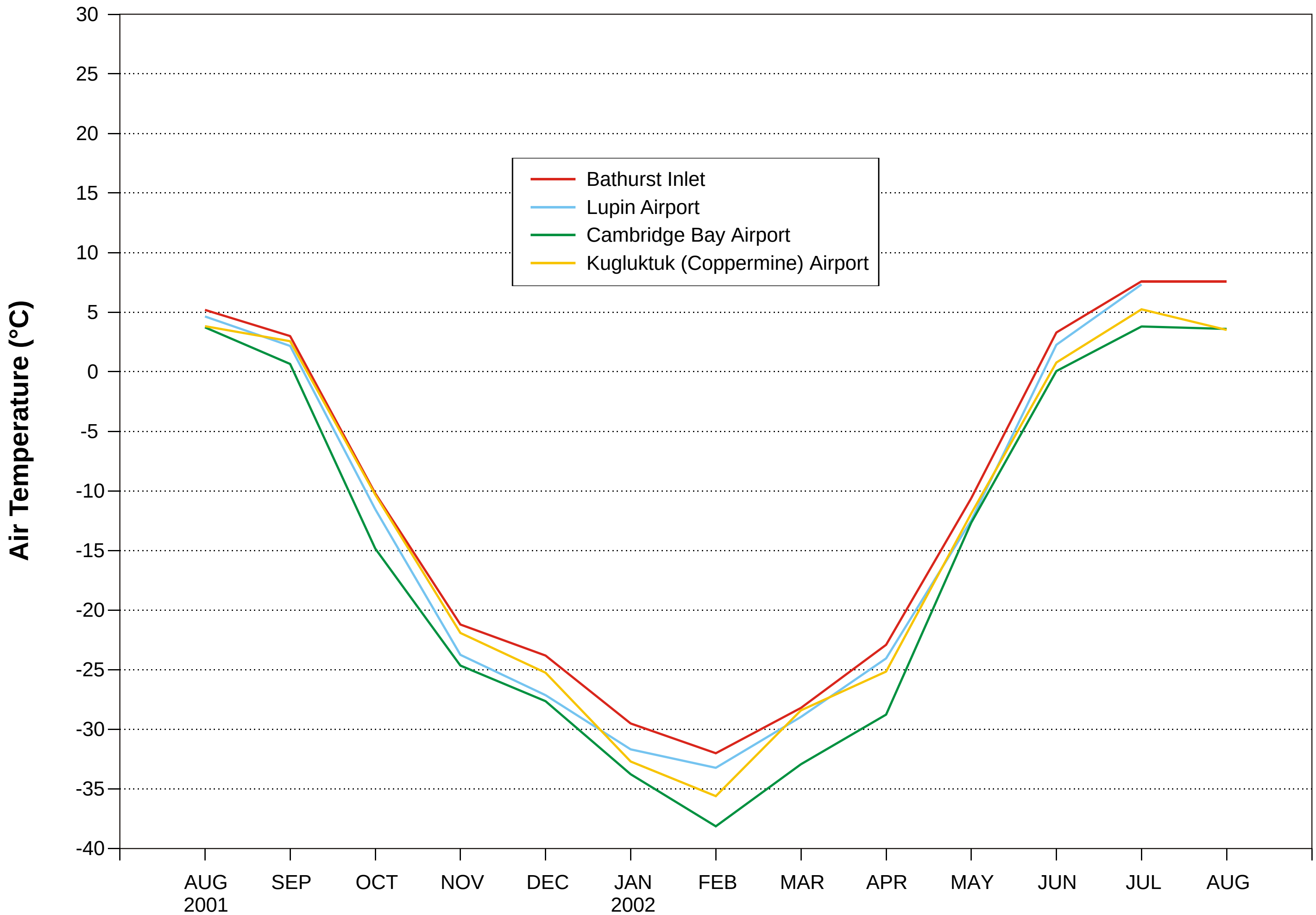

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FIGURE 3.1-3

Monthly Average Minimum Air Temperatures for Bathurst Inlet and Regional Stations

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Table 3.2-1
Total Monthly Precipitation at Bathurst Inlet and Regional Meteorological Stations, August 2001 to August 2002

Month	Bathurst Inlet Station[1]	Boston Station[2]	Cambridge Bay Airport[3]	Lupin Airport[3]	Kugluktuk (Coppermine) Airport[3]
August 2001	17.1[4]	n/a	31.0	46.4	26.4
September	75.2	10.6[5]	13.8	9.4	39.3
October	28.9	18.1	3.6	20.0	21.8
November	42.5	n/a	6.6	27.6	12.6
December	4.8	n/a	4.8	12.0	14.2
January 2002	5.1	9.8	4.0	7.6	12.5
February	4.8	0.7	1.8	2.2	1.6
March	9.0	n/a	3.2	6.4	6.9
April	11.4	n/a	2.8	15.8	8.7
May	8.8	n/a	6.8	4.4	7.4
June	43.2	n/a	10.4	35.6	24.0
July	21.8	n/a	8.2	67.0	31.3
August	0.7[6]	n/a	33.0	41.4	25.3
12 Month Total[7]	**273.2[8]**	n/a	**130.0[9]**	**295.8[9]**	**232.0[9]**
Normal	**279.2[10]**	n/a	**138.8**	**299.2**	**249.3**

n/a = not available

1: The total monthly precipitation for Bathurst included the snow-water-equivalent precipitation calculated from snow depth on the ground, and assumed an average snow density of 141 kg/m^3.

2: Precipitation data not available due to inaccurate rain gauge data.

3: MSC 2002a.

4: Data began on August 22, 2001.

5: Data was not available from the tipping bucket rain gauge for Sept. 1 to Sept. 12, 2001.

6: Data was available for August 1 to August 7, 2002 only.

7: August 1, 2001 to July 31, 2002.

8: A complete year of data was not available from the Bathurst Inlet station. A total of 349 days of data were available.

9: Canadian Climate Normals 1971-2000 from Environment Canada-Meteorological Services of Canada (MSC) website "www.msc.ec.gc.ca/climate/climate_normals/results_e.cfm".

10: 12 Month normal for Bathurst Inlet calculated from historical data from February 1958 to August 1962 (53 months). A mean air temperature for each complete month of data was calculated. Then a mean monthly air temperature was calculated for each full month of the year using the months with no missing data. The mean annual air temperature normal was then calculated as the average of the 12 month averages. This allowed the maximum amount of data to be used to generate the air temperature "normal" for the Bathurst Inlet historical station.

Table 3.2-2 summarizes the rainfall and snow-water-equivalent (SWE) precipitation recorded at the Bathurst station for 349 days of operation. Figure 3.2-2 summarizes the daily new snow accumulation and cumulative snow depths at the Bathurst meteorological station for the available period of record. SWE precipitation was calculated from the SR50 Sonic Ranger hourly snow depth readings. The snow depths were used to calculated SWE precipitation assuming a snow density of 141 kg/m^3. This is an average snow density for NWT barrens (east and west of longititude 110°) recommended by Metclafe and Ishida (1994). In reality snow density changes

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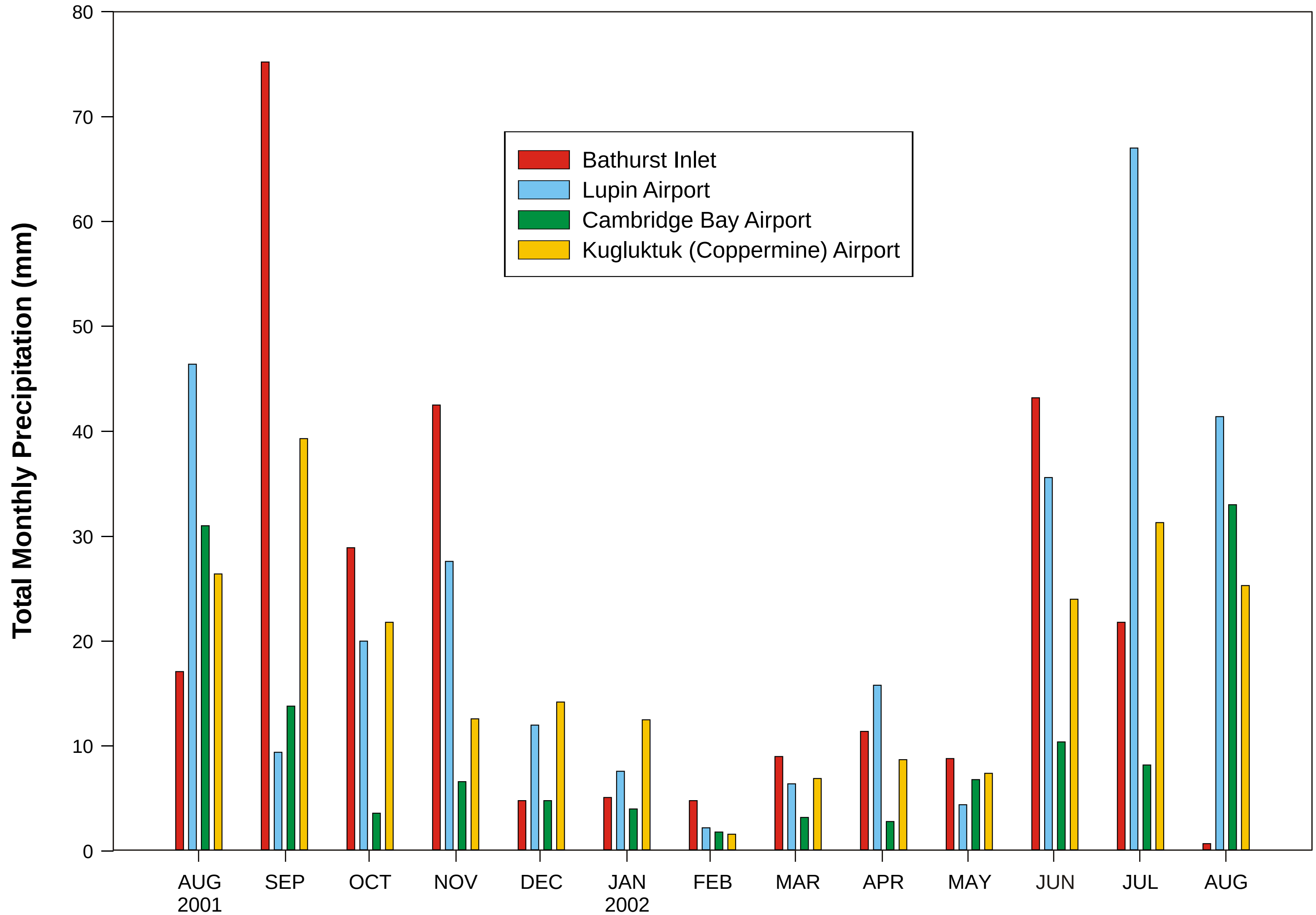

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Bathurst Inlet and Regional Stations, Total Monthly Precipitation
August 22, 2001 to August 7, 2002

FIGURE 3.2-1

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throughout the year depending upon the air temperature and relative humidity. Snow density is usually monitored using snow core samples. A series of 10 snow core sample points would comprise a "snow course". If a site is readily accessible a snow survey would be conducted during the first 6 days of each month from January to June. However, it was not possible to conduct snow surveys at the Bathurst Port site because of its remote location. In addition, there would be high variability in the results from a snow course conducted along the proposed road route due to persistent winds causing the snow to drift. A large number of sample stations would be required to obtain representation results for the proposed 290 km road. Considering all of the above, it is not economically or technically feasible to use snow courses to monitor snow precipitation along the road route.

Table 3.2-2
Total Monthly Precipitation at the Bathurst Inlet Meteorological Stations, August 2001 to August 2002

Month	Bathurst Inlet Station		
	Rainfall (mm)	Snow-Water Equivalent [1] (mm)	Total (mm)
August 2001	17.1[2]	0.0[3]	17.1
September	72.1	3.1	75.2
October	2.5	26.4	28.9
November	0.1	42.4	42.5
December	0.3	4.5	4.8
January 2002	0.0	5.1	5.1
February	0.0	4.8	4.8
March	2.3	6.6	8.9
April	1.1	10.3	11.4
May	0.5	8.3	8.8
June	39.7	3.5	43.2
July	21.8	0.0[3]	21.8
August	0.7[4]	0.0[3]	0.7
349 Day Total[5]	**158.2**	**115.0**	**273.2**

1: Snow-Water Equivalent was calculated using an average constant snow density of 141 kg/m^3, where in fact the actual snow density varies throughout the year.
2: Data available for only August 22 to August 31, 2001.
3: SWE data for months where the air temperature was above 0°C for the entire month was assumed to be zero.
4: Data available for only August 1 to August 7, 2002.
5: A full year of data was not available.

For the Bathurst Inlet meteorology station the hourly snow accumulation was calculated by subtracting the previous hours snow depth value from the present reading. Both positive and negative hourly accumulations were summed for each 24 hour period to give a daily total snow

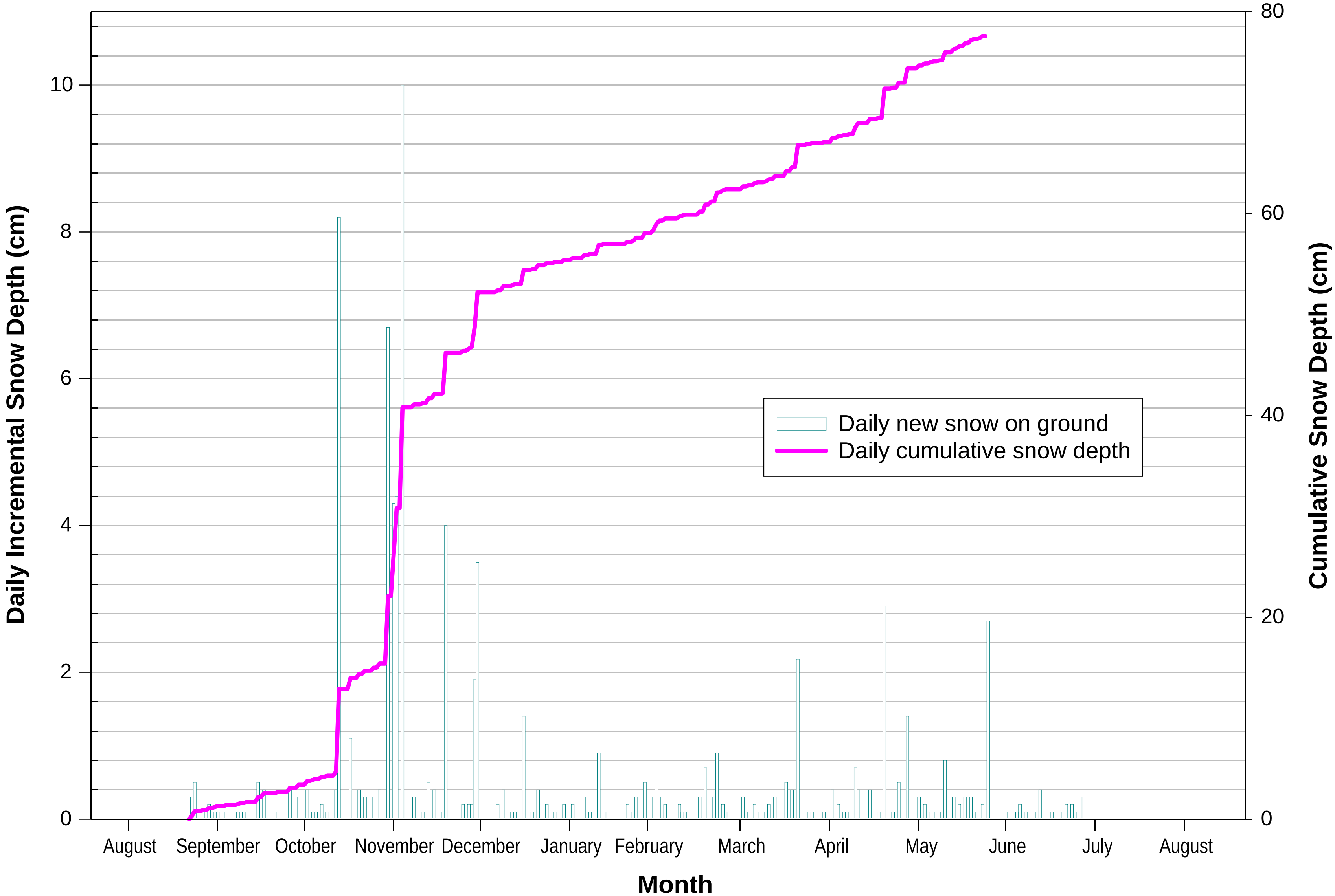

FIGURE 3.2-2

Bathurst Inlet Daily Incremental and Cumulative Snow Depth, August 22, 2001 to August 7, 2002

accumulation. Summing both the positive and the negative accumulations in the hourly data filtered out noise in the data caused by tower vibrations during windy conditions. On two occasions, March 21, 2002 and May 26, 2002, the instrument indicated an unrealistic amount of snow accumulation – most likely caused by blowing snow underneath the sensor. For these two dates the value for daily snow accumulation was replaced with twice that of the daily average for their respective months. A value of twice the average, rather than just the average, was used to reflect that there was a snowfall event on those particular days.

Metcalfe and Ishida (1994) indicated that measuring snow is much more difficult than rainfall because snow cover has a highly variable temporal and spatial structure related to land cover and terrain and redistribution by wind. In addition, snowfall is difficult to measure because of varying density, significant errors in gauge measurements due to wind, wetting and evaporation issues. The contribution of snow melt to a particular basin assists in the design of water diversion structures and culverts that would be required for potential future road crossings.

A total precipitation of 273 mm was recorded at the Bathurst Inlet site for almost a full year of observations (349 days). Approximately 42 % of this total was attributed to snow-water-equivalent (SWE). SWE was calculated from the daily snow accumulations at the automated meteorological station and assuming a snow density of 141 kg/m^3. The contribution from SWE to total annual precipitation was near normal. Normally 43% of the total annual precipitation is from SWE (based on historical data (1958 to 1962) from the Bathurst Inlet station). The wettest months at the current Bathurst station were September 2001 (75.2 mm) and June 2002 (43.2mm). The driest month at the Bathurst station was January 2002 (5.1 mm). Appendix C contains the daily summary for rain and SWE precipitation recorded at the Bathurst Inlet meteorological station.

3.3 Wind Speed and Direction

The wind speeds and directions at the Bathurst meteorological station for the available period or record (August 22, 2001 to August 7, 2002) are summarized in Figure 3.3-1. The wind rose diagram shows the most common wind speeds and directions at the Bathurst station. The most common wind direction was from the northwest (29.3% of time). Note that all of the wind directions were measured from true north. The magnetic declination (*i.e.*, difference between true north and magnetic north) at the Bathurst meteorological station was 19.4º east of north. The second most common wind direction was north (18.4% of time). The most common range of wind speeds was 2.5 to 5.0 m/s (29.4% of time). The second most common range of wind speeds was 5.0 to 7.5 m/s (27.8% of time). Calm winds (*e.g.*, hourly average wind speed of less than 1 m/s) occurred approximately 3.2% of the time. Overall the winds at the Bathurst site are consistently from the northwest and between 2.5 and 7.5 m/s.

Wind speed and direction are primarily determined by local topography, elevation (*i.e.*, the planetary boundary layer determines the wind speed at different heights above the ground), and aspect, therefore, no meaningful comparisons can be made with the regional stations at Lupin, Kugluktuk (Coppermine), Cambridge Bay and Boston.

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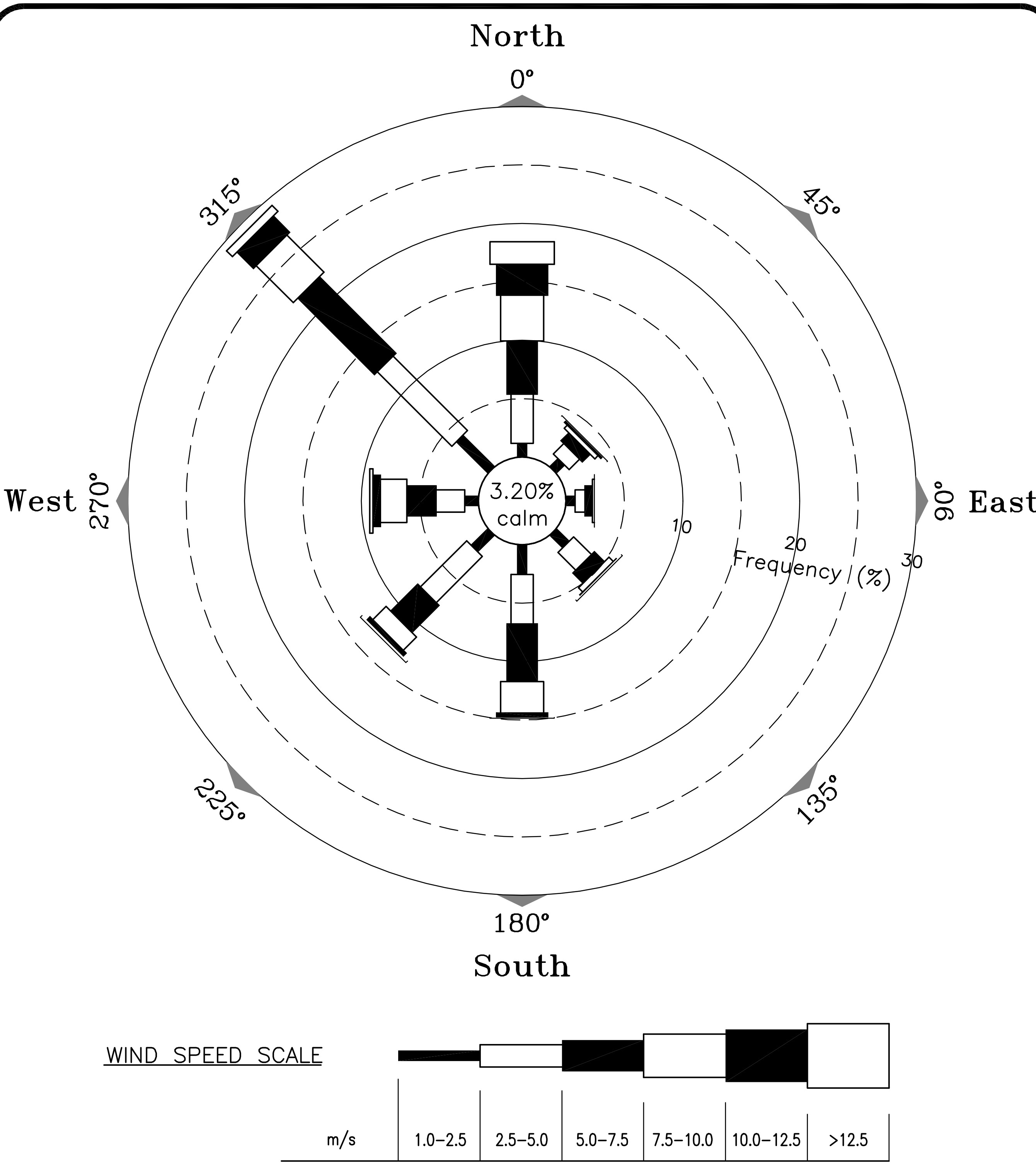

Period of record from August 22, 2001 to August 7, 2002

Bathurst Inlet Meteorological Station 2001/2002 Wind Rose

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Figure 3.3-1

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Cad No. C1016_620-4 Sht. 1 View C1 Job No. 620-4 Atmospheric Environment Scale 2 : 1 11/21/2002- 2:43pm RES_AP

3.4 Evaporation

Open water evaporation was not monitored at the Bathurst meteorology station during the open water season. The instruments required to monitor open water evaporation (*e.g.*, Class A evaporation pan) require consistent daily manual observations. Because the Bathurst site is so remote and there were only infrequent visits to the site, it was not possible to monitor open water evaporation during the meteorological baseline study.

Due to a short open water season at the Bathurst site the open water evaporation would be limited to early June to late September. A Class A evaporation pan was used at the Hope Bay Belt Gold Exploration Project (Hope Bay Joint Venture) between 1995 and 2000. However, the 1998 and 2000 data were questionable because of the high number of missing days and the presence of animals drinking from the pan which would over-estimate the mean daily evaporation rate. Overall the data from 1997 was considered most representative because of the length of the period of record with only a few missing days. For an 88 day period of record (June 15 to September 11) the Class A pan evaporation was approximately 261 mm (3.1 mm/day).

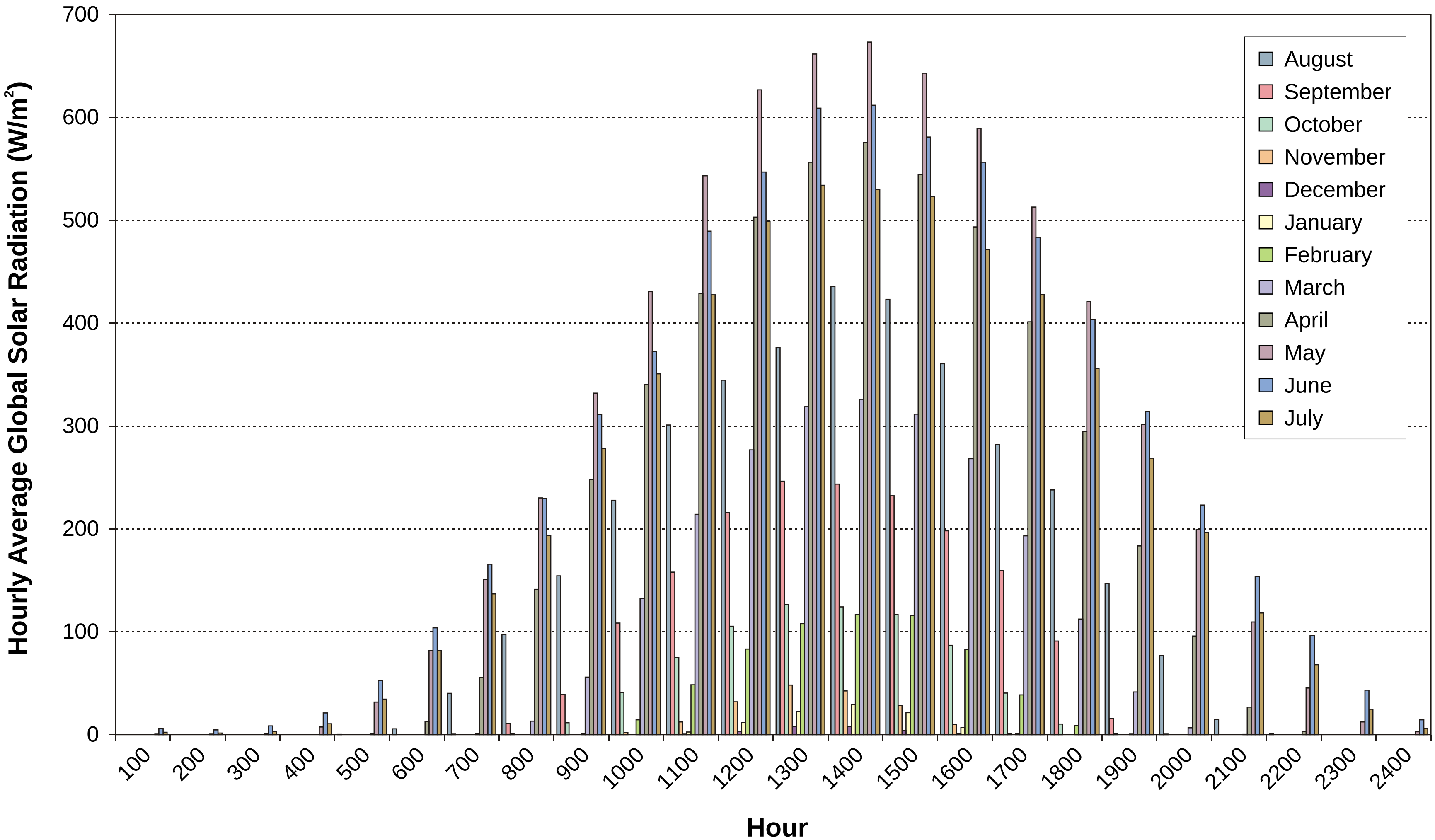
Open water or lake evaporation may be estimated by applying a coefficient to the Class A pan evaporation. Pan evaporation is almost always higher than lake evaporation because of radiation and boundary effects. Pan coefficients for the Yellowknife airport for 1992 to 1994 were in the range 0.69 to 0.72 (Reid, 1996) and a mean pan coefficient of 0.77 was reported by Linacre (1994) for the U.S.

If a pan coefficient of 0.75 is applied to the 1997 Class A pan data for an assumed open-water season at the Boston site (124 days), an estimated lake evaporation of 288 mm is obtained. In absence of more site-specific information it is assumed that the open water evaporation at the Bathurst port site would be approximately the same. Pending further studies the open water evaporation at the Bathurst Inlet site would likely be between 250 and 300 mm. (Mr. Bob Reid, Head-Water Resources/Water Management, Canadian Department of Indian Affairs and Northern Development (DIAND), personal communication (email) to Dan Jarratt, P.Eng., Rescan Environmental Services Ltd., November 21, 2002)

3.5 Solar Radiation

The silicon pyranometer at the Bathurst meteorology station measures global solar radiation which is the total incoming direct and diffuse short-wave solar radiation received from the whole dome of the sky on a horizontal surface measured in Watts per square meter (W/m^2). Figure 3.5-1 summarizes the hourly average global solar radiation values recorded for August 22, 2001 to the end of July 2002.

The most intense solar radiation occurs during July and gradually declines during August and September. The peak values recorded during mid-day in July are roughly 650 W/m^2. A similar instrument located near the equator would record peak values near 1,000 W/m^2. The latitude of



Bathurst Inlet Meteorological Station Global Solar Radiation
August 2001 to July 2002

FIGURE 3.5-1

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the Bathurst site (66º31’) causes the solar radiation to be less intense. Solar radiation data can be used to calculate the length of growing seasons and assist in the selection of vegetation for reclamation programs.

The hours of daylight at the Bathurst site vary depending upon the time of year. During July there are almost 24 hours of daylight and during January there are almost 24 hours of darkness. According to the Environment Canada Climate Atlas for Canada the mean number of hours of bright sunshine for the Bathurst site would be approximately 1,680 hours (70 days) per year. This was based upon data collected between 1951 and 1980.

3.6 Arctic Inversions and Ice Fog

The term “inversion” refers to a layer in the atmosphere in which there is an increase in air temperature with height. This differs from normal tropospheric conditions in which temperature decreases with height from the surface. Generally, an inversion layer is characterized by static stability so that a unit of air displaced vertically has a tendency to return to its original level. Polar inversions are generally caused by an energy deficit at the surface. The presence of Arctic inversion is closely related to the snow and ice surfaces that exist in the Arctic regions. For this reason, this low level inversion feature is present almost continuously over the entire Arctic region in winter and over snow and ice covered areas during the summer. The combination of the long duration of calm or light winds and persistent Arctic inversion provides one striking indicator of the high potential for poor air quality in the Canadian Arctic (Environment Canada, 1983).

Table 3.6-1 summarizes the mean number of days per month with surface based inversions at Cambridge Bay Airport and Kugluktuk (Coppermine) for 1100 and 2300 GMT. Upper air inversions occur less frequently than surface based inversions. The mean number of days per month with surface based inversions at the Bathurst site (based on the period 1967 to 1976) is approximately 20.5 (67%) during December to May at 1100 GMT. During June to November the mean number of days per month with surface based inversions at 1100 GMT falls to approximately 13.1 (43%). Surface based inversions at Bathurst Inlet at 2300 GMT have roughly the same mean number of days as 1100 GMT except the mean number of days per month decreases substantially to 6.4 (21%) from March to November. The lowest inversion thickness values occur during June to September and the highest in November to March. Generally, the main inversion layer is 1,000 to 1,500 m thick in winter, decreasing to 200 to 400 m by summer.

The phenomenon of ice fog is important in the Arctic because of its potential for disrupting both air and ground transport in the area – effects that must be considered in the construction of facilities such as pipeline pumping stations, buildings and roads. Ice fog has been studied in some detail by various authors. Environment Canada meteorological stations report “ice fog” when “a suspension of numerous minute ice crystals in the air” reduces visibility to 10 km (6 miles) or less (Environment Canada 1983). The mean number of days per month with ice fog

Table 3.6-1
Mean Number of Days with Surface Based Inversions at 1100 and 2300 GMT[1]

Station	Month												Annual Total
	J	F	M	A	M	J	J	A	S	O	N	D	
At 1100 GMT													
Cambridge Bay	23.9	21.6	24.8	24.0	24.8	12.9	13.3	13.3	12.6	13.0	12.6	23.9	220.7
Kugluktuk (Coppermine)	20.2	18.2	21.1	20.4	21.1	13.5	14.0	14.0	12.3	12.7	12.3	20.2	199.8
Bathurst Inlet[1]	20.2	18.2	21.7	21.0	21.7	14.1	14.6	14.6	11.7	12.1	11.7	20.2	201.6
At 2300 GMT													
Cambridge Bay	23.3	21.0	7.8	7.5	7.8	3.0	3.1	3.1	10.5	10.9	10.5	23.3	131.6
Kugluktuk (Coppermine)	19.8	17.9	7.8	7.5	7.8	6.6	6.8	6.8	8.4	8.7	8.4	19.8	126.3
Bathurst Inlet[1]	19.8	17.9	6.8	6.6	6.8	3.0	3.1	3.1	9.3	9.6	9.3	19.8	115.3

Period of record: Cambridge Bay Airport (1970 to 1976).
Kugluktuk (Coppermine) (1967 to 1970).
1: These values were extrapolated from percentage isolines produced by gridding data from regional meteorological stations.
***Source:* Environment Canada (1983).**

and blowing snow for selected stations near Bathurst Inlet are summarized in Table 3.6-2. The total number of days with fog per year is between 28 and 54 and the total number of days per year with blowing snow is between 48 and 77. The ice fog season is generally restricted to the November through April period although it may begin or end a month earlier or later, respectively, depending upon the particular location. The month of maximum mean percentage occurrence is equally likely to be January, February or March. Ice fog and blowing snow are of particular importance for the Bathurst Inlet Port and Road project because it has the potential to disrupt travel along the road, mostly during November to April. Based on the regional data the Bathurst Inlet site would be expected to have limited visibility caused by either fog, ice fog, freezing fog or blowing snow between 76 and 131 days per year.

Table 3.6-2
Mean Number of Days with Ice Fog or Blowing Snow at Regional Meteorology Stations (1971 to 2000) [1,2]

Station	Parameter	Month												Annual Total
		J	F	M	A	M	J	J	A	S	O	N	D	
Cambridge Bay Airport	Fog, Ice Fog or Freezing Fog	3.9	5.1	4.2	3.3	6.8	5.3	4.7	3.8	5.6	5.7	2.3	3.1	53.6
	Blowing Snow	13.0	11.5	10.8	7.3	4.7	0.63	0.0	0.13	1.2	8.0	9.0	10.8	77.1
Kugluktuk (Coppermine) Airport	Fog, Ice Fog or Freezing Fog	1.8	2.2	1.7	3.6	5.1	3.3	2.0	2.0	2.1	1.6	1.0	1.5	27.8
	Blowing Snow	9.4	9.5	6.5	2.9	1.1	0.0	0.0	0.0	0.26	4.3	5.2	9.0	48.1

Notes : [1]: No data available for Lupin Airport.
[2]: *Source:* MSC 2002b

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APPENDIX A – SUMMARY OF MEAN DAILY AIR TEMPERATURE AT BATHURST INLET STATION (AUGUST 2001 TO AUGUST 2002)

Appendix A
Summary of Mean Daily Air Temperature at Bathurst Inlet Station, August 2001 to August 2002

Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)
01-Aug-01	n/a	01-Sep-01	13.59	01-Oct-01	0.16	01-Nov-01	-14.65	01-Dec-01	-19.39	01-Jan-02	-19.01	01-Feb-02	-26.91
02-Aug-01	n/a	02-Sep-01	13.09	02-Oct-01	1.66	02-Nov-01	-16.50	02-Dec-01	-21.97	02-Jan-02	-21.49	02-Feb-02	-22.86
03-Aug-01	n/a	03-Sep-01	15.29	03-Oct-01	-3.96	03-Nov-01	-17.01	03-Dec-01	-24.34	03-Jan-02	-17.16	03-Feb-02	-28.00
04-Aug-01	n/a	04-Sep-01	13.34	04-Oct-01	-5.22	04-Nov-01	-15.10	04-Dec-01	-23.73	04-Jan-02	-18.28	04-Feb-02	-33.82
05-Aug-01	n/a	05-Sep-01	9.81	05-Oct-01	-4.58	05-Nov-01	-8.57	05-Dec-01	-24.02	05-Jan-02	-26.15	05-Feb-02	-32.04
06-Aug-01	n/a	06-Sep-01	7.62	06-Oct-01	1.38	06-Nov-01	-12.32	06-Dec-01	-26.11	06-Jan-02	-23.99	06-Feb-02	-30.29
07-Aug-01	n/a	07-Sep-01	4.62	07-Oct-01	2.57	07-Nov-01	-18.50	07-Dec-01	-24.22	07-Jan-02	-14.49	07-Feb-02	-32.54
08-Aug-01	n/a	08-Sep-01	5.55	08-Oct-01	-3.33	08-Nov-01	-18.24	08-Dec-01	-21.95	08-Jan-02	-13.60	08-Feb-02	-32.05
09-Aug-01	n/a	09-Sep-01	4.95	09-Oct-01	-3.28	09-Nov-01	-18.70	09-Dec-01	-22.80	09-Jan-02	-15.52	09-Feb-02	-29.09
10-Aug-01	n/a	10-Sep-01	4.78	10-Oct-01	-2.58	10-Nov-01	-18.58	10-Dec-01	-19.83	10-Jan-02	-19.78	10-Feb-02	-26.18
11-Aug-01	n/a	11-Sep-01	8.66	11-Oct-01	-1.60	11-Nov-01	-21.62	11-Dec-01	-21.35	11-Jan-02	-17.89	11-Feb-02	-29.16
12-Aug-01	n/a	12-Sep-01	10.96	12-Oct-01	-0.53	12-Nov-01	-17.61	12-Dec-01	-25.05	12-Jan-02	-20.75	12-Feb-02	-27.75
13-Aug-01	n/a	13-Sep-01	10.55	13-Oct-01	-0.51	13-Nov-01	-19.68	13-Dec-01	-26.46	13-Jan-02	-21.39	13-Feb-02	-33.01
14-Aug-01	n/a	14-Sep-01	12.01	14-Oct-01	-7.61	14-Nov-01	-27.61	14-Dec-01	-26.80	14-Jan-02	-18.48	14-Feb-02	-33.20
15-Aug-01	n/a	15-Sep-01	6.24	15-Oct-01	-9.96	15-Nov-01	-25.38	15-Dec-01	-23.96	15-Jan-02	-27.00	15-Feb-02	-30.96
16-Aug-01	n/a	16-Sep-01	4.67	16-Oct-01	-9.31	16-Nov-01	-13.73	16-Dec-01	-16.07	16-Jan-02	-27.15	16-Feb-02	-30.90
17-Aug-01	n/a	17-Sep-01	4.56	17-Oct-01	-10.14	17-Nov-01	-7.86	17-Dec-01	-23.17	17-Jan-02	-28.95	17-Feb-02	-35.12
18-Aug-01	n/a	18-Sep-01	-0.13	18-Oct-01	-9.61	18-Nov-01	-13.14	18-Dec-01	-22.62	18-Jan-02	-33.49	18-Feb-02	-31.18
19-Aug-01	n/a	19-Sep-01	0.65	19-Oct-01	-7.96	19-Nov-01	-13.50	19-Dec-01	-21.20	19-Jan-02	-38.69	19-Feb-02	-28.88
20-Aug-01	n/a	20-Sep-01	-0.82	20-Oct-01	-8.59	20-Nov-01	-19.39	20-Dec-01	-20.01	20-Jan-02	-36.34	20-Feb-02	-24.90
21-Aug-01	n/a	21-Sep-01	-1.31	21-Oct-01	-10.13	21-Nov-01	-22.62	21-Dec-01	-23.66	21-Jan-02	-36.30	21-Feb-02	-26.47
22-Aug-01	5.42	22-Sep-01	1.24	22-Oct-01	-11.59	22-Nov-01	-14.93	22-Dec-01	-17.32	22-Jan-02	-33.80	22-Feb-02	-25.66
23-Aug-01	8.77	23-Sep-01	4.30	23-Oct-01	-15.47	23-Nov-01	-23.86	23-Dec-01	-16.93	23-Jan-02	-34.39	23-Feb-02	-26.56
24-Aug-01	9.36	24-Sep-01	10.12	24-Oct-01	-18.02	24-Nov-01	-24.34	24-Dec-01	-14.86	24-Jan-02	-27.13	24-Feb-02	-23.41
25-Aug-01	8.33	25-Sep-01	9.01	25-Oct-01	-16.26	25-Nov-01	-22.45	25-Dec-01	-6.80	25-Jan-02	-26.23	25-Feb-02	-22.13
26-Aug-01	9.17	26-Sep-01	9.52	26-Oct-01	-14.14	26-Nov-01	-20.69	26-Dec-01	-17.11	26-Jan-02	-34.19	26-Feb-02	-32.53
27-Aug-01	9.72	27-Sep-01	10.13	27-Oct-01	-15.11	27-Nov-01	-21.11	27-Dec-01	-19.79	27-Jan-02	-32.43	27-Feb-02	-28.91
28-Aug-01	10.10	28-Sep-01	5.64	28-Oct-01	-16.41	28-Nov-01	-20.74	28-Dec-01	-19.45	28-Jan-02	-32.12	28-Feb-02	-25.70
29-Aug-01	8.56	29-Sep-01	0.39	29-Oct-01	-18.15	29-Nov-01	-15.14	29-Dec-01	-15.01	29-Jan-02	-33.84	mean	-28.94
30-Aug-01	10.80	30-Sep-01	0.10	30-Oct-01	-14.90	30-Nov-01	-13.36	30-Dec-01	-11.40	30-Jan-02	-33.15		
31-Aug-01	12.76	mean	6.64	31-Oct-00	-14.62	mean	-17.90	31-Dec-00	-12.37	31-Jan-02	-32.19		
mean	9.30			mean	-7.99			mean	-20.31	mean	-26.30		

(continued)

Appendix A

Summary of Mean Daily Air Temperature at Bathurst Inlet Station, August 2001 to August 2002

Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)	Date	Mean Daily Temperature (°C)
01-Mar-02	-27.33	01-Apr-02	-26.59	01-May-02	-18.54	01-Jun-02	-2.41	01-Jul-02	17.62	01-Aug-02	6.31
02-Mar-02	-16.39	02-Apr-02	-23.93	02-May-02	-17.62	02-Jun-02	-2.16	02-Jul-02	18.55	02-Aug-02	7.63
03-Mar-02	-25.38	03-Apr-02	-21.62	03-May-02	-16.65	03-Jun-02	0.39	03-Jul-02	11.93	03-Aug-02	9.58
04-Mar-02	-28.24	04-Apr-02	-21.13	04-May-02	-17.04	04-Jun-02	4.57	04-Jul-02	15.47	04-Aug-02	12.40
05-Mar-02	-27.22	05-Apr-02	-22.43	05-May-02	-13.49	05-Jun-02	5.02	05-Jul-02	7.29	05-Aug-02	16.62
06-Mar-02	-23.88	06-Apr-02	-16.26	06-May-02	-11.21	06-Jun-02	1.80	06-Jul-02	6.38	06-Aug-02	13.33
07-Mar-02	-23.96	07-Apr-02	-21.08	07-May-02	-9.95	07-Jun-02	1.68	07-Jul-02	6.67	07-Aug-02	n/a
08-Mar-02	-25.41	08-Apr-02	-28.04	08-May-02	-10.42	08-Jun-02	8.79	08-Jul-02	11.89	08-Aug-02	n/a
09-Mar-02	-33.27	09-Apr-02	-25.88	09-May-02	-12.05	09-Jun-02	12.80	09-Jul-02	17.02	09-Aug-02	n/a
10-Mar-02	-31.90	10-Apr-02	-26.05	10-May-02	-10.41	10-Jun-02	13.47	10-Jul-02	12.78	10-Aug-02	n/a
11-Mar-02	-29.92	11-Apr-02	-26.78	11-May-02	-9.73	11-Jun-02	10.34	11-Jul-02	12.91	11-Aug-02	n/a
12-Mar-02	-32.01	12-Apr-02	-21.79	12-May-02	-8.42	12-Jun-02	7.92	12-Jul-02	12.51	12-Aug-02	n/a
13-Mar-02	-24.62	13-Apr-02	-20.18	13-May-02	-9.74	13-Jun-02	1.25	13-Jul-02	9.95	13-Aug-02	n/a
14-Mar-02	-24.27	14-Apr-02	-23.72	14-May-02	-7.13	14-Jun-02	n/a	14-Jul-02	13.57	14-Aug-02	n/a
15-Mar-02	-28.64	15-Apr-02	-20.81	15-May-02	0.65	15-Jun-02	2.95	15-Jul-02	13.68	15-Aug-02	n/a
16-Mar-02	-28.78	16-Apr-02	-13.40	16-May-02	0.29	16-Jun-02	4.89	16-Jul-02	10.33	16-Aug-02	n/a
17-Mar-02	-30.15	17-Apr-02	-17.49	17-May-02	3.37	17-Jun-02	n/a	17-Jul-02	10.30	17-Aug-02	n/a
18-Mar-02	-26.46	18-Apr-02	-15.77	18-May-02	1.69	18-Jun-02	n/a	18-Jul-02	14.45	18-Aug-02	n/a
19-Mar-02	-27.24	19-Apr-02	-8.26	19-May-02	-1.12	19-Jun-02	7.34	19-Jul-02	10.80	19-Aug-02	n/a
20-Mar-02	-17.80	20-Apr-02	-11.81	20-May-02	-4.09	20-Jun-02	6.98	20-Jul-02	11.13	20-Aug-02	n/a
21-Mar-02	-12.79	21-Apr-02	-16.35	21-May-02	-9.87	21-Jun-02	4.39	21-Jul-02	14.34	21-Aug-02	n/a
22-Mar-02	-13.82	22-Apr-02	-21.61	22-May-02	-9.07	22-Jun-02	9.39	22-Jul-02	17.88	22-Aug-02	n/a
23-Mar-02	-14.46	23-Apr-02	-20.38	23-May-02	-2.22	23-Jun-02	6.04	23-Jul-02	17.88	23-Aug-02	n/a
24-Mar-02	-14.21	24-Apr-02	-17.87	24-May-02	-2.13	24-Jun-02	13.58	24-Jul-02	16.58	24-Aug-02	n/a
25-Mar-02	-18.35	25-Apr-02	-15.26	25-May-02	-3.05	25-Jun-02	16.40	25-Jul-02	18.52	25-Aug-02	n/a
26-Mar-02	-15.65	26-Apr-02	-8.86	26-May-02	-4.63	26-Jun-02	16.60	26-Jul-02	10.58	26-Aug-02	n/a
27-Mar-02	-19.27	27-Apr-02	-5.85	27-May-02	-6.53	27-Jun-02	15.60	27-Jul-02	10.33	27-Aug-02	n/a
28-Mar-02	-28.20	28-Apr-02	-5.69	28-May-02	-3.07	28-Jun-02	15.99	28-Jul-02	11.42	28-Aug-02	n/a
29-Mar-02	-31.43	29-Apr-02	-12.11	29-May-02	-2.12	29-Jun-02	16.90	29-Jul-02	9.10	29-Aug-02	n/a
30-Mar-02	-30.66	30-Apr-02	-17.43	30-May-02	-1.25	30-Jun-02	17.80	30-Jul-02	6.86	30-Aug-02	n/a
31-Mar-02	-27.75	mean	-18.48	31-May-02	-2.46	mean	8.09	31-Jul-02	5.46	31-Aug-02	n/a
mean	-24.50			mean	-7.03			mean	12.39	mean	10.98

APPENDIX B – SUMMARY OF TOTAL DAILY RAINFALL AT BATHURST INLET RECORDED WITH THE TIPPING BUCKET RAIN GAUGE (AUGUST 2001 TO AUGUST 2002)

Appendix B
Summary of Total Daily Rainfall at Bathurst Inlet Recorded with the Tipping Bucket Rain Gauge, August 2001 to August 2002

Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)
01-Aug-01	n/a	01-Sep-01	0.0	01-Oct-01	0.0	01-Nov-01	0.0	01-Dec-01	0.0	01-Jan-02	0.0	01-Feb-02	0.0
02-Aug-01	n/a	02-Sep-01	2.1	02-Oct-01	0.1	02-Nov-01	0.0	02-Dec-01	0.0	02-Jan-02	0.0	02-Feb-02	0.0
03-Aug-01	n/a	03-Sep-01	0.0	03-Oct-01	0.1	03-Nov-01	0.0	03-Dec-01	0.0	03-Jan-02	0.0	03-Feb-02	0.0
04-Aug-01	n/a	04-Sep-01	0.0	04-Oct-01	0.0	04-Nov-01	0.0	04-Dec-01	0.0	04-Jan-02	0.0	04-Feb-02	0.0
05-Aug-01	n/a	05-Sep-01	1.0	05-Oct-01	0.0	05-Nov-01	0.0	05-Dec-01	0.0	05-Jan-02	0.0	05-Feb-02	0.0
06-Aug-01	n/a	06-Sep-01	0.0	06-Oct-01	0.5	06-Nov-01	0.0	06-Dec-01	0.0	06-Jan-02	0.0	06-Feb-02	0.0
07-Aug-01	n/a	07-Sep-01	0.0	07-Oct-01	1.7	07-Nov-01	0.0	07-Dec-01	0.0	07-Jan-02	0.0	07-Feb-02	0.0
08-Aug-01	n/a	08-Sep-01	0.0	08-Oct-01	0.0	08-Nov-01	0.0	08-Dec-01	0.0	08-Jan-02	0.0	08-Feb-02	0.0
09-Aug-01	n/a	09-Sep-01	0.0	09-Oct-01	0.0	09-Nov-01	0.0	09-Dec-01	0.0	09-Jan-02	0.0	09-Feb-02	0.0
10-Aug-01	n/a	10-Sep-01	0.0	10-Oct-01	0.0	10-Nov-01	0.0	10-Dec-01	0.0	10-Jan-02	0.0	10-Feb-02	0.0
11-Aug-01	n/a	11-Sep-01	0.0	11-Oct-01	0.0	11-Nov-01	0.0	11-Dec-01	0.0	11-Jan-02	0.0	11-Feb-02	0.0
12-Aug-01	n/a	12-Sep-01	0.0	12-Oct-01	0.1	12-Nov-01	0.0	12-Dec-01	0.0	12-Jan-02	0.0	12-Feb-02	0.0
13-Aug-01	n/a	13-Sep-01	0.2	13-Oct-01	0.0	13-Nov-01	0.0	13-Dec-01	0.0	13-Jan-02	0.0	13-Feb-02	0.0
14-Aug-01	n/a	14-Sep-01	6.0	14-Oct-01	0.0	14-Nov-01	0.0	14-Dec-01	0.0	14-Jan-02	0.0	14-Feb-02	0.0
15-Aug-01	n/a	15-Sep-01	0.0	15-Oct-01	0.0	15-Nov-01	0.0	15-Dec-01	0.0	15-Jan-02	0.0	15-Feb-02	0.0
16-Aug-01	n/a	16-Sep-01	0.2	16-Oct-01	0.0	16-Nov-01	0.0	16-Dec-01	0.0	16-Jan-02	0.0	16-Feb-02	0.0
17-Aug-01	n/a	17-Sep-01	11.1	17-Oct-01	0.0	17-Nov-01	0.0	17-Dec-01	0.0	17-Jan-02	0.0	17-Feb-02	0.0
18-Aug-01	n/a	18-Sep-01	3.0	18-Oct-01	0.0	18-Nov-01	0.0	18-Dec-01	0.0	18-Jan-02	0.0	18-Feb-02	0.0
19-Aug-01	n/a	19-Sep-01	0.0	19-Oct-01	0.0	19-Nov-01	0.0	19-Dec-01	0.0	19-Jan-02	0.0	19-Feb-02	0.0
20-Aug-01	n/a	20-Sep-01	0.3	20-Oct-01	0.0	20-Nov-01	0.0	20-Dec-01	0.2	20-Jan-02	0.0	20-Feb-02	0.0
21-Aug-01	n/a	21-Sep-01	0.6	21-Oct-01	0.0	21-Nov-01	0.0	21-Dec-01	0.0	21-Jan-02	0.0	21-Feb-02	0.0
22-Aug-01	0.0	22-Sep-01	0.0	22-Oct-01	0.0	22-Nov-01	0.0	22-Dec-01	0.0	22-Jan-02	0.0	22-Feb-02	0.0
23-Aug-01	0.0	23-Sep-01	0.1	23-Oct-01	0.0	23-Nov-01	0.0	23-Dec-01	0.0	23-Jan-02	0.0	23-Feb-02	0.0
24-Aug-01	7.8	24-Sep-01	0.9	24-Oct-01	0.0	24-Nov-01	0.0	24-Dec-01	0.0	24-Jan-02	0.0	24-Feb-02	0.0
25-Aug-01	9.2	25-Sep-01	0.0	25-Oct-01	0.0	25-Nov-01	0.1	25-Dec-01	0.0	25-Jan-02	0.0	25-Feb-02	0.0
26-Aug-01	0.0	26-Sep-01	0.0	26-Oct-01	0.0	26-Nov-01	0.0	26-Dec-01	0.0	26-Jan-02	0.0	26-Feb-02	0.0
27-Aug-01	0.1	27-Sep-01	0.0	27-Oct-01	0.0	27-Nov-01	0.0	27-Dec-01	0.0	27-Jan-02	0.0	27-Feb-02	0.0
28-Aug-01	0.0	28-Sep-01	27.0	28-Oct-01	0.0	28-Nov-01	0.0	28-Dec-01	0.0	28-Jan-02	0.0	28-Feb-02	0.0
29-Aug-01	0.0	29-Sep-01	19.6	29-Oct-01	0.0	29-Nov-01	0.0	29-Dec-01	0.0	29-Jan-02	0.0		
30-Aug-01	0.0	30-Sep-01	0.0	30-Oct-01	0.0	30-Nov-01	0.0	30-Dec-01	0.1	30-Jan-02	0.0	total	0.0
31-Aug-01	0.0	total	72.1	31-Oct-01	0.0	total	0.1	31-Dec-01	0.0	31-Jan-02	0.0		
total	17.1			total	7.6			total	0.3	total	0.0		

(continued)

Appendix B
Summary of Total Daily Rainfall at Bathurst Inlet Recorded with the Tipping Bucket Rain Gauge, August 2001 to August 2002

Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)	Date	Daily Rain (mm)
01-Mar-02	0.0	01-Apr-02	0.0	01-May-02	0.0	01-Jun-02	0	01-Jul-02	0.0	01-Aug-02	0.0
02-Mar-02	2.3	02-Apr-02	0.0	02-May-02	0.0	02-Jun-02	0	02-Jul-02	0.5	02-Aug-02	0.0
03-Mar-02	0.0	03-Apr-02	0.0	03-May-02	0.0	03-Jun-02	0	03-Jul-02	0.7	03-Aug-02	0.0
04-Mar-02	0.0	04-Apr-02	0.0	04-May-02	0.0	04-Jun-02	0	04-Jul-02	0.0	04-Aug-02	0.1
05-Mar-02	0.0	05-Apr-02	0.0	05-May-02	0.0	05-Jun-02	0.4	05-Jul-02	0.4	05-Aug-02	0.1
06-Mar-02	0.0	06-Apr-02	0.0	06-May-02	0.0	06-Jun-02	0.1	06-Jul-02	0.0	06-Aug-02	0.5
07-Mar-02	0.0	07-Apr-02	0.0	07-May-02	0.0	07-Jun-02	0	07-Jul-02	0.4	07-Aug-02	n/a
08-Mar-02	0.0	08-Apr-02	0.0	08-May-02	0.0	08-Jun-02	0.1	08-Jul-02	0.1	08-Aug-02	n/a
09-Mar-02	0.0	09-Apr-02	0.0	09-May-02	0.0	09-Jun-02	0.1	09-Jul-02	8.3	09-Aug-02	n/a
10-Mar-02	0.0	10-Apr-02	0.0	10-May-02	0.0	10-Jun-02	0	10-Jul-02	3.9	10-Aug-02	n/a
11-Mar-02	0.0	11-Apr-02	0.0	11-May-02	0.0	11-Jun-02	0	11-Jul-02	0.0	11-Aug-02	n/a
12-Mar-02	0.0	12-Apr-02	0.0	12-May-02	0.0	12-Jun-02	0	12-Jul-02	0.0	12-Aug-02	n/a
13-Mar-02	0.0	13-Apr-02	0.0	13-May-02	0.0	13-Jun-02	6.8	13-Jul-02	0.5	13-Aug-02	n/a
14-Mar-02	0.0	14-Apr-02	0.0	14-May-02	0.0	14-Jun-02	1.5	14-Jul-02	0.0	14-Aug-02	n/a
15-Mar-02	0.0	15-Apr-02	0.0	15-May-02	0.0	15-Jun-02	0.1	15-Jul-02	0.0	15-Aug-02	n/a
16-Mar-02	0.0	16-Apr-02	0.0	16-May-02	0.0	16-Jun-02	0	16-Jul-02	0.9	16-Aug-02	n/a
17-Mar-02	0.0	17-Apr-02	0.0	17-May-02	0.0	17-Jun-02	0	17-Jul-02	0.4	17-Aug-02	n/a
18-Mar-02	0.0	18-Apr-02	0.0	18-May-02	0.0	18-Jun-02	0	18-Jul-02	0.0	18-Aug-02	n/a
19-Mar-02	0.0	19-Apr-02	0.0	19-May-02	0.0	19-Jun-02	0	19-Jul-02	0.0	19-Aug-02	n/a
20-Mar-02	0.0	20-Apr-02	0.0	20-May-02	0.0	20-Jun-02	2.9	20-Jul-02	0.0	20-Aug-02	n/a
21-Mar-02	0.0	21-Apr-02	0.0	21-May-02	0.0	21-Jun-02	2.4	21-Jul-02	0.0	21-Aug-02	n/a
22-Mar-02	0.0	22-Apr-02	0.0	22-May-02	0.0	22-Jun-02	1.9	22-Jul-02	0.0	22-Aug-02	n/a
23-Mar-02	0.0	23-Apr-02	0.0	23-May-02	0.0	23-Jun-02	20.6	23-Jul-02	0.0	23-Aug-02	n/a
24-Mar-02	0.0	24-Apr-02	0.0	24-May-02	0.1	24-Jun-02	0	24-Jul-02	0.0	24-Aug-02	n/a
25-Mar-02	0.0	25-Apr-02	0.0	25-May-02	0.3	25-Jun-02	0	25-Jul-02	0.2	25-Aug-02	n/a
26-Mar-02	0.0	26-Apr-02	0.0	26-May-02	0.0	26-Jun-02	0	26-Jul-02	0.0	26-Aug-02	n/a
27-Mar-02	0.0	27-Apr-02	0.1	27-May-02	0.1	27-Jun-02	2.8	27-Jul-02	0.0	27-Aug-02	n/a
28-Mar-02	0.0	28-Apr-02	0.9	28-May-02	0.0	28-Jun-02	0	28-Jul-02	0.0	28-Aug-02	n/a
29-Mar-02	0.0	29-Apr-02	0.1	29-May-02	0.0	29-Jun-02	0	29-Jul-02	5.5	29-Aug-02	n/a
30-Mar-02	0.0	30-Apr-02	0.0	30-May-02	0.0	30-Jun-02	0	30-Jul-02	0.0	30-Aug-02	n/a
31-Mar-02	0.0	total	1.1	31-May-02	0.0	total	39.7	31-Jul-02	0.0	31-Aug-02	n/a
total	2.3			total	0.5			total	21.8	total	0.7

APPENDIX C – SUMMARY OF RAIN AND SNOW-WATER-EQUIVALENT (SWE) PRECIPITATION AT BATHURST INLET (AUGUST 2001 TO AUGUST 2002)

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Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
22-Aug-01	0.0	0.0	0.0
23-Aug-01	0.0	0.0	0.0
24-Aug-01	7.8	0.0	7.8
25-Aug-01	9.2	0.0	9.2
26-Aug-01	0.0	0.0	0.0
27-Aug-01	0.1	0.0	0.1
28-Aug-01	0.0	0.0	0.0
29-Aug-01	0.0	0.0	0.0
30-Aug-01	0.0	0.0	0.0
31-Aug-01	0.0	0.0	0.0
Month total	**17.1**	**0.0**	**17.1**
01-Sep-01	0.0	0.1	0.1
02-Sep-01	2.1	0.0	2.1
03-Sep-01	0.0	0.0	0.0
04-Sep-01	0.0	0.1	0.1
05-Sep-01	1.0	0.0	1.0
06-Sep-01	0.0	0.0	0.0
07-Sep-01	0.0	0.0	0.0
08-Sep-01	0.0	0.1	0.1
09-Sep-01	0.0	0.1	0.1
10-Sep-01	0.0	0.0	0.0
11-Sep-01	0.0	0.1	0.1
12-Sep-01	0.0	0.0	0.0
13-Sep-01	0.2	0.0	0.2
14-Sep-01	6.0	0.0	6.0
15-Sep-01	0.0	0.7	0.7
16-Sep-01	0.2	0.0	0.2
17-Sep-01	11.1	0.6	11.7
18-Sep-01	3.0	0.0	3.0
19-Sep-01	0.0	0.0	0.0
20-Sep-01	0.3	0.0	0.3
21-Sep-01	0.6	0.0	0.6
22-Sep-01	0.0	0.1	0.1
23-Sep-01	0.1	0.0	0.1
24-Sep-01	0.9	0.0	0.9
25-Sep-01	0.0	0.0	0.0
26-Sep-01	0.0	0.6	0.6
27-Sep-01	0.0	0.0	0.0
28-Sep-01	27.0	0.0	27.0
29-Sep-01	19.6	0.4	20.0
30-Sep-01	0.0	0.0	0.0
Month total	**72.1**	**3.1**	**75.2**
01-Oct-01	0.0	0.0	0.0
02-Oct-01	0.1	0.6	0.7
03-Oct-01	0.1	0.0	0.1
04-Oct-01	0.0	0.1	0.1
05-Oct-01	0.0	0.1	0.1
06-Oct-01	0.5	0.0	0.5
07-Oct-01	1.7	0.3	2.0
08-Oct-01	0.0	0.0	0.0
09-Oct-01	0.0	0.1	0.1
10-Oct-01	0.0	0.0	0.0
11-Oct-01	0.0	0.0	0.0
12-Oct-01	0.1	0.6	0.7

(continued)

Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
13-Oct-01	0.0	11.6	11.6
14-Oct-01	0.0	0.0	0.0
15-Oct-01	0.0	0.0	0.0
16-Oct-01	0.0	0.0	0.0
17-Oct-01	0.0	1.6	1.6
18-Oct-01	0.0	0.0	0.0
19-Oct-01	0.0	0.0	0.0
20-Oct-01	0.0	0.6	0.6
21-Oct-01	0.0	0.0	0.0
22-Oct-01	0.0	0.4	0.4
23-Oct-01	0.0	0.0	0.0
24-Oct-01	0.0	0.0	0.0
25-Oct-01	0.0	0.4	0.4
26-Oct-01	0.0	0.0	0.0
27-Oct-01	0.0	0.6	0.6
28-Oct-01	0.0	0.0	0.0
29-Oct-01	0.0	0.0	0.0
30-Oct-01	0.0	9.4	9.4
31-Oct-01	0.0	0.0	0.0
Month total	**2.5**	**26.4**	**28.9**
01-Nov-01	0.0	6.1	6.1
02-Nov-01	0.0	6.2	6.2
03-Nov-01	0.0	0.0	0.0
04-Nov-01	0.0	14.1	14.1
05-Nov-01	0.0	0.0	0.0
06-Nov-01	0.0	0.0	0.0
07-Nov-01	0.0	0.0	0.0
08-Nov-01	0.0	0.4	0.4
09-Nov-01	0.0	0.0	0.0
10-Nov-01	0.0	0.0	0.0
11-Nov-01	0.0	0.1	0.1
12-Nov-01	0.0	0.0	0.0
13-Nov-01	0.0	0.7	0.7
14-Nov-01	0.0	0.0	0.0
15-Nov-01	0.0	0.6	0.6
16-Nov-01	0.0	0.0	0.0
17-Nov-01	0.0	0.0	0.0
18-Nov-01	0.0	0.1	0.1
19-Nov-01	0.0	5.6	5.6
20-Nov-01	0.0	0.0	0.0
21-Nov-01	0.0	0.0	0.0
22-Nov-01	0.0	0.0	0.0
23-Nov-01	0.0	0.0	0.0
24-Nov-01	0.0	0.0	0.0
11/25/201	0.1	0.3	0.4
26-Nov-01	0.0	0.0	0.0
27-Nov-01	0.0	0.3	0.3
28-Nov-01	0.0	0.3	0.3
29-Nov-01	0.0	2.7	2.7
30-Nov-01	0.0	4.9	4.9
Month total	**0.1**	**42.4**	**42.5**
01-Dec-01	0.0	0.0	0.0
02-Dec-01	0.0	0.0	0.0

(continued)

Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
03-Dec-01	0.0	0.0	0.0
04-Dec-01	0.0	0.0	0.0
05-Dec-01	0.0	0.0	0.0
06-Dec-01	0.0	0.0	0.0
07-Dec-01	0.0	0.3	0.3
08-Dec-01	0.0	0.0	0.0
09-Dec-01	0.0	0.6	0.6
10-Dec-01	0.0	0.0	0.0
11-Dec-01	0.0	0.0	0.0
12-Dec-01	0.0	0.1	0.1
13-Dec-01	0.0	0.1	0.1
14-Dec-01	0.0	0.0	0.0
15-Dec-01	0.0	0.0	0.0
16-Dec-01	0.0	2.0	2.0
17-Dec-01	0.0	0.0	0.0
18-Dec-01	0.0	0.0	0.0
19-Dec-01	0.0	0.1	0.1
20-Dec-01	0.2	0.0	0.2
21-Dec-01	0.0	0.6	0.6
22-Dec-01	0.0	0.0	0.0
23-Dec-01	0.0	0.0	0.0
24-Dec-01	0.0	0.3	0.3
25-Dec-01	0.0	0.0	0.0
26-Dec-01	0.0	0.0	0.0
27-Dec-01	0.0	0.1	0.1
28-Dec-01	0.0	0.0	0.0
29-Dec-01	0.0	0.0	0.0
30-Dec-01	0.1	0.3	0.4
31-Dec-01	0.0	0.0	0.0
Month total	**0.3**	**4.5**	**4.8**
01-Jan-02	0.0	0.0	0.0
02-Jan-02	0.0	0.3	0.3
03-Jan-02	0.0	0.0	0.0
04-Jan-02	0.0	0.0	0.0
05-Jan-02	0.0	0.0	0.0
06-Jan-02	0.0	0.4	0.4
07-Jan-02	0.0	0.0	0.0
08-Jan-02	0.0	0.1	0.1
09-Jan-02	0.0	0.0	0.0
10-Jan-02	0.0	0.0	0.0
11-Jan-02	0.0	1.3	1.3
12-Jan-02	0.0	0.0	0.0
13-Jan-02	0.0	0.1	0.1
14-Jan-02	0.0	0.0	0.0
15-Jan-02	0.0	0.0	0.0
16-Jan-02	0.0	0.0	0.0
17-Jan-02	0.0	0.0	0.0
18-Jan-02	0.0	0.0	0.0
19-Jan-02	0.0	0.0	0.0
20-Jan-02	0.0	0.0	0.0
21-Jan-02	0.0	0.3	0.3
22-Jan-02	0.0	0.0	0.0
23-Jan-02	0.0	0.1	0.1
24-Jan-02	0.0	0.4	0.4
25-Jan-02	0.0	0.0	0.0

(continued)

Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
26-Jan-02	0.0	0.0	0.0
27-Jan-02	0.0	0.7	0.7
28-Jan-02	0.0	0.0	0.0
29-Jan-02	0.0	0.0	0.0
30-Jan-02	0.0	0.4	0.4
31-Jan-02	0.0	0.8	0.8
Month total	**0.0**	**5.1**	**5.1**
01-Feb-02	0.0	0.4	0.4
02-Feb-02	0.0	0.0	0.0
03-Feb-02	0.0	0.3	0.3
04-Feb-02	0.0	0.0	0.0
05-Feb-02	0.0	0.0	0.0
06-Feb-02	0.0	0.0	0.0
07-Feb-02	0.0	0.0	0.0
08-Feb-02	0.0	0.3	0.3
09-Feb-02	0.0	0.1	0.1
10-Feb-02	0.0	0.1	0.1
11-Feb-02	0.0	0.0	0.0
12-Feb-02	0.0	0.0	0.0
13-Feb-02	0.0	0.0	0.0
14-Feb-02	0.0	0.0	0.0
15-Feb-02	0.0	0.4	0.4
16-Feb-02	0.0	0.0	0.0
17-Feb-02	0.0	1.0	1.0
18-Feb-02	0.0	0.0	0.0
19-Feb-02	0.0	0.4	0.4
20-Feb-02	0.0	0.0	0.0
21-Feb-02	0.0	1.3	1.3
22-Feb-02	0.0	0.0	0.0
23-Feb-02	0.0	0.3	0.3
24-Feb-02	0.0	0.1	0.1
25-Feb-02	0.0	0.0	0.0
26-Feb-02	0.0	0.0	0.0
27-Feb-02	0.0	0.0	0.0
28-Feb-02	0.0	0.0	0.0
Month total	**0.0**	**4.8**	**4.8**
01-Mar-02	0.0	0.0	0.0
02-Mar-02	2.3	0.4	2.7
03-Mar-02	0.0	0.0	0.0
04-Mar-02	0.0	0.1	0.1
05-Mar-02	0.0	0.0	0.0
06-Mar-02	0.0	0.3	0.3
07-Mar-02	0.0	0.1	0.1
08-Mar-02	0.0	0.0	0.0
09-Mar-02	0.0	0.0	0.0
10-Mar-02	0.0	0.1	0.1
11-Mar-02	0.0	0.3	0.3
12-Mar-02	0.0	0.0	0.0
13-Mar-02	0.0	0.4	0.4
14-Mar-02	0.0	0.0	0.0
15-Mar-02	0.0	0.0	0.0
16-Mar-02	0.0	0.0	0.0
17-Mar-02	0.0	0.7	0.7
18-Mar-02	0.0	0.0	0.0

(continued)

Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
19-Mar-02	0.0	0.6	0.6
20-Mar-02	0.0	0.0	0.0
21-Mar-02	0.0	47.0 (2.2) [1]	47.0 (2.2) [1]
22-Mar-02	0.0	0.0	0.0
24-Mar-02	0.0	0.1	0.1
25-Mar-02	0.0	0.0	0.0
26-Mar-02	0.0	0.1	0.1
27-Mar-02	0.0	0.0	0.0
28-Mar-02	0.0	0.0	0.0
29-Mar-02	0.0	0.0	0.0
30-Mar-02	0.0	0.1	0.1
31-Mar-02	0.0	0.0	0.0
Month total	**2.3**	**50.5 (6.6) [1]**	**52.8 (8.9) [1]**
01-Apr-02	0.0	0.0	0.0
02-Apr-02	0.0	0.6	0.6
03-Apr-02	0.0	0.0	0.0
04-Apr-02	0.0	0.3	0.3
05-Apr-02	0.0	0.0	0.0
06-Apr-02	0.0	0.1	0.1
07-Apr-02	0.0	0.0	0.0
08-Apr-02	0.0	0.1	0.1
09-Apr-02	0.0	0.0	0.0
10-Apr-02	0.0	1.0	1.0
11-Apr-02	0.0	0.6	0.6
12-Apr-02	0.0	0.0	0.0
13-Apr-02	0.0	0.0	0.0
14-Apr-02	0.0	0.0	0.0
15-Apr-02	0.0	0.6	0.6
16-Apr-02	0.0	0.0	0.0
17-Apr-02	0.0	0.0	0.0
18-Apr-02	0.0	0.1	0.1
19-Apr-02	0.0	0.0	0.0
20-Apr-02	0.0	4.1	4.1
21-Apr-02	0.0	0.0	0.0
22-Apr-02	0.0	0.0	0.0
23-Apr-02	0.0	0.1	0.1
24-Apr-02	0.0	0.0	0.0
25-Apr-02	0.0	0.7	0.7
26-Apr-02	0.0	0.0	0.0
27-Apr-02	0.1	0.0	0.1
28-Apr-02	0.9	2.0	2.9
29-Apr-02	0.1	0.0	0.1
30-Apr-02	0.0	0.0	0.0
Month Total	**1.1**	**10.3**	**11.3**
01-May-02	0.0	0.0	0.0
02-May-02	0.0	0.4	0.4
03-May-02	0.0	0.0	0.0
04-May-02	0.0	0.3	0.3
05-May-02	0.0	0.0	0.0
06-May-02	0.0	0.1	0.1
07-May-02	0.0	0.1	0.1
08-May-02	0.0	0.0	0.0
09-May-02	0.0	0.1	0.1
10-May-02	0.0	0.0	0.0
11-May-02	0.0	1.1	1.1
12-May-02	0.0	0.0	0.0

(continued)

Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
13-May-02	0.0	0.0	0.0
14-May-02	0.0	0.4	0.4
15-May-02	0.0	0.1	0.1
16-May-02	0.0	0.3	0.3
17-May-02	0.0	0.0	0.0
18-May-02	0.0	0.4	0.4
19-May-02	0.0	0.0	0.0
20-May-02	0.0	0.4	0.4
21-May-02	0.0	0.1	0.1
22-May-02	0.0	0.0	0.0
23-May-02	0.0	0.1	0.1
24-May-02	0.1	0.3	0.4
25-May-02	0.3	0.0	0.3
26-May-02	0.0	36.5 (2.7) [2]	36.5 (2.7) [2]
27-May-02	0.1	0.0	0.1
28-May-02	0.0	0.0	0.0
29-May-02	0.0	0.0	0.0
30-May-02	0.0	0.0	0.0
31-May-02	0.0	0.0	0.0
Month Total	**0.5**	**41.0 (8.3)** [2]	**41.5 (8.8)** [2]
01-Jun-02	0.0	0.0	0.0
02-Jun-02	0.0	0.1	0.1
03-Jun-02	0.0	0.0	0.0
04-Jun-02	0.0	0.0	0.0
05-Jun-02	0.4	0.1	0.5
06-Jun-02	0.1	0.3	0.4
07-Jun-02	0.0	0.0	0.0
08-Jun-02	0.1	0.1	0.2
09-Jun-02	0.1	0.0	0.1
10-Jun-02	0.0	0.4	0.4
11-Jun-02	0.0	0.1	0.1
12-Jun-02	0.0	0.0	0.0
13-Jun-02	6.8	0.6	7.4
14-Jun-02	1.5	0.0	1.5
15-Jun-02	0.1	0.0	0.1
16-Jun-02	0.0	0.0	0.0
17-Jun-02	0.0	0.1	0.1
18-Jun-02	0.0	0.0	0.0
19-Jun-02	0.0	0.0	0.0
20-Jun-02	2.9	0.1	3.0
21-Jun-02	2.4	0.0	2.4
22-Jun-02	1.9	0.3	2.2
23-Jun-02	20.6	0.0	20.6
24-Jun-02	0.0	0.3	0.3
25-Jun-02	0.0	0.1	0.1
26-Jun-02	0.0	0.0	0.0
27-Jun-02	2.8	0.4	3.2
28-Jun-02	0.0	0.0	0.0
29-Jun-02	0.0	0.3	0.3
30-Jun-02	0.0	0.0	0.0
Month Total	**39.7**	**3.5**	**43.2**
01-Jul-02	0.0	0.0	0.0
02-Jul-02	0.5	0.0	0.5
03-Jul-02	0.7	0.0	0.7
04-Jul-02	0.0	0.0	0.0
05-Jul-02	0.4	0.0	0.4
06-Jul-02	0.0	0.0	0.0

(continued)

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Appendix C
Summary of Rain and Snow-Water-Equivalent (SWE) Precipitation at Bathurst Inlet (August 22, 2001 to August 7, 2002)

Date	Daily Rain (mm)	Daily Total SWE (mm)	Daily Total Precip. (mm)
07-Jul-02	0.4	0.0	0.4
08-Jul-02	0.1	0.0	0.1
09-Jul-02	8.3	0.0	8.3
10-Jul-02	3.9	0.0	3.9
11-Jul-02	0.0	0.0	0.0
12-Jul-02	0.0	0.0	0.0
13-Jul-02	0.5	0.0	0.5
14-Jul-02	0.0	0.0	0.0
15-Jul-02	0.0	0.0	0.0
16-Jul-02	0.9	0.0	0.9
17-Jul-02	0.4	0.0	0.4
18-Jul-02	0.0	0.0	0.0
19-Jul-02	0.0	0.0	0.0
20-Jul-02	0.0	0.0	0.0
21-Jul-02	0.0	0.0	0.0
22-Jul-02	0.0	0.0	0.0
23-Jul-02	0.0	0.0	0.0
24-Jul-02	0.0	0.0	0.0
25-Jul-02	0.2	0.0	0.2
26-Jul-02	0.0	0.0	0.0
27-Jul-02	0.0	0.0	0.0
28-Jul-02	0.0	0.0	0.0
29-Jul-02	5.5	0.0	5.5
30-Jul-02	0.0	0.0	0.0
31-Jul-02	0.0	0.0	0.0
Month Total	**21.8**	**0.0**	**21.8**
01-Aug-02	0.0	0.0	0.0
02-Aug-02	0.0	0.0	0.0
03-Aug-02	0.0	0.0	0.0
04-Aug-02	0.1	0.0	0.1
05-Aug-02	0.1	0.0	0.1
06-Aug-02	0.5	0.0	0.5
07-Aug-02		0.0	0.0
Month Total	**0.7**	**0.0**	**0.7**
349 Day Total	**158.2**	**191.6 (115.0)** [1,2]	**349.8 (273.2)** [1,2]

(completed)

Notes 1: The SR50 Sonic Ranger recorded an unrealistic snow accumulation for March 21, 2002 - most likely caused by blowing snow under the SR50 sensor. The unrealistic value for snow accumulation on this day was replaced with that of the daily average for March 2002.

2: The SR50 Sonic Ranger recorded an unrealistic snow accumulation for May 26, 2002 - most likely caused by blowing snow under the SR50 sensor. The unrealistic value for snow accumulation on this day was replaced with that of the daily average for May 2002.