MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

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Glossary and Abbreviations

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

ANFO	Ammonium nitrate/fuel oil
CEA Agency	Canadian Environmental Assessment Agency
CFC	Chlorofluorocarbon
CH_4	Methane
CO	Carbon Monoxide
(CO_{2eq})	Carbon Dioxide Equivalent
ECCC	Environment and Climate Change Canada
EC-MSC	Environment Canada-Meteorological Services of Canada
EDMS	Emissions and Dispersion Modeling System
EIS	Environmental Impact Statement
ERM	ERM Consultants Canada Ltd.
GHG	Greenhouse gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometre
kt	Kilotonne (thousand tonnes)
m	metre
m^3	Cubic metre
mg	milligram
Mt	Megatonne (million tonnes)
NIRB	Nunavut Impact Review Board
N_2O	Nitrous Oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NTKP	Naonaiyaotit Traditional Knowledge Project
NWT	Northwest Territories

O_3	Ground-level ozone
PDA	Project development area
Rescan	Rescan Environmental Services Ltd.
SO_2	Sulphur dioxide
TIA	Tailings Impoundment Area (Doris)
TK	Traditional Knowledge
TMA	Tailings Management Area (Boston)
TMAC	TMAC Resources Inc.
US EPA	United States Environmental Protection Agency
VEC	Valued Ecosystem Component
VOC	Volatile Organic Compound

1. Climate and Meteorology

The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory (NU), and is situated east of Bathurst Inlet. The climate in the area is characterized by extremes. The Project area experiences relatively low amounts of precipitation, but due to sub-zero temperatures for the majority of the year, also experiences high snow accumulation. Summer is a season of nearly perpetual sunlight, while winter is dominated by night, twilight and extreme cold. Due to the relative absence of obstructions to impede the wind (e.g., trees, buildings, mountains), wind speeds are generally high.

Available baseline data has been used to help in Project design, for assessing potential effects on air quality, and for understanding trends in climate change. The following provides a summary of baseline meteorological conditions within the Madrid-Boston Project area, with detailed baseline reports included in Appendices V4-1A through V4-1H.

Climate and meteorology is addressed as Subject of Note and considers Project related effects on climate and meteorology through a comparison of estimated greenhouse gas (GHG) emissions to relevant sector, regional, national, and international GHG inventories as well as applicable regulatory thresholds related to GHG emission. Project effects on criteria air contaminants such as SO_2, NO_x, CO, VOCs and O_3 are covered in the air quality effects assessment (Volume 4, Chapter 2).

1.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

1.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The report *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project Naonaiyaotit Traditional Knowledge Project (NTKP)* report (NTKP report; Banci and Spicker 2016) was reviewed for information related to climate and meteorology. The TK report indicated that Inuit have seen many changes relating to climate over the past few decades, including: changes in weather, shallower lakes and rivers that drain to the ocean, reduction in river flow, and an increase in the length of time for the Arctic Ocean to freeze. Observations regarding climate change expressed by some of the individuals consulted include:

> *"Everywhere you go it's different now, compared to many years ago, due to climate change."* (NTKP report; pg. 90).
>
> *"The ice is thinner than many years ago. Both in lakes and the ocean."* (NTKP report; pg. 109).
>
> *"I was talking about trails, the difference between now and earlier years because of climate change (it is more difficult to travel now compared to the past because there is less snow). Back then it used to rain lots and lots of rain and snow. We don't get much snow nowadays compared to 40 years ago, 50 years ago."* (NTKP report; pg. 110*)*.
>
> *"That's one reason why our waters are so low. There's hardly any more snow."* (NTKP report; pg. 111).
>
> *"There is less snow all over."* (NTKP report; pg. 111).
>
> *"Talking about snow, igloo building snow, the quality is not there anymore. Over the winter you notice that the snow has turned into ice because there is hardly any fresh snow coming down. It turns into ice from all the wind and the age because there is no fresh stuff underneath."* (NTKP report; p 112).

These conclusions were similar to those of other regional TK studies carried out in the area (Thorpe et al. 2001). Comments made as part of these regional TK studies included:

- changes in snow consistency;
- thinning ice;
- decreased snowfall;
- longer summers, shorter winters;
- changes in berry picking locations due to warmer climate;
- changes in wildlife habits due to changes in climate; and
- increasing unpredictability and variability of the weather.

1.1.2 Incorporation of Traditional Knowledge for Subject of Note Selection

The results of the NTKP report (were used for scoping and refining the potential VEC, VSEC, and Subject of Note list (Volume 2, Chapter 4). The report presents clear maps of valued animal species, environmental components, and traditional land use activities. This information was used to determine if these valued aspects potentially interacted with the proposed Project, and if so, they were included in the VEC, VSEC, and Subject of Note list. There were several comments relating to climate and climate change as noted in Section 1.1.1, that indicates that that the Naonaiyaotit have experienced local climate change trends and thus supports inclusion of the climate and meteorology as a Subject of Note.

1.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The NTKP report includes several comments related to local trends in climate attributed to climate change over the past 20 to 50 years (see Section 1.1.1) and that the trends have been observed "everywhere". These observations over decades support consideration of climate change into the future and at a spatial scale beyond the historical ranges of the Naonaiyaotit.

1.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

Observation of local climate change trends in the NTKP report (see Section 1.1.1) support inclusion of climate and meteorology as a Subject of Note, though did not directly influence the methods used in the assessment that has been completed and presented in this chapter.

1.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

There are no references to mitigation or adaptive management measures in the available TK report and as there are not believed to be any mitigation methods prevalent in TK that could influence climate change, none are included in the management plan.

1.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

1.2.1 Data Sources

Baseline meteorological data and information was collected from primarily three data sources:

1. Site-specific meteorological monitoring program conducted from 2009 through 2014 that included monitoring stations in the Doris, Boston, and Roberts Bay areas (Appendices V4-1A through V4-1H). Additional data was collected prior to 2009 but did not conform to Environment Canada – Meteorological Service of Canada (EC-MSC) standards.

2. Inuit Traditional Knowledge (NTKP Report; Banci and Spicker 2016).
3. Environment Canada – Meteorological Service of Canada (EC-MSC) meteorological stations in the region. Climate normals and extremes currently offered by EC-MSC are based on Canadian climate stations with at least 15 years of data between 1981 to 2010 (EC 2015a).

1.2.2 Methods

Site-specific meteorological monitoring has been conducted in the Boston, Doris, and Roberts Bay areas for over 20 years (Figures 1.2-1 and 1.2-2). Both the Boston and Doris meteorological station sensors were moved from a tripod to a 10-m tower in August 2009 to have wind data available for atmospheric dispersion modeling (Plate 1.2-1 and Plate 1.2-2). The configuration of the permanent towers is consistent with the EC-MSC standard for sensor height used in the collection of meteorological data for atmospheric dispersion modelling (EC-MSC 2004). These stations continue to be operational and record temperature, precipitation, wind speed and direction, and solar radiation. In addition, a micro-meteorology station (micro-met) was installed for seasonal operation at Doris Lake in 2009. This station additionally gathers data (temperature, precipitation, wind speed and direction, and solar radiation) for the calculation of site-specific evaporation rates (Plate 1.2-3). From May 2011 to September 2012 a 3-m tripod was installed along the shore of Roberts Bay to measure wind speed and direction (Figure 1.2-2; Plate 1.2-4). Wind data collection at Roberts Bay was completed to gain an initial understanding of wind patterns near the marine terminal rather than to provide input for atmospheric dispersion modeling. Additional details on methods applied for the data collection at the Doris micro-meteorological station and Doris and Boston meteorological stations are available in appendices V4-1A through V4-1H.

Plate 1.2-1. Doris meteorology station, August 2009.

Plate 1.2-2. Boston meteorology station, August 2009.

Figure 1.2-1

Locations of the Environment Canada and Project Meteorological Stations

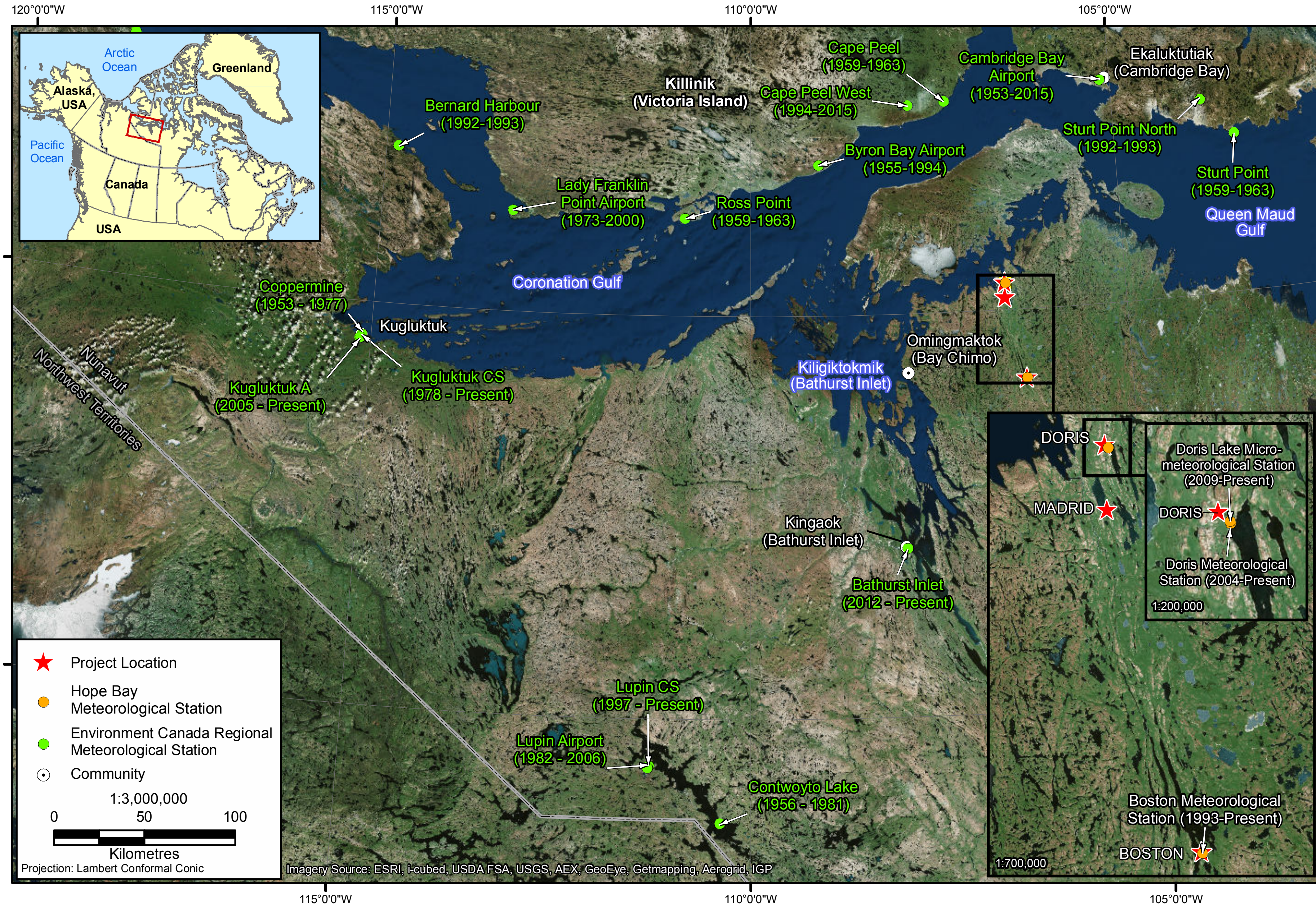

Figure 1.2-2
Locations of Project Meteorological Stations

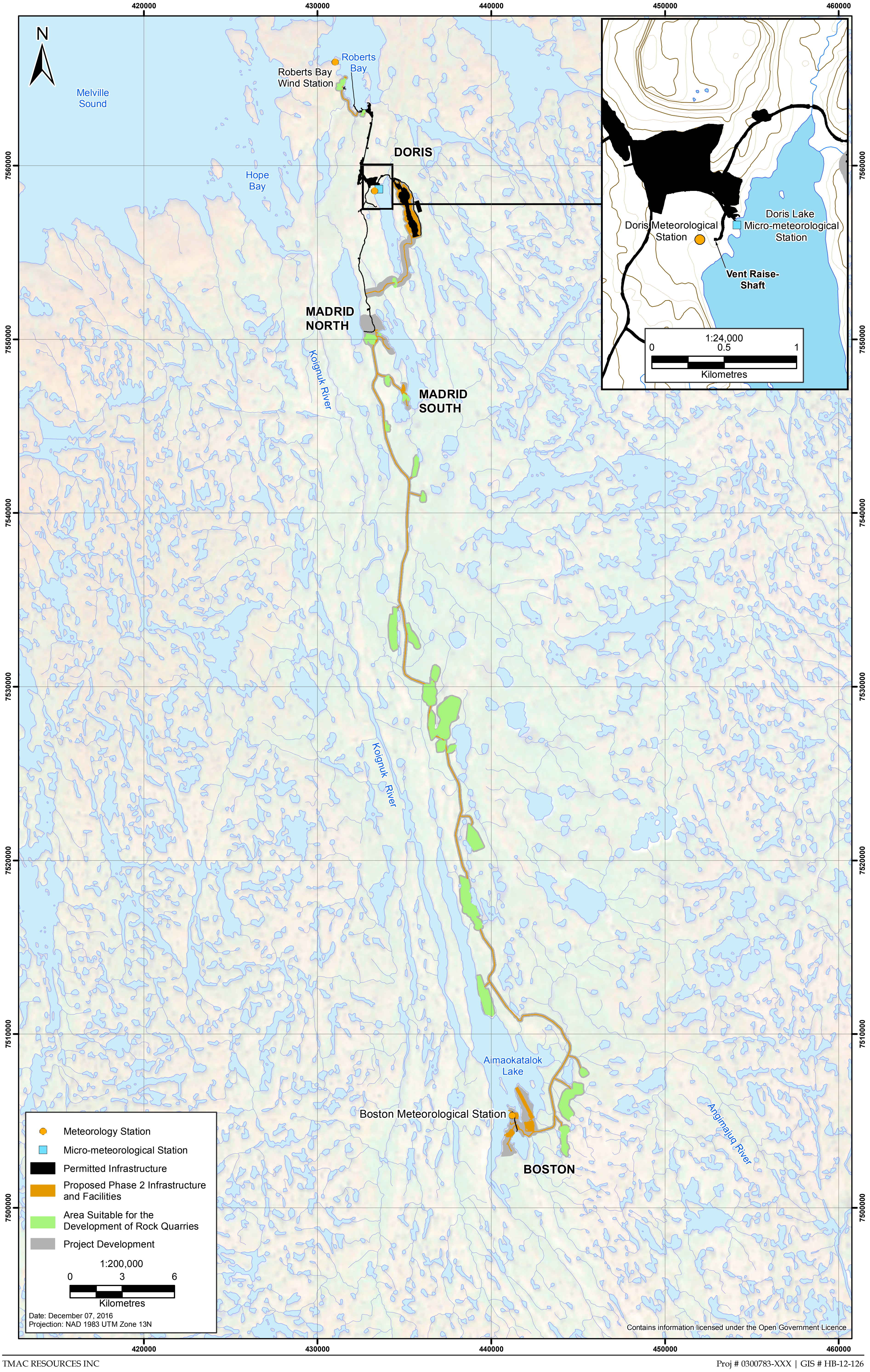

Plate 1.2-3. The Doris Lake micro-meteorological (evaporation) station, July 2013.

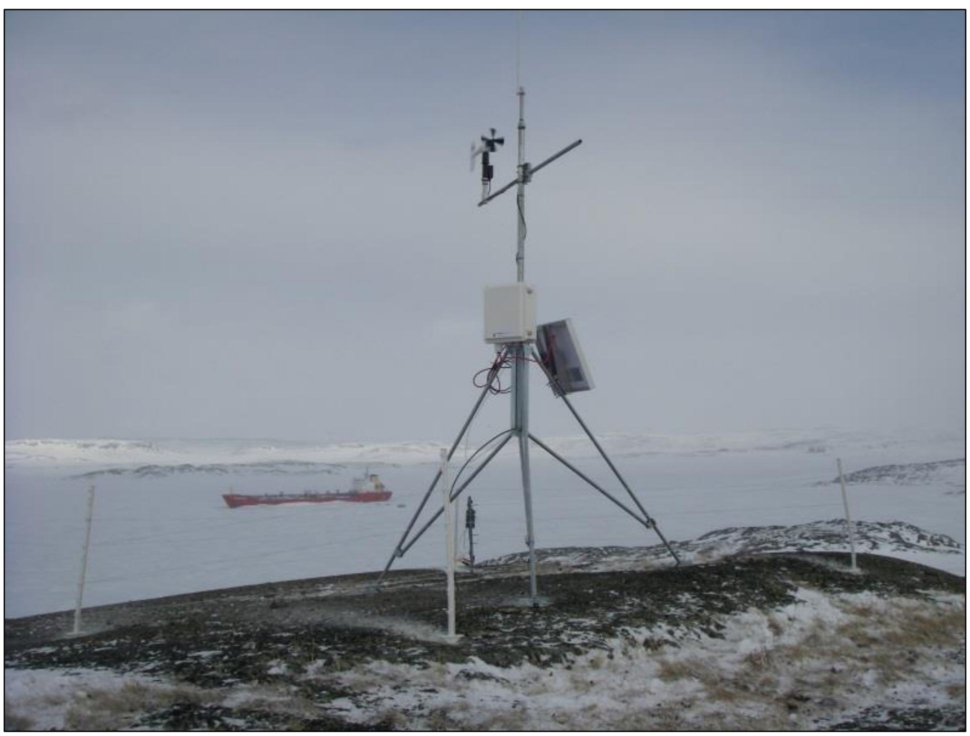

Plate 1.2-4. The Roberts Bay Wind Station, May 2011.

The closest EC-MSC meteorological stations that are currently operating are, in order of proximity to the Project, Cambridge A, Lupin A, and Kugluktuk A meteorological stations (Figure 1.2-1). Climate normal data (arithmetic averages of climate elements over a prescribed 30-year interval) from these EC-MSC stations are presented in the EIS. The most up-to-date climate normals and extremes currently offered by EC are based on Canadian climate stations with at least 15 years of data between 1981 to 2010 (EC 2015b).

1.2.2.1 Air Temperature

Table 1.2-1 provides monthly averages from the Doris and Boston Meteorological station. Figures 1.2-3 and 1.2-4 provide a graphical representation of daily average, maximum and minimum temperatures over the reported period. The annual average air temperatures for the Project area were colder than climate normals at the Lupin A and Kugluktuk A EC-MSC stations in 2009, 2013, and 2014 (Table 1.2-1). Annual average temperatures from the Project area in 2011 and 2012 were similar to climate normals recorded at these EC-MSC stations while the 2010 annual average air temperature were significantly warmer than the EC-MSC stations (Table 1.2-1). It is likely that there is no consistent difference in annual temperatures between the Project area and the Lupin A and Kugluktuk A EC-MSC stations and the year to year variability were the result of short-term local meteorological events. In contrast, the annual average air temperatures for the Project area was consistently warmer than the climate normals recorded at the Cambridge A EC-MSC meteorological station for all years, 2009 to 2014 (Table 1.2-1). Cambridge Bay being on Victoria Island away from the continental microthermal climate as well as being more northerly may account for the differences compared to the Project temperatures. Tables 1.2-2 and 1.2-3 summarize available data for each year for Doris and Boston, respectively.

For minimum and maximum air temperatures, the observations at the Doris and Boston meteorological stations from 2009 to 2014 indicate warmer minimums and generally cooler maximums in comparison to the regional climate normals based on Cambridge A, Lupin A, and Kugluktuk A EC-MSC stations (Table 1.2-1). The daily average maximum temperatures at the Doris and Boston meteorological stations over this period were 29.4ºC and 28.1ºC, respectively, both occurring on June 29, 2013. The daily minimum temperatures were -43.5ºC and -45.2ºC, respectively, both occurring on January 21, 2012. The record daily maximum temperature was 34.9ºC recorded at the Kugluktuk A station in July 1989 while the record daily minimum temperature was -52.8ºC which was recorded on January 1935 at the Cambridge A station.

1.2.2.2 Precipitation

The main factors that influence variation in precipitation include: local topography, proximity to sources of moisture, land use and ground cover. Generally, precipitation is greater in areas which are mountainous, close to a source of moisture such as a large waterbody, and in areas which experience convective heating. During the summer, precipitation in the Project Area is primarily affected by its proximity to the Arctic Ocean, while during the winter frontal weather systems typically have the most impact on precipitation. Typically, precipitation associated with frontal weather systems is evenly distributed over an area.

Climate normal precipitation ranges from 141.8 mm to 298.6 mm per year at the Cambridge A and Lupin A stations, respectively. This range is characteristic of this region (NRCan 2010; Table 1.2-4). Precipitation within the Project Area was measured as rainfall during the summer period (June, July, August, and September), when temperatures are above freezing (Table 1.2-4). During 2009 to 2014, summer monthly rainfall ranged from 1.3 mm (June 2010) to 41.7 mm (July 2014) for the Doris station. The Boston meteorological station precipitation gauge periodically malfunctioned in 2010, 2012, 2013 and June 2014 (Table 1.2-3). In comparison, the summer periods in 2011 and 2014 were complete (except June 2014). The Doris meteorological station summer total rainfall between June and September ranged from 47.8 mm (2012) to 97.8 mm (2011).

Figure 1.2-3

Doris Meteorological Station Maximum, Minimum and Average Daily Air Temperatures 2009 to 2014

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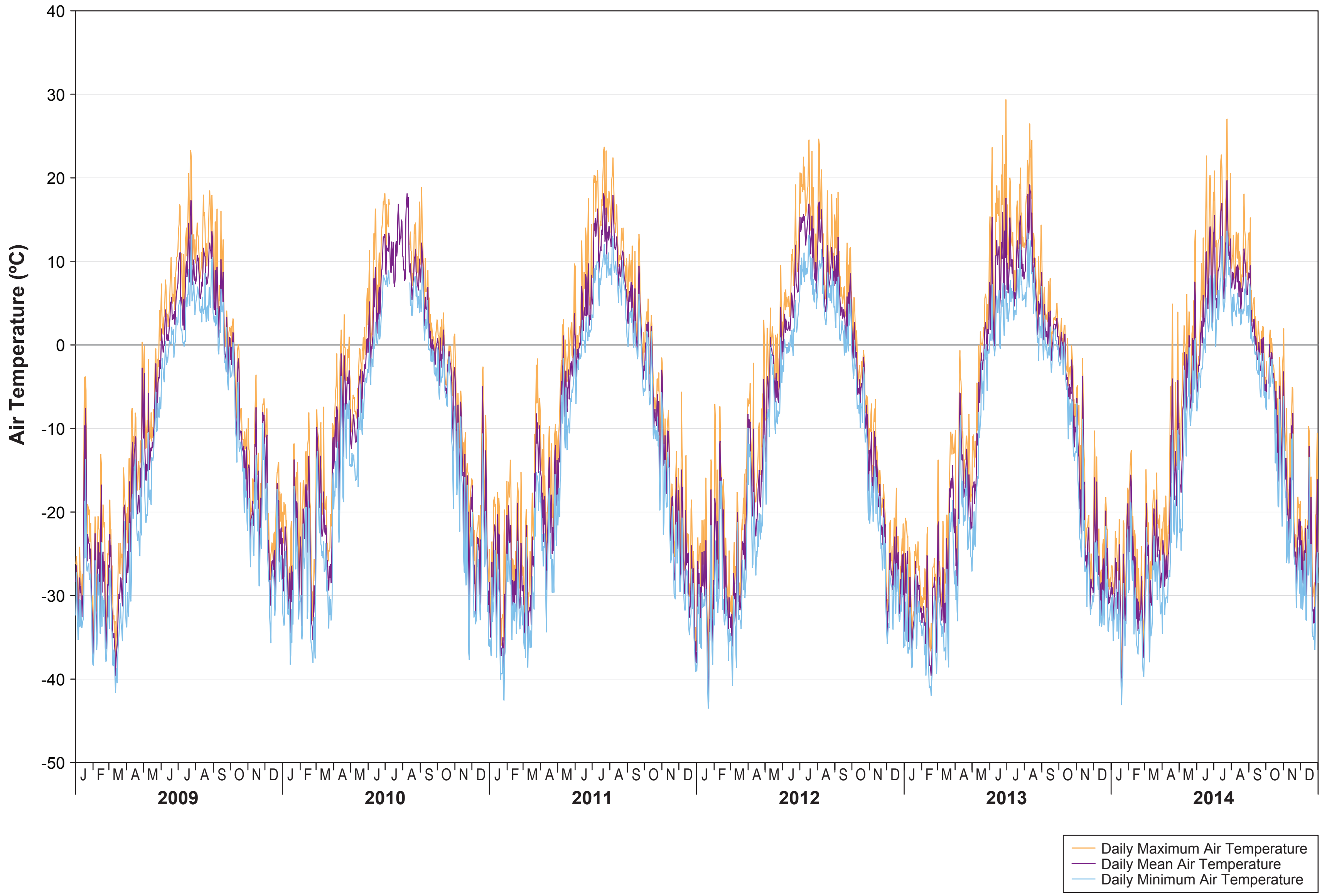


Figure 1.2-4

Boston Meteorological Station Maximum, Minimum and Average Daily Air Temperatures 2009 to 2014

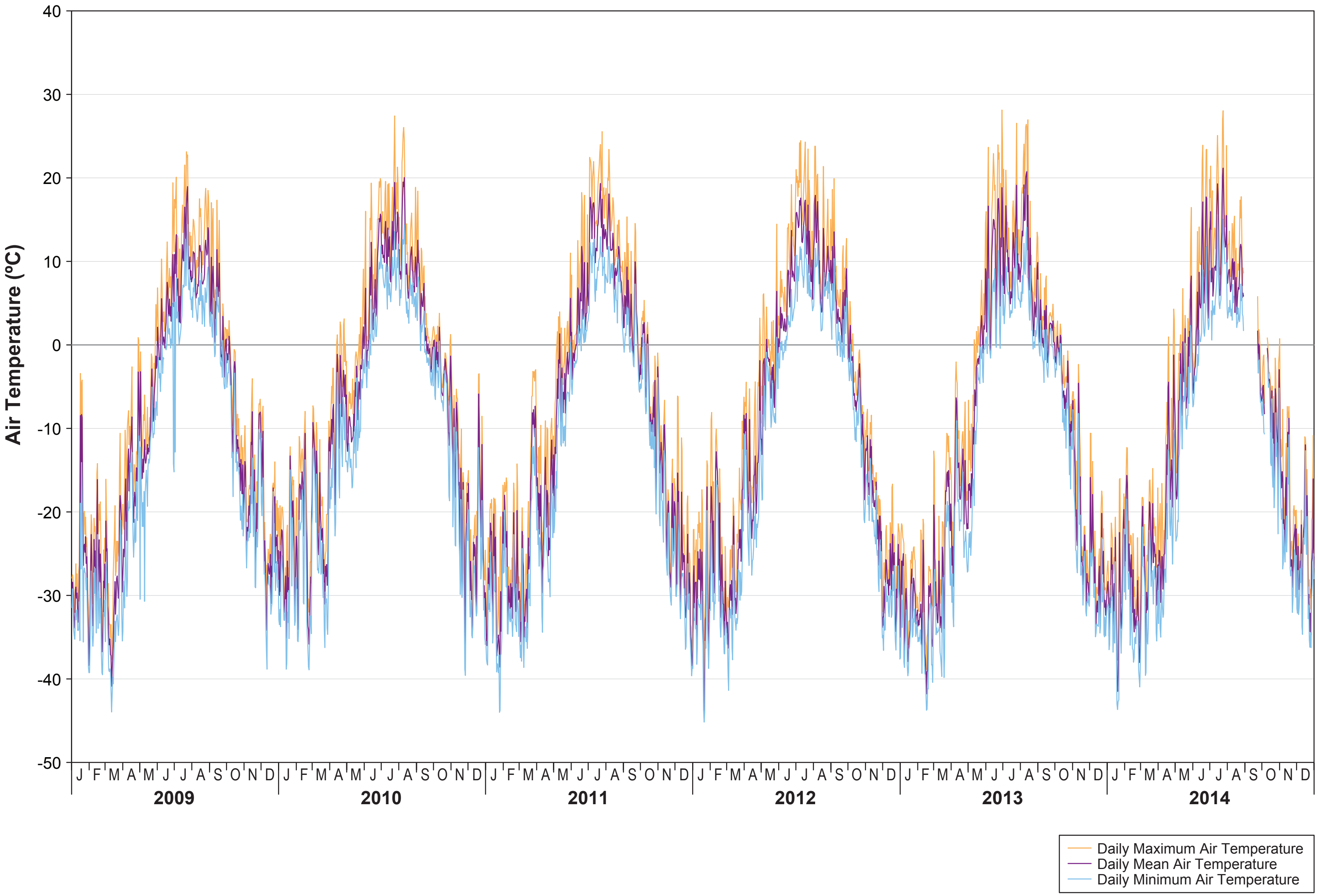


Table 1.2-1. Measured Monthly and Climate Normal Temperature (°C)

Month	2009		2010		2011		2012		2013		2014		Climate Normal (1981-2010)		
	Doris (°C)	Boston (°C)	Doris (°C)	Boston (°C)	Doris (°C)	Boston (°C)	Doris (°C)	Boston (°C)	Doris (°C)	Boston (°C)	Doris (°C)	Boston (°C)	Cambridge A (°C)	Lupin A (°C)	Kugluktuk A (°C)
Jan	-26.1	-26.7	-25.6	-25.8	-29.8	-29.9	-30.3	-30.4	-30.8	-31.4	-29.7	-30.0	-32.0	-29.9	-27.3
Feb	-28.7	-28.4	-25.0	-23.6	-27.1	-27.2	-25.2	-25.0	-33.3	-33.4	-28.3	-28.7	-32.5	-28.5	-27.7
Mar	-29.9	-30.0	-20.7	-20.5	-23.4	-23.0	-27.0	-26.8	-25.2	-25.4	-25.7	-26.1	-29.3	-24.8	-25.3
Apr	-17.3	-16.7	-8.1	-8.1	-19.8	-19.7	-15.6	-15.0	-17.6	-17.7	-18.7	-18.6	-20.8	-15.8	-16.3
May	-9.1	-9.6	-6.5	-6.8	-5.4	-5.1	-4.1	-3.5	-6.0	-5.8	-5.3	-4.9	-9.3	-5.9	-5.3
Jun	2.9	3.1	5.3	6.2	2.9	3.3	4.5	5.5	8.9	10.1	4.4	5.9	2.7	6.4	5.5
Jul	8.8	10.0	11.5	12.4	13.0	13.9	12.8	13.2	9.5	10.0	10.8	12.0	8.9	11.5	10.9
Aug	9.3	9.5	9.9	10.4	10.6	10.6	9.9	10.2	9.7	10.3	7.7	7.7[a]	6.8	8.8	9.0
Sep	3.4	3.6	3.0	2.8	3.0	2.8	5.2	5.2	1.7	1.6	0.5	-2.5[b]	0.3	2.1	3.3
Oct	-8.3	-9.2	-3.1	-3.5	-5.1	-5.3	-5.2	-6.0	-4.1	-4.7	-7.0	-7.6[c]	-10.4	-8.4	-6.6
Nov	-17.1	-17.3	-16.8	-17.4	-17.6	-18.0	-18.0	-18.8	-20.8	-21.4	-19.1	-19.9	-22.3	-20.4	-18.7
Dec	-23.0	-23.7	-23.6	-23.9	-27.4	-27.4	-28.1	-28.5	-26.6	-27.5	-25.8	-25.7	-28.3	-26.2	-24.5
Average	**-11.3**	**-11.3**	**-8.3**	**-8.1**	**-10.5**	**-10.4**	**-10.1**	**-10.0**	**-11.2**	**-11.3**	**-11.4**	**-11.5**	**-13.9**	**-10.9**	**-10.3**
Daily Minimum	**-41.6**	**-43.9**	**-38.3**	**-39.6**	**-42.6**	**-44.0**	**-43.5**	**-45.2**	**-42.0**	**-43.8**	**-43.1**	**-43.7**	**-52.8**	**-49.0**	**-47.3**
Daily Maximum	**23.3**	**23.1**	**18.9**	**27.4**	**23.7**	**25.5**	**24.6**	**24.4**	**29.4**	**28.1**	**27.0**	**28.0**	**28.9**	**27.5**	**34.9**

Notes:
[a] *Temperature data from August 30 and 31, 2014 is missing.*
[b] *Temperature data from September 1 through 22, 2014 is missing.*
[c] *Temperature data from October 5 through 9, 2014 is missing*

Table 1.2-2. Doris Meteorological Station Baseline Data Completeness

Parameter		Sampling Frequency	Data Completeness (%)						
			2009	2010	2011	2012	2013	2014	2015
Temperature	Average	Daily	100	100	100	100	100	99	100
	Maximum	Daily	100	90	100	100	100	100	100
	Minimum	Daily	100	90	100	100	100	100	100
Precipitation	Annual Total	Monthly	42	58	50	58	67	67	50
	Jun-Sep Total	Monthly	100	100	100	100	100	100	100
Solar Radiation	Average	Daily	100	100	100	100	100	100	100
Wind	Average	Hourly	97	100	98	99	97	99	98

Table 1.2-3. Boston Meteorological Station Baseline Data Completeness

Parameter		Sampling Frequency	Data Completeness (%)					
			2009	2010	2011	2012	2013	2014
Temperature	Average	Daily	100	100	100	100	100	92
	Maximum	Daily	100	100	100	100	100	92
	Minimum	Daily	100	100	100	100	100	91
Precipitation	Annual	Monthly	17	0	50	0	0	75
	Jun-Sep	Monthly	50	0	100	0	0	33
Wind	Average	Hourly	100	98	100	100	98	99

Precipitation data is available from the Project stations for the summer months of 2009 through 2012, and for the summer and winter from 2012 to present. Winter precipitation adapters installed on the precipitation gauges are susceptible to malfunctioning during the extreme cold that the Arctic consistently endures, hence, their inconsistency in the winter datasets. Comparison of the precipitation totals for the months June through September, between the Project and regional stations, indicate the precipitation is generally similar and therefore annual precipitation at the Doris and Boston meteorological stations can be inferred from the regional station data (Table 1.2-4).

Values for climate normal total annual precipitation are 141.8 mm, 298.6 mm and 247.2 mm at the Cambridge A, Lupin A and Kugluktuk A meteorological stations, respectively (Table 1.2-4). Summer climate normal precipitation amounts were 82.5 mm, 177.0 mm and 144.0 mm at the Cambridge A, Lupin A, and Kugluktuk A meteorological stations, respectively. Compared to climate normals, total precipitation during the summer months at the Project stations was generally similar to the Cambridge A station and lower in all years in comparison to the Lupin A and Kugluktuk A stations. Climate normal data (1981 to 2010) indicate that approximately 62% of the total precipitation fell as rain during the short summer (June through September), indicating that the winter is proportionately drier.

The maximum daily rainfall at the Doris and Boston meteorological stations from 2009 to 2014 was 13.7 mm (June 21, 2012) and 25.7 mm (July 18, 2014), respectively. The climate normal record maximum daily rainfall amounts were 35.8 mm (July 24, 1988), 41.8 mm (July 9, 1983) and 118.3 mm (July 21, 2007) at the Cambridge A, Lupin A, and Kugluktuk A stations, respectively.

1.2.2.3 Snow

An ultrasonic snow depth sensor was installed at Boston station on August 13, 2009. However, due to the exposed nature of the meteorological station and high and consistent winds, snow was redistributed from the area. For this reason, it is difficult to get an accurate single-point measurement of snow depth in Arctic areas. Data recorded by the ultrasonic snow sensor is not representative of the

Table 1.2-4. Measured Monthly and Climate Normal Precipitation (mm)

Month	2009		2010		2011		2012		2013		2014		Climate Normal (1981-2010)		
	Doris (mm)	Boston (mm)	Doris (mm)	Boston (mm)	Doris (mm)	Boston (mm)	Doris (mm)	Boston (mm)	Doris (mm)	Boston (mm)	Doris (mm)	Boston (mm)	Cambridge A (mm)	Lupin A (mm)	Kugluktuk A (mm)
Jan	-	-	-	-	-	-	-	-	-	-	-	-	5.8	9.4	10.4
Feb	-	-	-	-	-	-	-	-	-	-	-	-	4.9	7.8	8.4
Mar	-	-	-	-	-	-	-	-	-	-	-	-	7.1	12.2	9.9
Apr	-	-	0.5	-	-	-	0.3	-	0.3	-	-	-	5.7	14.6	10.0
May	-	-	0.3	-	9.1	4.8	4.6	-	0.3	-	2.3	-	7.0	17.8	14.6
Jun	4.8	-	1.3	-	32.0	20.1	5.8	-	13.2	-	11.4	-	13.6	30.4	16.6
Jul	22.4	25.1	34.0	-	21.1	33.8	23.4	-	26.9	-	41.7	46.5	24.1	41.5	44.5
Aug	28.7	50.5	20.8	-	12.7	20.1	12.7	-	10.5	-	12.4	1.3	25.7	62.5	45.1
Sep	19.3	-	23.9	-	32.0	21.6	5.8	-	26.0	-	30.0	12.2	19.1	42.6	37.8
Oct	2.5	-	16.0	-	0.3	5.3	11.7	-	9.4	-	22.6	11.8	14.7	28.7	26.5
Nov	-	-	-	-	-	-	-	-	5.8	-	0.3	-	8.0	17.4	13.0
Dec	-	-	-	-	-	-	-	-	-	-	15.0	-	6.1	13.7	10.4
Annual Total	**77.7**	**75.7**	**96.8**	**-**	**107.2**	**105.7**	**64.3**	**0.0**	**92.5**	**0.0**	**120.7**	**71.7**	**135.7**	**284.9**	**236.8**
Jun to Sep Total	**75.2**	**-**	**80.0**	**-**	**97.8**	**95.5**	**47.8**	**-**	**76.7**	**-**	**95.5**	**-**	**82.5**	**177.0**	**144.0**

Project area and was therefore excluded from this characterization. Some general statements about snow in Arctic areas as well as a summary of snow survey data previously collected from the Project area are provided below.

Arctic snow cover is often hard packed and denser than the snow of the subarctic (Williams 1957). The snow stratigraphy generally follows the description by Benson et al. (1982) derived from observations in Greenland, Antarctica and northern Alaska. Four major varieties of snow are recognized, including:

1. fresh snow at the surface with variable crystal forms and a density between 150 and 200 kg m^3;
2. hard and fine-grained windslab with a density between 305 and 450 kg m^3;
3. medium-grained snow at a density of between 230 and 350 kg m^3; and
4. depth hoar consisting of coarse, loosely-bonded crystals yielding an average density of between 200 and 300 kg m^3.

Wind redistributes snowfall over the course of a winter, and in general, exposed terrain, such as open lakes, collects less snow than sheltered lowland areas (Benson et. al. 1982). Similarly, prevailing winds redistributes snow unequally across slopes depending on the aspect of the terrain. With respect to snow depth, these effects may result in substantial differences between terrain types in some cases. However, this baseline study involved sampling sites in an area with little vegetation, and a wide range of snow depths were recorded within each terrain type. As such, detailed calculation of the mean snow water equivalent based on the relative proportion of each terrain type is not recommended.

Based on the 2004 to 2008 sampling, an un-weighted mean of the snow water equivalent (SWE) values for various terrain types of 71.3 mm may be used for site-specific water balance calculations (Rescan 2009). Results collected during 2008 which separated Boston and Doris and Madrid Project areas suggest that un-weighted mean SWE values should be slightly higher for the Boston area than for Doris area. Overall, SWE were higher in 2008 than previous years suggesting that snowpacks were greater during that year (Rescan 2009).

The extreme snow depth measured at the Cambridge Bay station was 59 cm and was recorded on May 9, 1993. The highest monthly average climate normal (1981 to 2010) snow depth at that station is 34 cm for April and May. On average, there are 263 days per annum when there is greater than 1 cm of snow on the ground and 165 days when snow is 20 cm or deeper at the Cambridge Bay station. The climate normal record extreme daily snowfall was 31.8 cm, which was recorded at the Lupin A station on October 28, 1998.

1.2.2.4 Wind

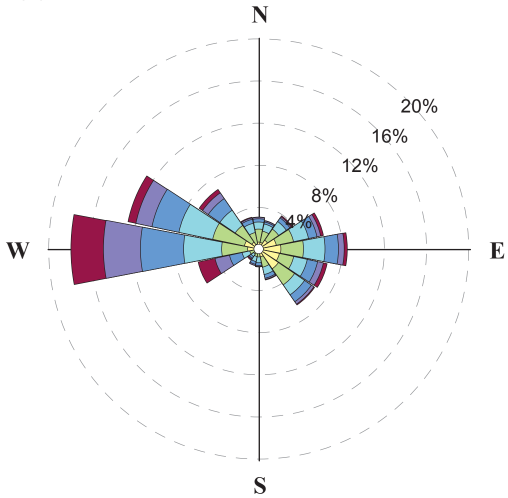
The Project area lies within the northern reaches of the North American continent. As such, it is primarily subject to cold, dry Arctic air masses and American continental air masses from the south. The area is subject to high wind speeds due to the relative absence of obstructions to the wind (e.g., trees, mountains, and other obstructive terrain features).

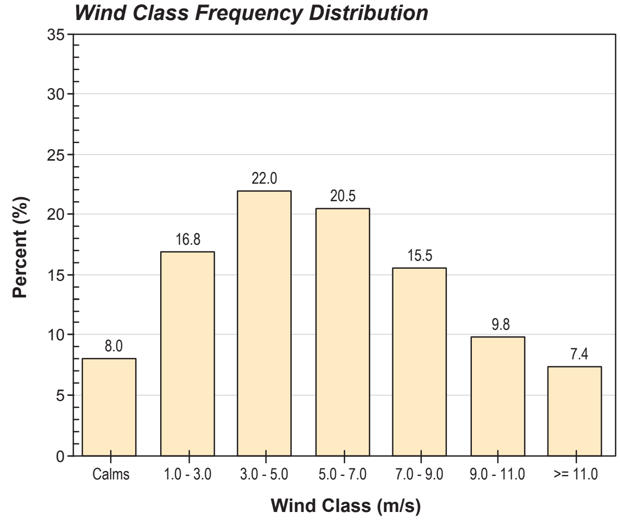
Figures 1.2-5 and 1.2-6 presents the average annual, summer and winter windroses and frequency distributions based on data collected during the measurement period from 2009 through 2014 for the Doris and Boston stations, respectively. Figure 1.2-7 presents the average annual, summer and winter wind roses and frequency distributions based on data collected during the measurement period from May 2, 2011 to September 8, 2012. At both Project meteorological stations (Doris and Boston), the trends in wind speed and direction are consistent for the years 2009 to 2014. Tables 1.2-2 and 1.2-3 present the percentage of available yearly data for Doris and Boston, respectively.

Figure 1.2-5

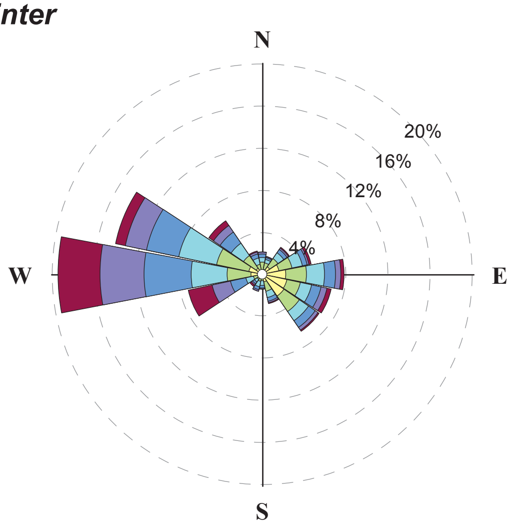
Doris Meteorological Station Wind Roses and Frequency Distributions 2009 to 2014

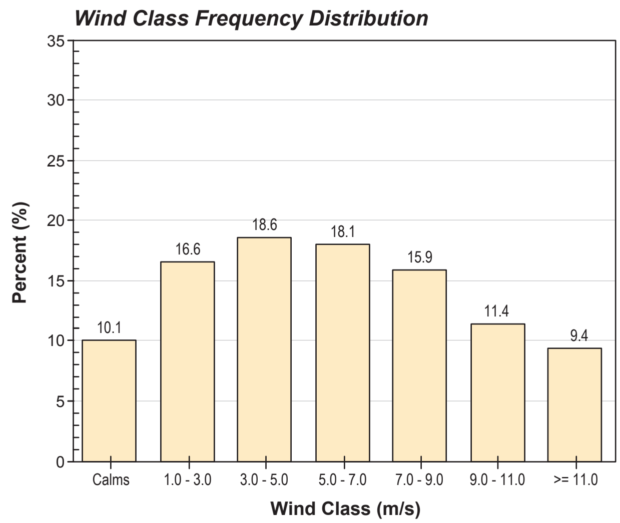
Annual



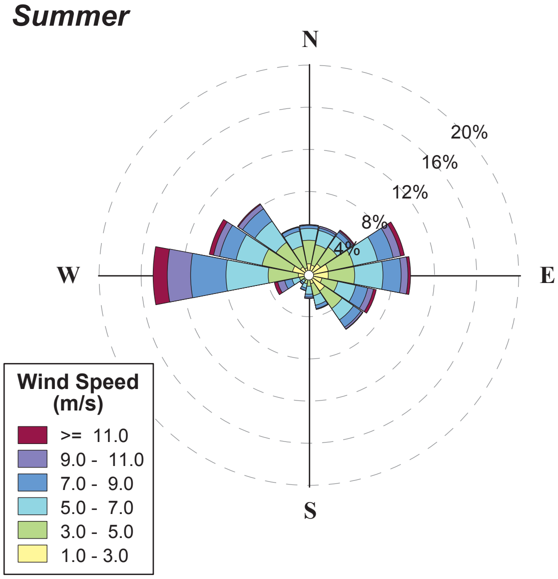


Winter





Summer



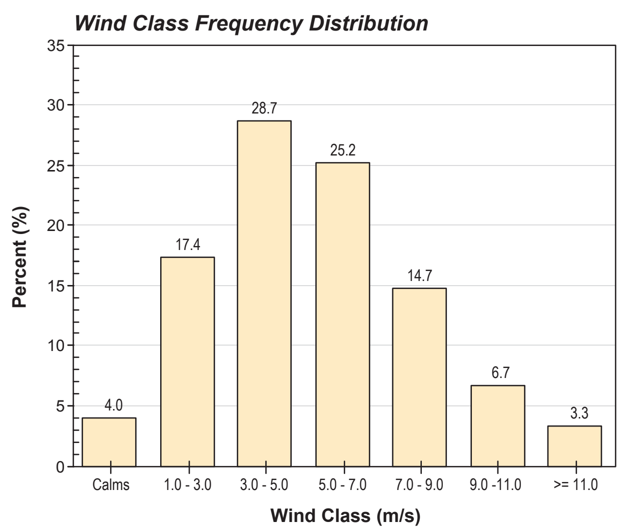
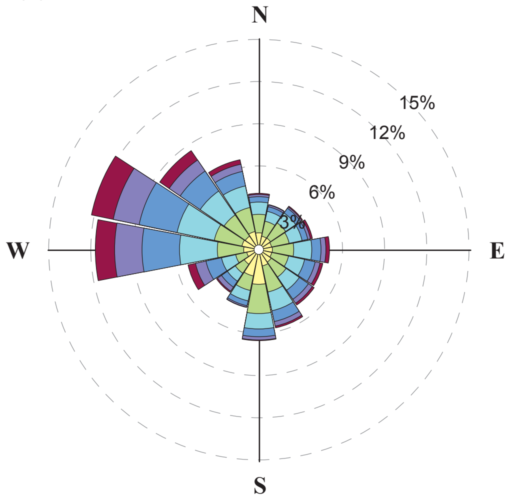
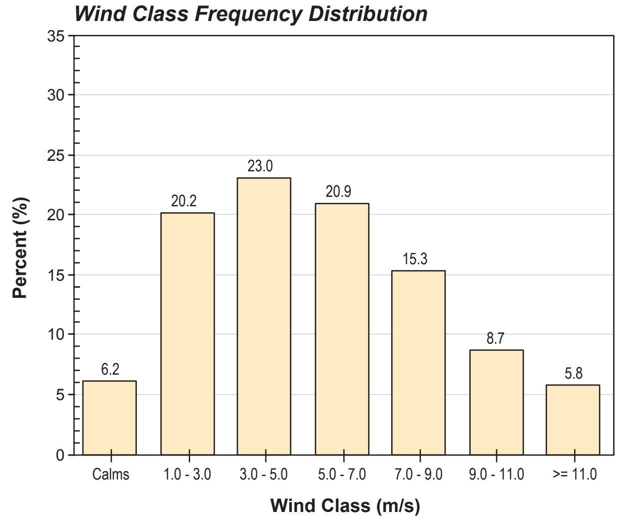


Figure 1.2-6

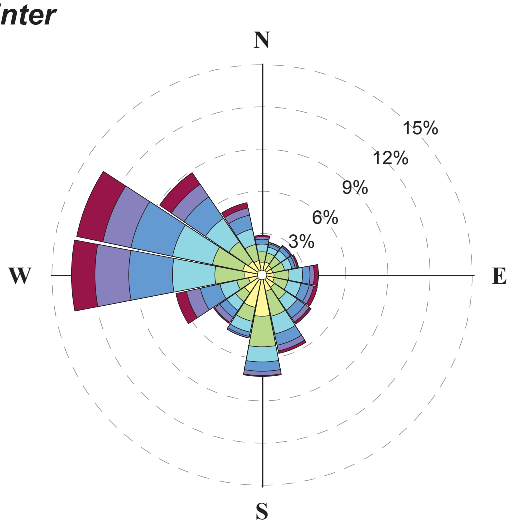
Boston Meteorological Station Wind Roses and Frequency Distributions 2009 to 2014

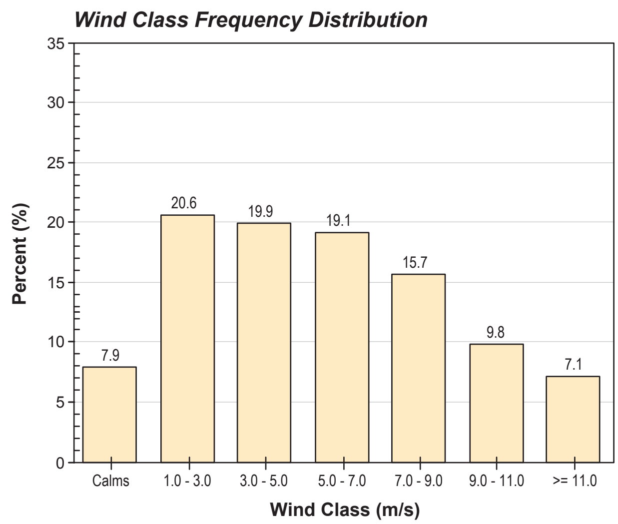
Annual



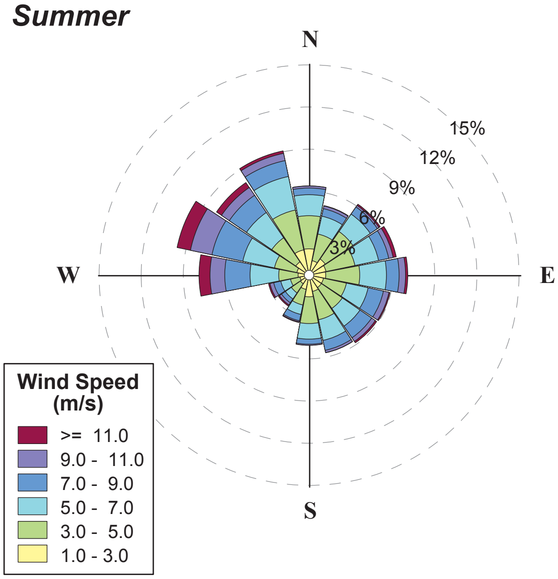


Winter





Summer



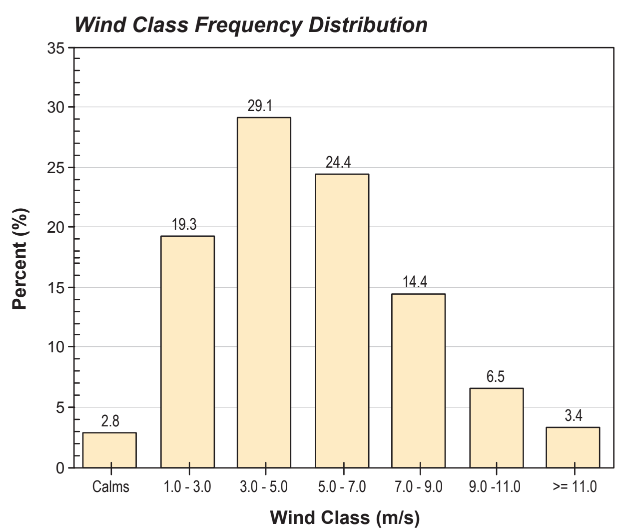
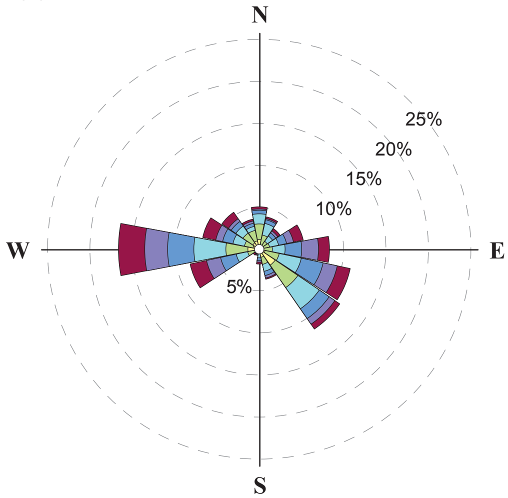
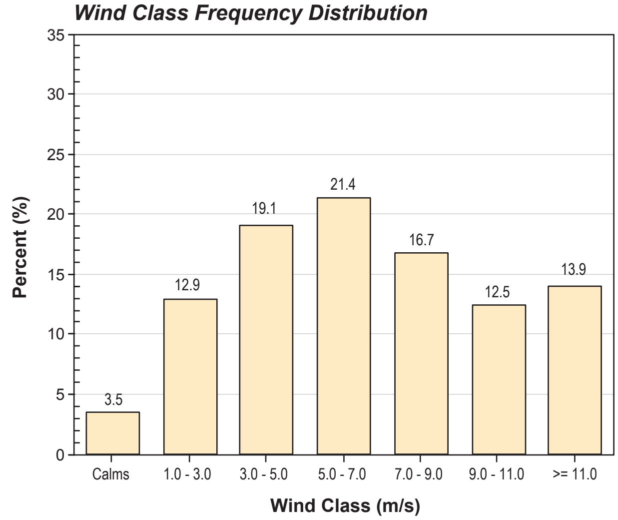


Figure 1.2-7

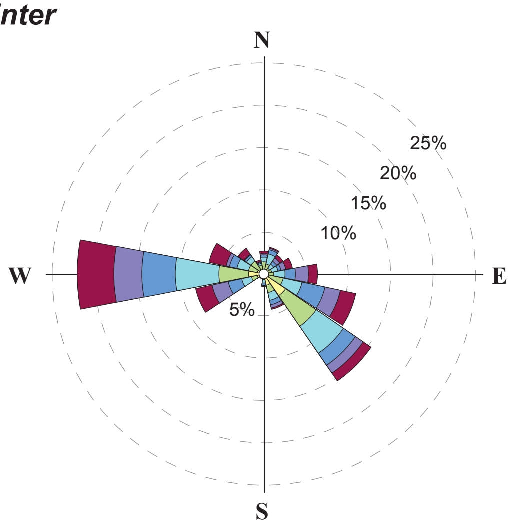
Roberts Bay Wind Monitoring Station Wind Roses and Frequency Distributions, May 2, 2011 to September 8, 2012

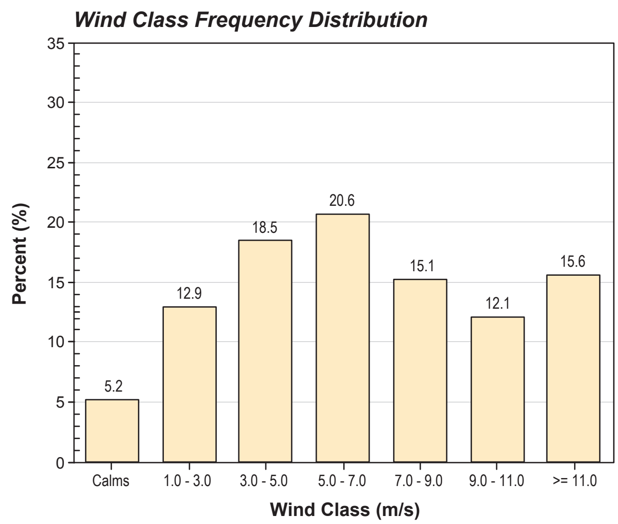
Annual



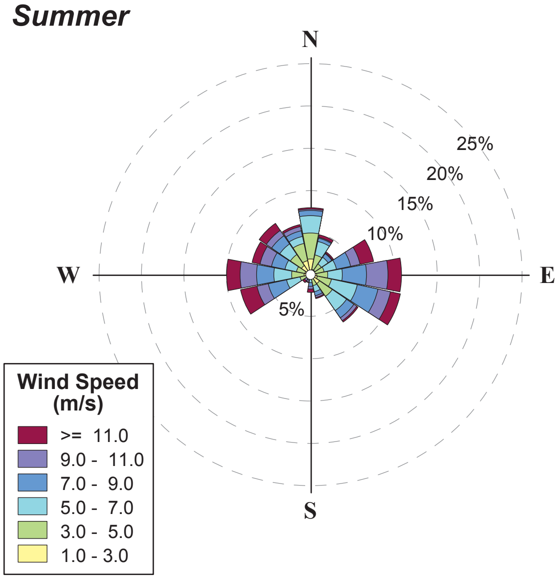


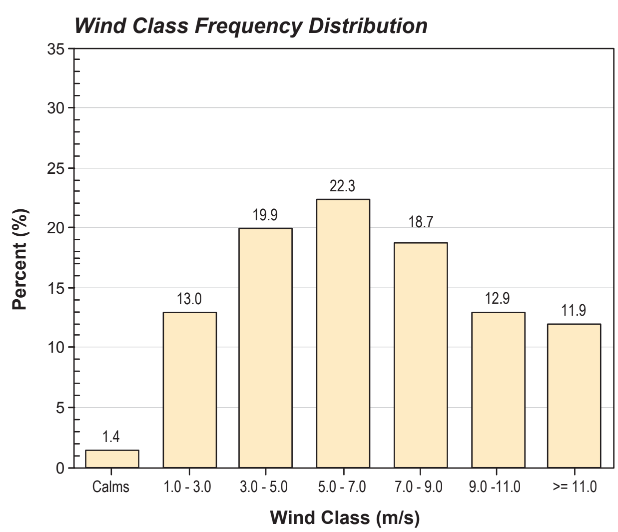
Winter





Summer





At the Doris meteorological station, the winds blow mainly from westerly directions with a slight increase in easterly winds in the summer months (Figure 1.2-5). Wind speeds were in excess of 5 m/s for all seasons approximately 53% of the time. Broken down into summer (June to September) and winter (October to May), wind speeds in excess of 5 m/s were experienced 55% and 50% of the time, respectively. In the winter, wind directions were from the west approximately 46% of the time. In the summer, wind directions were from the west to northwest approximately 34% of the time and from the east for approximately 33% of the time. There was a higher percentage of calm winds (less than 1 m/s) in winter (10.1%) compared to summer (4.0%). There was also a higher proportion of strong winds (over 11 m/s) in winter (9.4%) compared with summer (3.3%).

At the Boston meteorological station, during all seasons, the dominant winds are from the west to northwest quadrants (Figure 1.2-6). Wind speeds were in excess of 5 m/s in all seasons over 50% of the time. Broken down into summer (June to September) and winter seasons (October to May), wind speeds in excess of 5 m/s were experienced 49% and 52% of the time, respectively. In the winter period the dominant wind direction was from the west to northwest quadrant approximately 45% of the time. The summer wind direction was predominantly also from the west to northwest quadrant approximately 38% of the time but the station also received consistent winds through the north, east and south quadrants (Figure 1.2-6). There was a higher proportion of calm winds (less than 1 m/s) in winter (7.8%) compared with summer (2.8%). There was also a higher proportion of strong winds (over 11 m/s) in winter (7.1%) compared to summer (3.4%).

At the Roberts Bay wind station, during all seasons, the dominant wind direction is from the west, with the southeast quadrant also providing a significant contribution (Figure 1.2-7). Wind speeds were in excess of 5 m/s in all seasons over 64% of the time. Broken down into summer (June to September) and winter seasons (October to May), wind speeds in excess of 5 m/s were experienced 66% and 63% of the time, respectively. In winter, the dominant wind direction was from the west for approximately 40% of the time, with southeasterly winds occurring approximately 35% of the time. The summer wind directions were also predominantly also from easterly and westerly directions. There was a higher proportion of calm winds (less than 1 m/s) in winter (5.2%) compared with summer (1.4%). There was also a higher proportion of strong winds (over 11 m/s) in winter (15.6%) compared to summer (11.9%).

1.2.2.5 Solar Radiation

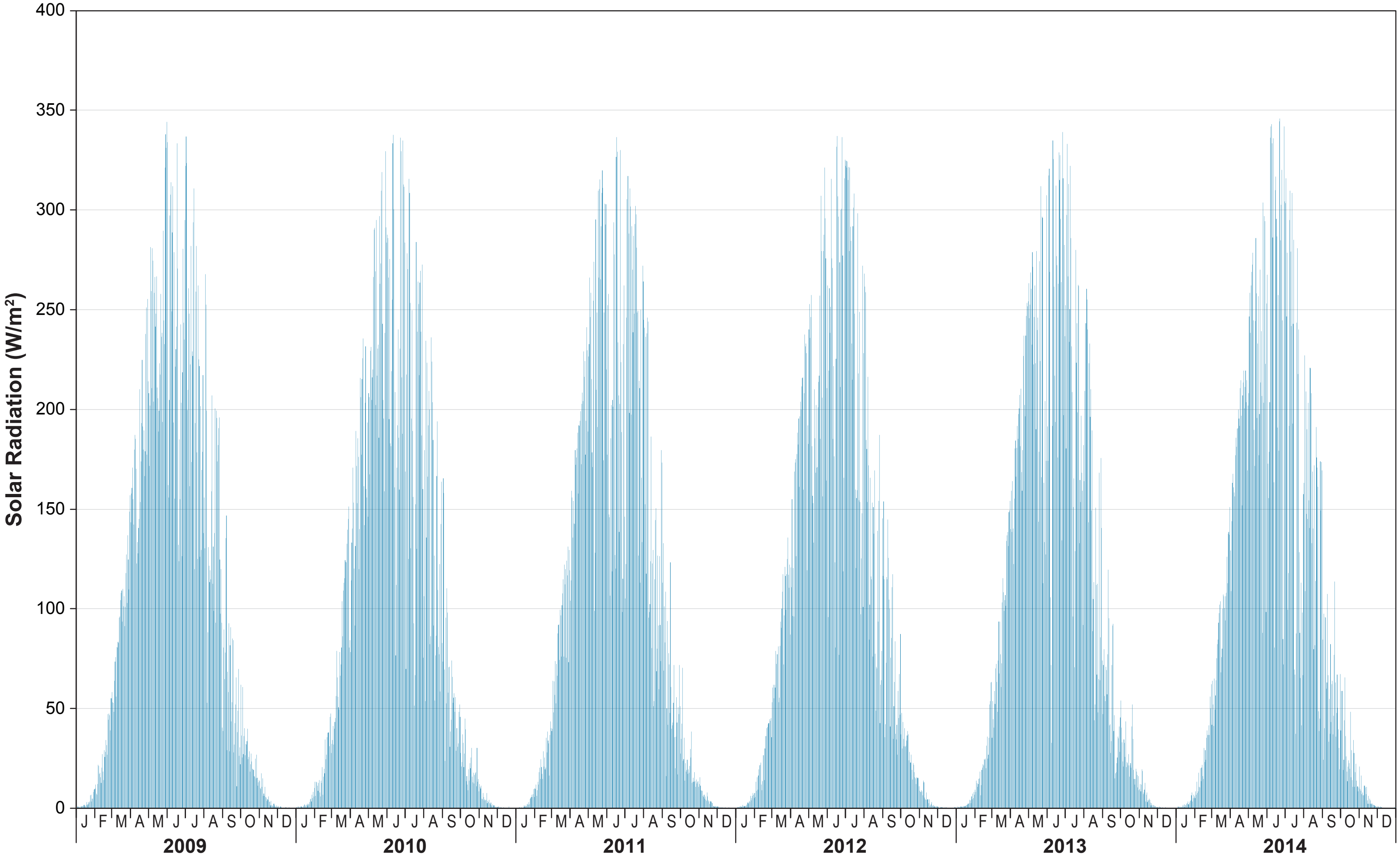
Solar radiation is electromagnetic energy from the sun, which accounts for 99% of the Earth's energy budget. The solar radiation incident above the terrestrial atmosphere is called extraterrestrial solar radiation. Short-wave radiation (0.29 to 3.0 microns) accounts for 97% of the extraterrestrial solar radiation. Upon entering the atmosphere this radiation may be reflected, refracted, or absorbed by gases and aerosols. Through these processes a portion of the incoming radiation will be lost to outer space while the remainder will make it to the Earth's surface. Global solar radiation is the total incident direct and diffuse short-wave solar radiation received from the whole dome of the sky on a horizontal surface.

Figure 1.2-8 summarizes the daily mean solar radiation values for the 2009 to 2014 period at the Doris meteorological station. The highest daily average solar radiation reading was 346 W/m^2, recorded on June 22, 2014. The maximum hourly average solar radiation value of 833 W/m^2 was recorded on June 18, 2009. The maximum estimated theoretical solar radiation for the region is approximately 968 W/m^2.

The lowest solar radiation values were recorded during winter months, when the sun is low and the Arctic experiences near perpetual darkness and twilight for several weeks. This period starts in late November and ends in mid-January. Average daily and hourly solar radiation values are at or near zero during this period. All the hourly average solar radiation values recorded during night time hours in the winter months were 0 W/m^2.

Figure 1.2-8

Doris Meteorological Station Average Daily Solar Radiation 2009 to 2014



1.2.2.6 Evaporation

Lake evaporation rates were calculated using data from the Doris Lake micro-meteorology station installed during the ice-free months starting in July. On average, the Project area experiences an open-water season that starts in July; however, there is year to year variation in the length of the open-water season.

Based on Penman Combination (Chow et al. 1998) and Priestly-Taylor (Shuttleworth 1993) methods, the average total monthly evaporation from 2009 to 2014 was estimated to be 143.6 mm and 139.4 mm, respectively (Table 1.2-5). Net radiation has the largest influence on evaporation rate, and the water surface receives significantly more net radiation during July than August, after which it decreases significantly.

Table 1.2-5. Total Monthly Evaporation (mm)

	Total Monthly Evaporation (mm)	
Year	**Penman Method**	**Priestly-Taylor Method**
2009	167.0	170.0
2010	174.0	168.0
2011	163.5	156.0
2012	122.6	124.6
2013	138.9	128.7
2014	95.7	88.8
Average	**143.6**	**139.4**

1.2.3 Climate Trends and Climate Change

Climate change refers to any significant change in the climatic conditions such as temperature, precipitation or wind patterns, which occurs over several decades or longer (US EPA 2013). Climate change may be due to natural internal processes such as ocean variability, external forces such as orbital variations and solar output, or persistent anthropogenic changes in the composition of the atmosphere or land use (IPCC 2007). Since the mid-twentieth century, however, the burning of fossil fuels and changes in land use patterns have been the dominant cause of observed climatic changes (Lemmen et al 2008). Anthropogenic climatic changes are predicted to continue over the next few decades leading to further warming and changes in the global climate system (IPCC 2007).

Climate trends and climate change have been noted by local Inuit groups and recorded in the NTKP report (see Section 1.1.1). Historical climate data collected over the last half a century is able to quantitatively support the qualitative information collected in the NTKP report.

Global observations through the twentieth century show climatic changes, including increased average surface temperature, precipitation, frequency of heavy precipitation events, and cloud cover, together with reductions in the length of the freeze season, the frequency of extreme low temperatures, and the extent of snow cover and mountain glaciers (Parry et al 2007).

In Canada, increases in temperature and precipitation have been experienced across most of the country over the past century. During the period 1948 to 2006 average national temperature increased by 1.3°C, which is more than double the increase in mean global surface temperature during the same time interval. In Nunavut, annual precipitation has increased by 25 to 45% in the same time period (Lemmen et al 2008). Changes in temperature and precipitation have led to changes in other variables including sea ice, snow cover, permafrost, evaporation, and sea level (Lemmen et al 2008).

The vast majority of the Project area is located in the Southern Arctic Ecozone. The Arctic Climate Impact Assessment (ACIA), which was the first comprehensive, integrated assessment of climate change across the entire Arctic region, provides a scientific synthesis of available information about observed and projected changes in climate (Arctic Council and International Arctic Science Committee; ACIASC 2005). It states that the Arctic, together with the Antarctic Peninsula, experienced the greatest regional warming on earth in recent decades, due to various feedback processes, such as changes in ice albedo. Between 1950 and 2005 average annual temperatures have risen by about 2 to 3ºC, which is more than double the Canadian average, and winter temperatures by up to 4ºC. The warming has been accompanied by increases in precipitation of up to 20% in parts of northern Canada during the period 1965 to 2005.

The Intergovernmental Panel on Climate Change (IPCC) states that for 2100, the projection for Northern Canada is approximately a 5ºC to 6ºC increase in temperature relative to 1980-1999 temperatures (IPPC 2007). The projected increase in mean annual air temperatures would lead to effects on the regional cryosphere. This would likely include alterations to sea, river, and lake ice regimes, and winter snow pack, especially during shoulder seasons of spring and fall, as well as to permafrost conditions.

Average annual precipitation is also expected to rise in the northern regions, the IPCC projects an increase in annual mean precipitation in the north of up to 20% by 2100 (IPCC 2007). Lemmen et al (2008) predict that total annual precipitation could increase from 5 to 8% for the climate normal period 2010 to 2030 and 15 to 30% for the climate normal period 2070 to 2100, compared to 1961 to 1990 baseline.

Despite the high degree of uncertainty associated with climate change projections, the evidence that climate change is occurring is sufficient to necessitate a consideration of its impact on the Project. Potential interactions with the Project include changes in temperature and precipitation, and the associated potential impacts on permafrost, active layer depth, and snow depth. Potential climate change implications on Project infrastructure are discussed in Volume 1, Annex V1-7, Package P5-1, *Climate Change Analysis Report*.

1.3 VALUED ECOSYSTEM COMPONENTS AND SUBJECTS OF NOTE

1.3.1 Potential Valued Ecosystem Components and Scoping

As the local climate has an influence on all other aspects of the environment, climate and meteorology was included in the scoping process to identify environmental components to be assessed within the EIS. The full VEC/VSEC scoping process is described in Volume 2, Chapter 4, Effects Assessment Methodology.

1.3.2 Valued Ecosystem Components and Subjects of Note Included in the Assessment

Climate and a changing climate have influence on all other aspects of the environment. As described in Section 1.1, local Inuit groups have been observing climate change in their historical territories and these changes have been influencing their way of life. Under the Copenhagen Accord in 2009, Canada signed on to reduce its total GHG emissions by 17% from 2005 levels by 2020 (Environment Canada 2016a) and has implemented regulations under the *Canadian Environmental Protection Act* (CEPA) 1999 as part of the Greenhouse Gas Emissions Reporting Program to begin collecting information on facility level emissions within Canada.

The Project will result in GHG emissions and is expected to exceed the relevant reporting threshold for the Greenhouse Gas Emissions Reporting Program. Thus, consideration of the Project's potential influence on the climate is warranted.

However, as the incremental contribution to climate change by an individual Project cannot be identified (CEA Agency 2003), climate and meteorology is considered a Subject of Note for the purposes of the EIS rather than a Valued Environmental Component (VEC).

1.3.3 Valued Ecosystem Components and Subjects of Note Excluded from the Assessment

Climate and meteorology is considered a Subject of Note; no potential Valued Ecosystem Components related to climate and meteorology are included from the assessment.

1.4 SPATIAL BOUNDARIES

The spatial boundary for the climate and meteorology assessment is defined as the area subject to potential effects from Project emissions. As mentioned, GHGs emitted by the Project will enter an atmospheric pool that is globally unbound, therefore, as is standard for environmental assessments for mining projects, spatial boundaries for GHG emissions are defined by Project GHG sources for facility emissions. The assessment considers all Project-related emissions from the Project components, including aircraft takeoff and landing and local shipping lanes, up to 0.75 hours (1 way) away from the Project.

1.5 TEMPORAL BOUNDARIES

Temporal boundaries, provided in Table 1.5-1, are the time periods considered in the assessment for various Project phases and activities. Temporal boundaries reflect those periods during which planned Project activities are reasonably expected to result in GHG emissions. To provide a conservative assessment of GHG emissions associated with the Project, the GHG assessment has focused on the period of peak activity. This is anticipated to occur during the Operation phase. GHG emissions associated with other Project phases are expected to be lower than those estimates during Operation. Thus, the quantitative estimates presented in the following sections are considered to represent conservatively high values for Construction, Closure, and Post-Closure phases.

Once released into the atmosphere, it is assumed that the potential effect on atmospheric GHG levels from the Project GHG emissions will be 50 to 200 years corresponding to the maximum lifetime of CO_2 in the atmosphere (IPC 2001a).

1.6 PROJECT-RELATED EFFECTS ASSESSMENT

1.6.1 Methodology Overview

The global climate is influenced by the presence of natural and human-made GHGs. GHGs (water vapour, CO_2 [carbon dioxide], CH_4 [methane], N_2O [nitrous oxide], O_3 [ozone] and CFCs [chlorofluorocarbon]) help the earth's atmosphere trap the sun's heat, creating a "greenhouse effect" that keeps the earth warm and sustains life. The rising levels of GHGs mean more heat stays in the earth's atmosphere, causing increases in the average global temperature. The primary GHGs from anthropogenic sources are CO_2, CH_4 and N_2O. All phases of the Project will lead to the emission of GHGs, mostly in the form of CO_2 from the combustion of diesel fuel; however, they are significantly lower during the Closure and Post-closure phases.

Current scientific knowledge does not allow for the effects of the individual Project phases on climate change to be assessed. The Project is therefore assessed in terms of CO_2eq produced and compared with sector, provincial/territorial, national, and international levels, consistent with guidance by the CEA Agency (2003).

Table 1.5-1. Temporal Boundaries for the Effects Assessment for Climate and Meteorology

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

The majority of direct GHGs from the Project will be generated by on-site diesel combustion and waste incineration. There will also be indirect emissions associated with shipping and aircraft use. In order to calculate the emissions associated with the Project, the Mining Association of Canada's (MAC 2014) categorization of GHG emissions has been adopted:

- Scope 1 emissions - Direct emissions by equipment owned or controlled by the company;
- Scope 2 emissions – Indirect Emissions from purchased electricity; and
- Scope 3 emissions – Other indirect emissions from upstream and downstream activities, such as air travel and shipping.

The GHG assessment for the Project uses facility-level activity data including stationary and mobile machinery/equipment use (Scope 1), and third-party transportation of workers and goods (Scope 3). The remote location of the Project does not allow for the purchase of electricity from another source therefore Scope 2 emissions are not included.

Global warming potential emission factors, defined as 1 for CO_2, 25 for CH_4, and 298 for N_2O, respectively, were used to convert all individual GHG emissions to CO_2eq. Project GHG emissions were based on information provided by TMAC and SRK consultants. Greenhouse gas emission estimates have been provided for what is expected to be the peak year (Year 12) of diesel fuel usage which will be the primary source of GHG emissions for the Project.

1.6.2 Potential Effects and Interactions with Project

The effect of the Project on climate and meteorology will be through the emission of GHGs. Greenhouse gases will be emitted directly or indirectly during the Construction, Operation, Closure and Post-closure phases.

Table 1.6-1 provides a summary of an impact scoping matrix of Project components and activities expected to interact with the climate and meteorology Subject of Note. A complete list of Project interactions can be found in Table 4.3-3, Volume 2, Chapter 4, *Effects Assessment Methodology*.

Table 1.6-1. Project Interaction with Climate and Meteorology Subject of Note

Project Component/Activity	Project Interaction with Climate and Meteorology (Subject of Note)	Potential Effect
Construction		
Blasting	X	Produce Scope 1 Greenhouse Gas Emissions
Camp and diesel generator facilities	X	Produce Scope 1 Greenhouse Gas Emissions
Marine and air transport	X	Produce Scope 3 Greenhouse Gas Emissions
Mobile and stationary equipment use	X	Produce Scope 1 Greenhouse Gas Emissions
Operation		
Blasting	X	Produce Scope 1 Greenhouse Gas Emissions
Camp, diesel generators, air heating and processing plant facilities	X	Produce Scope 1 Greenhouse Gas Emissions
Marine and air transport	X	Produce Scope 3 Greenhouse Gas Emissions
Mobile and stationary equipment use	X	Produce Scope 1 Greenhouse Gas Emissions
Road use and maintenance	X	Produce Scope 1 Greenhouse Gas Emissions
Reclamation and Closure		
Camp and diesel generator facilities	X	Produce Scope 1 Greenhouse Gas Emissions
Marine and air transport	X	Produce Scope 3 Greenhouse Gas Emissions
Mobile and stationary equipment use	X	Produce Scope 1 Greenhouse Gas Emissions
Post-closure		
Post closure monitoring activities	X	Produce Scope 1 Greenhouse Gas Emissions
Temporary Closure		
Camp and diesel generator facilities	X	Produce Scope 1 Greenhouse Gas Emissions
Mobile and stationary equipment use	X	Produce Scope 1 Greenhouse Gas Emissions

1.6.3 Characterization of Potential Project-related Effects

The effect of the Project on climate and meteorology will be through the emission of GHGs and contribution to global climate change. Characterization of Project-related effects is completed by comparing estimated Project GHG emissions to relevant sector, regional, national, and international GHG inventories as well as applicable regulatory thresholds related to GHG emission. Estimated Project GHG emissions are presented in Section 1.6.5.

1.6.4 Mitigation and Adaptive Management

The major source of GHG emissions associated with the Project is fuel combustion associated with the vehicle fleet, equipment and electricity generation. Aspects of project design and mitigation and management measures that reduce and limit energy use are the primary means to reduce Project-related GHG emissions.

1.6.4.1 Mitigation by Project Design

TMAC will implement a number of design features that will act to reduce Project-related GHG emissions, including:

- The design of haul roads has been optimized to minimize the distance travelled which will reduce emissions associated with construction and operation.
- Using underground mining will result in significant reductions in GHGs emitted by the Project compared to open pit mining methods, such as from fuel burned during excavating and hauling waste rock.
- The Doris power plant will be supplemented by power generated by two wind turbines (nominal power of 4.2 MW). The operation of the wind turbines will lead to reduced GHG emissions relative to the estimates in Section 1.6.5, which assumes the power plant supplies 100% of the that site’s energy need.

1.6.4.2 Best Management Practices

TMAC will implement a number of best management practices that will reduce GHG emissions, including:

- selection of clean, high-efficiency technologies for diesel mining equipment;
- implementation of an idling policy to limit vehicle and equipment idling when not in use;
- use of large haul trucks for ore and waste transport to minimize the number of trips required between the source and the destination;
- regular servicing of all mobile and stationary engines to maintain efficiency;
- implementation of a recycling and waste management program to reduce the amount of incinerated waste; and
- recycling program and waste segregation to ensure the incinerator stream is free of plastics.

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.

1.6.4.3 Monitoring

An assessment of GHG emissions will be carried out annually to determine whether reporting is required. Sources of GHG emissions (e.g., fuel use for power, mobile and stationary equipment operation) will be monitored and resultant data will be used for GHG assessments.

1.6.4.4 Adaptive Management

Results from the monitoring programs will be reviewed annually to determine if any trends are evident and if target criteria are being met. The need for any corrective actions to on-site emission management or installation of additional control measures will be determined on a case-by-case basis.

1.6.5 Project-related Residual Effects

Project-related effects on climate and meteorology will occur through emissions of GHGs that will contribute to global GHG levels and are assessed by comparison to territorial, national, and international GHG inventories. The following section estimates GHG emissions for the Project considering the mitigation measures described in Section 1.6.4. The assessment is concentrated on the Construction and Operation phases rather than Closure and Post-closure phases as the GHG emissions for these phases are expected to be much lower than during Construction or Operation.

1.6.5.1 Greenhouse Gas Estimates

The majority of direct GHGs from the Project will be generated by on-site diesel combustion, with additional emissions from waste incineration, explosive use, and fuel storage. There will also be indirect emissions associated with shipping and aircraft use. In order to calculate the emissions associated with the Project, the Mining Association of Canada's (MAC 2014) categorization of GHG emissions has been adopted:

- Scope 1 emissions - Direct emissions by equipment owned or controlled by the company;
- Scope 2 emissions – Indirect Emissions from purchased electricity; and
- Scope 3 emissions – Other indirect emissions from upstream and downstream activities, such as air travel and shipping.

Diesel fuel combustion is categorized as Scope 1 emissions (i.e., direct GHG emissions occurring from sources owned or controlled by the company), whereas emissions associated with shipping and aircraft are defined as Scope 3 emissions. Scope 1 and Scope 3 emission sources are relevant to the Project and included in this study. Scope 2 emission sources, those indirectly generated through the consumption of purchased electricity, are not relevant for this Project since the Project does not purchase electricity from an electrical grid.

Land use changes can also directly (through decomposition or burning of waste organic material) and indirectly (through reduction in carbon sink) contribute to GHG emissions. GHG emissions from land use change are generally related to the amount of vegetation removed from an area and the combustion of this biomass; with greater vegetation removal and combustion associated with greater direct emissions. Direct CO_2 emissions from the combustion of biomass are not to be included in Scope 1 emissions but reported separately (MAC 2014). As all land use change for the Project will occur within tundra ecosystems that lack substantive vegetation, and without the combustion of the tundra biomass, GHG emissions from land use change are expected to be minimal and are not assessed.

All emissions presented in the following assessment are shown in CO_2 equivalent (CO_2eq). CO_2-equivalent emissions are the amount of CO_2 emissions that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long-lived GHG or a mixture of GHGs (IPCC 2007). The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP). Total GHGs is obtained by summing the equivalent CO_2 emissions of each gas. The GWP values are 1 for CO_2, 25 for CH_4 and 298 for N_2O (EC 2015a Fourth Assessment).

Scope 1 Emissions – Diesel Consumption

Diesel fuel combustion will be the primary source of Scope 1 emissions for the Project. Diesel will be used to fuel on-site generates providing the primary power source for the Project and will be required to power equipment for all constructed components, drilling, loading, hauling, mine operation, crushing, and other engines.

Total diesel consumption will vary over the life of the Project estimated to range from 21.5 million litres in Year 1 to approximately 46.2 million litres in Year 7 during peak mine production (see Volume 3 - Project Description).

GHG emissions from diesel fuel combustion are calculated by multiplying the estimated annual fuel needs by the associated combined emission factor for diesel fuel. Emission factors for diesel fuel were available from the Canada National Inventory Report 1990-2014 (EC 2016a). CO_2 emission factors for fossil fuel combustion are dependent primarily on fuel properties and, to a lesser extent, on the combustion technology. Emissions from CH_4 and N_2O are technology-dependent, and emission factors were developed based on technologies typically used in Canada. Table 1.6-2 shows the emission factors used for diesel fuel consumption. CO_2 emissions from diesel combustion are assumed to equal 2.813 kg CO_2 equivalents (CO_2eq) per litre of diesel fuel.

Table 1.6-2. Emission Factors and Global Warming Potential of Diesel Fuel

Source	Emission Factor			
	CO_2	CH_4	N_2O	Total
Diesel - Refineries and Other (g/L)[a]	2,690	0.133	0.4	-
100 Year GWP[b]	1	25.0	298	-
CO_2 eq (g/L)	2,690	3.3	119.2	2813

Notes:
[a] *Canada—National Inventory Report 1990-2014—Part 2 (page 194)*
[b] *Canada—National Inventory Report 1990-2014—Part 1 (page 30)*

Based on diesel consumption for Year 7 (highest expected fuel consumption), annual GHG emissions would be 130.0 kilotonnes (kt) CO_2eq (Table 1.6-3). The average annual GHG emission from diesel combustion would be substantively lower than this value.

Table 1.6-3. Total GHG Emissions from Diesel Fuel for Worst-case Year (Year 7)

Source	Fuel Consumption (litres)	GHG (kt CO_2eq)
Mining and Power Generation Requirement for Peak Production Year (Year 17)	46,200,000	130.0

Scope 1 Emissions – Waste Incineration

The relevant gases emitted during waste incineration include CO_2, CH_4, and N_2O. Greenhouse gas emissions from the municipal waste incineration of one tonne of municipal waste are associated with the release of approximately 0.7 to 1.2 tonne of carbon dioxide (IPCC 2001a). Typically, emissions of CO_2 from waste incineration are considered more significant than CH_4, and N_2O emissions (IPCC 2001b). Thus, CO_2 emissions were considered to be equal to CO_2eq emissions for this assessment. Estimated waste production from the Doris, Madrid, and Boston camps and associated GHG emissions based on the lower and upper CO_2 emission factors is presented in Table 1.6-4.

The total GHG emissions emitted from the combined camps is predicted to reach up to 1.35 kt CO_2eq per year.

Table 1.6-4. Maximum Annual Project Emissions from Waste Incineration

Source	Waste Produced (tonnes/yr)	GHG (kt CO_2eq)	
		Based on Lower Emission Factor	Based on Upper Emission Factor
Doris and Madrid	740	0.52	0.89
Boston	380	0.27	0.46
Total	**1,120**	**0.79**	**1.35**

Scope 1 Emissions – Explosives

Total explosives requirements will range from 1,130 tonnes in Year 3 to 3,933 tonnes of explosives in Year 10. Environment Canada (EC 2004) provides an emission factor of 0.189 tonnes of CO_2 per tonne of ammonium nitrate/fuel oil (ANFO). Based on this emission factor, peak GHG emissions from explosives use are estimated to be 0.74 kt of CO_2eq per year.

Scope 1 Emissions – Fuel Tank Venting

Tank farms are currently located at Roberts Bay and Doris Camp with a capacity of 5,000,000 and 1,500,000 liters respectively. These tank farms will continue to be used throughout the Construction and Operations phase of the Project. Tank venting will result in the emission of CH4. Scaling calculations were performed after using the US EPA Tanks Emissions Estimation software to estimate CH_4 venting from a diesel tank of 114,000 L (US EPA 2005). The associated GHG emissions for the current fuel storage tanks are 0.21 kt CO_2eq/yr. (Table 1.6-5). Assumptions included that the vented gas is CH_4, and that there were 365 turnovers per year, which is a conservative estimate.

Table 1.6-5. Maximum Annual Project Emissions from Tank Venting

Source	Total Fuel Storage (l)	Emissions	
		CH_4 (tonnes)	GHG (kt CO_2eq)
Roberts Bay	45,000,000	11.3	0.29
Doris Camp	7,800,000	1.9	0.05
Total	**32,800,000**	**13.2**	**0.34**

Scope 3 Emissions – Aircraft and Shipping Emissions

Aircraft expected to be used regularly for the Project includes both fixed- and rotary-wing aircraft (Table 1.6-6). GHG emissions from aircraft were calculated by multiplying the number of flights per year by the emission factors provided in the Emissions and Dispersion Modeling System (EDMS) version 5.1.4.1. The EDMS is a combined emissions and dispersion model for assessing air quality at airports and has been used to inform the air quality effects assessment presented in Volume 4, Chapter 2 of the EIS. The EDMS provides emissions for CO_2, however, it does not provide values for N_2O, CH_4 or CO_2eq. The CO_2 emissions were therefore considered to be equal to CO_2eq emissions. The aircraft operations taken into account for the calculations include: taxi out, takeoff, climb out, approach and taxi in. The annual average GHG emissions associated with aircraft are shown in Table 1.6-6.

Table 1.6-6. Annual Average GHG Emissions from Aircraft

Aircraft	Flights per year	CO_2 Emissions per flight (kg)	GHG (kt CO_2eq)
737-200 Aircraft	84	1,417	0.12
Dash 8 aircraft	208	178	0.04
Hercules C-130	20	653	0.01
Bell 206 Long Ranger Helicopter	208	17	0.01
Total	-	-	**0.18**

A maximum of seven ships per year are expected during peak operation. Fuel consumption and thus GHG emissions are dependent on the activity of each ship. The scope of shipping activity considered for the GHG assessment is consistent with the scope of activities used to inform the air quality effects assessment (Volume 4, Chapter 2) and includes: docked ship, near-shore maneuvering, and slow cruise. Full cruising was considered to be beyond the scope of this assessment. Assumptions for the amount of time the shipping operations took to perform were:

- Docked ship - 7 days;
- Maneuvering ship - 0.75 hours per one way trip; and
- Slow Cruise - 1 hour per one-way trip.

GHG emissions from shipping were calculated using the emission factors provided in the US EPA, *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data* (US EPA 2000). The total GHG emissions associated with peak year of shipping activity are estimated to be 0.90 kt of CO_2eq (Table 1.6-7). The assumptions used in the calculations are conservative and the GHG emission results are therefore conservative.

Table 1.6-7. Annual Average GHG Emissions from Shipping

Shipping Activity	Maximum Number of Vessels per year	CO_2 Emissions (Main Engine) (g/kW-hr)	CO_2 Emissions (Aux Engine) (g/kW-hr)	CO_2 Emissions per activity (kg)	GHG (kt CO_2eq)
Docked Ship	7	0	692.7	814,545	0.82
Maneuvering	7	869.1	692.7	28,887	0.03
Slow Cruise	7	758.9	692.7	53,364	0.05
Total	-	-	-	-	**0.90**

Total Project Emissions

Total annual Project-related GHG emissions are expected to reach 133.5 kt CO_2eq including Scope 1 and Scope 3 emissions (Table 1.6-8). This total is based on expected peak production conditions for the Project (Year 12), and would be less throughout the other Project years.

Table 1.6-8. Summary of Project-related GHG Emissions

Source	GHG (kt CO_2eq)
Scope 1	
Fuel Use	130.0
Waste Incineration	1.35
Explosives	0.74
Tank Venting	0.34
Total	**132.4**
Scope 3	
Aircraft	0.18
Shipping	0.9
Total	**1.08**
Grand Total	**133.5**

Under the Copenhagen Accord in 2009, Canada signed on to reduce its total GHG emissions by 17% from 2005 levels by 2020 (Environment Canada 2016a). To meet this national GHG reduction target, Canada has begun to implement regulations under the *Canadian Environmental Protection Act* (CEPA) 1999 CEPA reporting regulations for GHG emissions were put in place in 2010. Facilities in Canada that emit over 50 kt of CO_2 equivalent have been required to report emissions to Environment and Climate Change Canada for the Greenhouse Gas Emissions Reporting Program (EC 2015a). It is expected that the Project will need to report annual GHG emissions under this program on an annual basis.

1.6.5.2 Comparison to Sector, Territorial, National, and International Inventories

Current scientific knowledge does not allow for the effects of the individual Project phases on climate change to be assessed. For the purposes of environmental assessment (CEA Agency 2003), Project emissions are typically assessed in terms of comparison to sector, provincial/territorial, national, and international levels, consistent with guidance by the CEA Agency (2003).

There are no local greenhouse gas (GHG) emissions data available for the area as there are no major anthropogenic sources. However, territorial data are available for Nunavut. Environment and Climate Change Canada (ECCC) is responsible for preparing Canada's official national inventory, which includes details of emissions from each providence and territory (EC 2016a). For the 2014 calendar year, 574 facilities reported their GHG emissions (EC 2016b), however only one of these, the Meadowbank gold mine, was located in Nunavut (Table 1.6-9). Table 1.6-9 shows a comparison between emissions from the Project compared to those from other mines in the region. The estimated Project emissions are substantively lower than those estimated for the Mary River Mine DEIS, and similar to the operating Diavik, Ekati, and Snap Lake mines.

Table 1.6-9. Summary of Project-related GHG Emissions from Northern Based Mines

Facility	Project Status	Territory	GHG (kt CO_2eq/year)
Back River[a]	Proposed	Nunavut	156
Mary River[b]	Operating	Nunavut	443
Division Meadowbank[c]	Operating	Nunavut	180
Diavik Diamond Mine[c]	Operating	Northwest Territories	179
Ekati[c]	Operating	Northwest Territories	199
Snap Lake[c]	Operating	Northwest Territories	109

Notes:
[a] *Source: Sabina Gold & Silver November 2015. Estimated Value (Scope 1 and 3 Emissions).*
[b] *Source: RWDI 2012. Estimated Value (Scope 1 Emissions).*
[c] *Source: Environment Canada (2016b). Based on 2014 data.*

Table 1.6-10 shows a comparison between estimated peak annual emissions from the Project compared to those on a territorial, national and global level. In 2014, the most recent annual dataset, Canada's total GHG emissions were estimated to be 732 Mt CO_2eq, of which 0.269 Mt CO_2eq were emitted in Nunavut (EC 2016a).

1.7 CUMULATIVE EFFECTS ASSESSMENT

The Project's effect on climate and meteorology will be through contribution to global atmospheric GHG pool. The assessment above (Section 1.6) compares estimate peak Project emissions to territorial, national, and international GHG emissions and is thus cumulative in nature. As such, no additional cumulative effects assessment is required.

Table 1.6-10. Comparison on a Regional, National and Global Scale

Source	GHG Emissions (Mt CO_2eq/year)	Comparison to Peak Project Emissions (%)
Nunavut[a]	0.269	49.6
Mining in Canada[b]	101	0.13
Canada[b]	732	0.018
Global[c]	53,937	0.0002

Notes:
[a] *Source: Environment Canada National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada - Part 3 (page 69). Based on 2014 data.*
[b] *Source: Environment Canada National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada - Part 3 (page 15). Based on 2014 data. Includes stationary combustion sources from mining and oil and gas extraction.*
[c] *Source: Olivier JGJ, Janssens-Maenhout G, Muntean M and Peters JAHW (2015), Trends in global CO_2 emissions; 2015 Report, The Hague: PBL Netherlands Environmental Assessment Agency; Ispra: European Commission, Joint Research Centre (link on page 23). Based on 2012 data. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012.*

Nunavut has relatively low industrial activity, with only one site reporting over 50 kt of CO_2eq in 2014, therefore total GHG emissions are low. Project GHG emissions would account for 0.1% of emissions associated with mining in Canada and substantively less than that compared to total Canadian (0.01%) and global (0.0001%) emissions.

1.8 TRANSBOUNDARY EFFECTS

GHGs emitted by the Project will contribute to global GHG levels, which in turn will influence on global climate change trends.

1.9 ASSESSMENT CONCLUSIONS FOR CLIMATE AND METEOROLOGY

Current scientific knowledge does not allow for the effects of the individual Project phases on climate change to be assessed. The Project is therefore assessed in terms of CO_2eq produced and compared with sector, provincial/territorial, national, and international levels, consistent with guidance by the CEA Agency (2003).

The Project will emit GHG emissions throughout its lifetime due to fuel and energy requirements and to a lesser degree by other activities carried out on-site (e.g., waste incineration and explosive use). GHG emissions will primarily occur during the Construction and Operation phases and expected to be substantively lower during the Closure and Post-closure phases. GHG emissions during peak Project activities have been compared against the national reporting threshold as well as to sector, territorial, national, and international GHG levels.

The Project is estimated to emit 133.5 kt CO_2e/year of GHG (Scopes 1 to 3) during the peak year of production (Year 7). Emissions are expected to be lower than this during Construction, Closure, and Post-closure and through much of Operation. The estimated GHG emissions are comparable to other mine projects in Nunavut and Northwest Territories, and low in comparison to national and global GHG inventories. However, it is expected that the Project will emit sufficient Scope 1 facility-level GHGs during the Construction and Operation phases of the Project to require reporting to Environment and Climate Change Canada on an annual basis as well as having them verified by a third party.

The Proponent will continue to monitor and mitigate Project GHG emissions over the Project life primarily through implementing fuel and energy efficiency measures and improvements.

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