DOMINION DIAMOND

ANNEX I

AIR QUALITY AND METEOROLOGICAL BASELINE REPORT FOR THE JAY PROJECT

AIR QUALITY AND METEOROLOGICAL BASELINE REPORT FOR THE JAY PROJECT

Prepared for: Dominion Diamond Ekati Corporation

Prepared by: Golder Associates Ltd.

September 2014

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Abbreviations

Abbreviation	Definition
CAAQS	Canadian Ambient Air Quality Standards
CAMS	continuous air monitoring station
CAPMoN	Canadian Air and Precipitation Monitoring Network
CO	carbon monoxide
CWS	Canada-Wide Standards
De Beers	De Beers Canada Inc.
Dominion Diamond	Dominion Diamond Ekati Corporation
e.g.,	for example
Ekati Mine	Ekati Diamond Mine
Ekati A	Ekati Airport monitoring station
GNWT	Government of the Northwest Territories
HVAS	high-volume air sampler
i.e.,	that is
Koala Station	Koala Meteorological Station
Lupin A	Lupin Airport monitoring station
N	north
NAD	North America Datum
NH_3	ammonia
NO_x	nitrogen oxides
NO_2	nitrogen dioxide
NW	northwest
NWT	Northwest Territories
O_3	ozone
PM	particulate matter
$PM_{2.5}$	particulate matter of mean aerodynamic diameter less than 2.5 microns
PM_{10}	particulate matter of mean aerodynamic diameter less than 10 microns
Polar Station	Polar Lake Meteorological Station
Project	Jay Project
S	south
SO_2	sulphur dioxide
SW	southwest
TSP	total suspended particulate
UTM	Universal Transverse Mercator
W	west
WNW	west-northwest

Units of Measure

Unit	Definition
°	degrees
°C	degrees Celsius
%	percent
<	less than
>	greater than
$\mu g/m^3$	micrograms per cubic metre
cm	centimetre
km	kilometre
km/hr	kilometres per hour
kW/m^2	kilowatts per square metre
m	metre
mm	millimetre
W/m^2	watts per square metre

1 INTRODUCTION

1.1 Background and Scope

Dominion Diamond Ekati Corporation (Dominion Diamond) is a Canadian-owned and Northwest Territories (NWT) based mining company that mines, processes, and markets Canadian diamonds from its Ekati Diamond Mine (Ekati Mine). The existing Ekati Mine is located approximately 200 kilometres (km) south of the Arctic Circle and 300 km northeast of Yellowknife, NWT (Map 1.1-1).

Dominion Diamond is proposing to develop the Jay kimberlite pipe (Jay pipe) located beneath Lac du Sauvage. The proposed Jay Project (Project) will be an extension of the Ekati Mine, which is a large, stable, and successful mining operation that has been operating for 16 years. Most of the facilities required to support the development of the Jay pipe and to process the kimberlite currently exist at the Ekati Mine. The Project is located in the southeastern portion of the Ekati claim block approximately 25 km from the main facilities and approximately 7 km to the northeast of the Misery Pit, in the Lac de Gras watershed (Map 1.1-2).

The Air Quality and Meteorological Baseline is one component of a comprehensive environmental and socio-economic baseline program designed to describe the natural and socio-economic environment near the Project. This report summarizes baseline air quality and meteorological data collected by Ekati Mine from 1994 to 2013, with an emphasis placed on 2013 data. This report also summarizes regional meteorological station data published by Environment Canada, air quality monitoring data in the Northwest Territories (NWT) published by Environment Canada, and air quality monitoring data within the NWT collected by the Government of the Northwest Territories (GNWT).

1.2 Objectives

The purpose of this baseline report is to describe the existing air quality and meteorological conditions in the vicinity of the Project, and to provide context for air quality predictions. The objectives of the baseline report are to:

- present representative baseline concentrations of select air quality compounds for comparison to concentrations predicted in the impact assessment; and,
- provide baseline climate and representative meteorological data for use in the air quality assessment.

LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- ALL-SEASON ROAD
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- TREELINE
- WATERCOURSE
- WATERBODY

150 0 150

SCALE 1:6,000,000 KILOMETRES

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
PROJECTION: CANADA LAMBERT CONFORMAL CONIC

DOCUMENT

AIR QUALITY BASELINE REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF THE JAY PROJECT

Golder Associates

PROJECT		13-1328-0041	FILE No. B_JC_Air_002_GIS	
DESIGN	ANK	29/01/14	SCALE AS SHOWN	REV. 0
GIS	ANK	10/09/14		
CHECK	CG	10/09/14	MAP 1.1-1	
REVIEW	SM	10/09/14		

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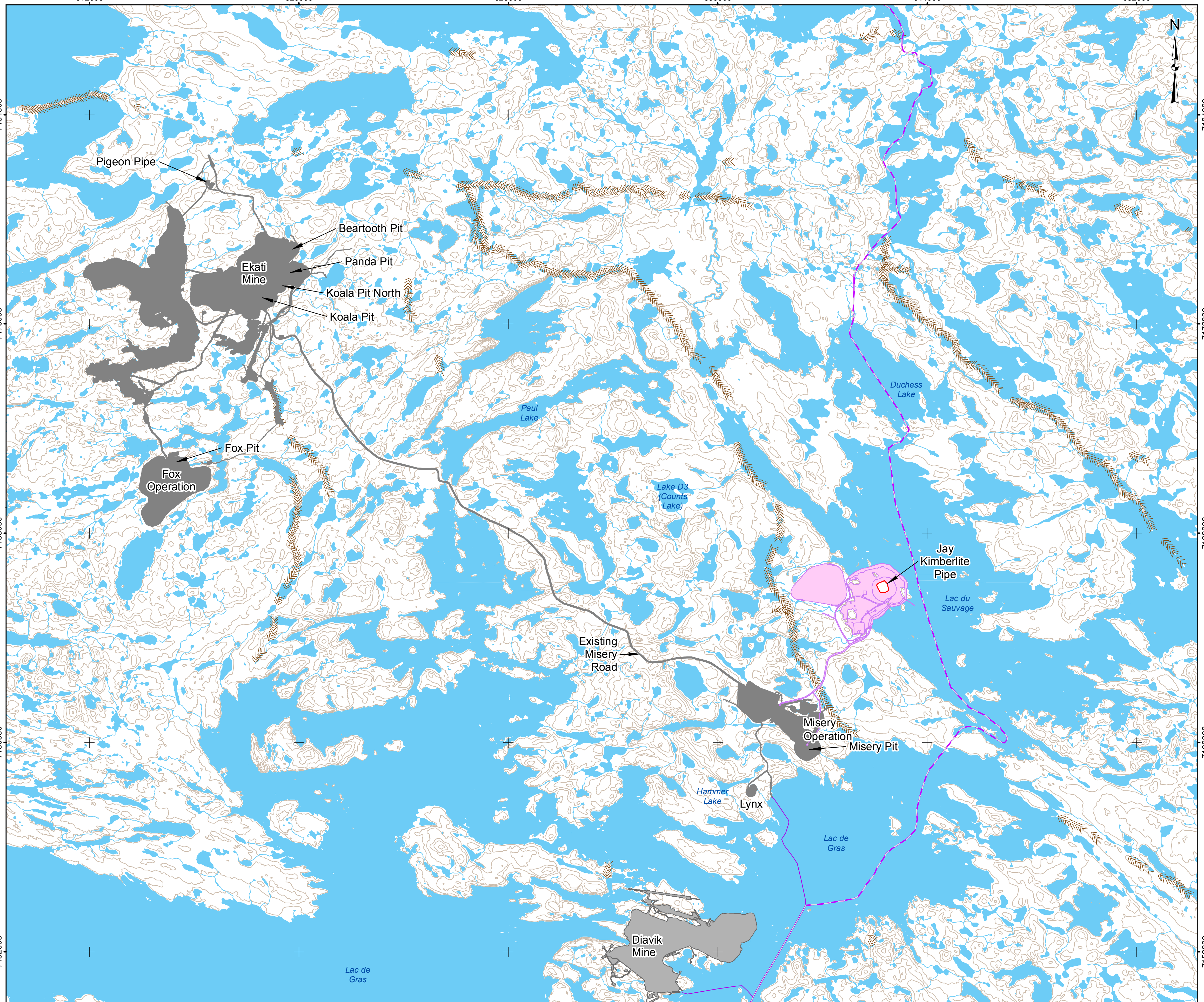

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LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- KIMBERLITE PIPE
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

AIR QUALITY BASELINE REPORT

3 0 3
SCALE 1:150,000 KILOMETRES

PROJECT

DOMINION DIAMOND™

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

EKATI PROPERTY MAP

Golder Associates

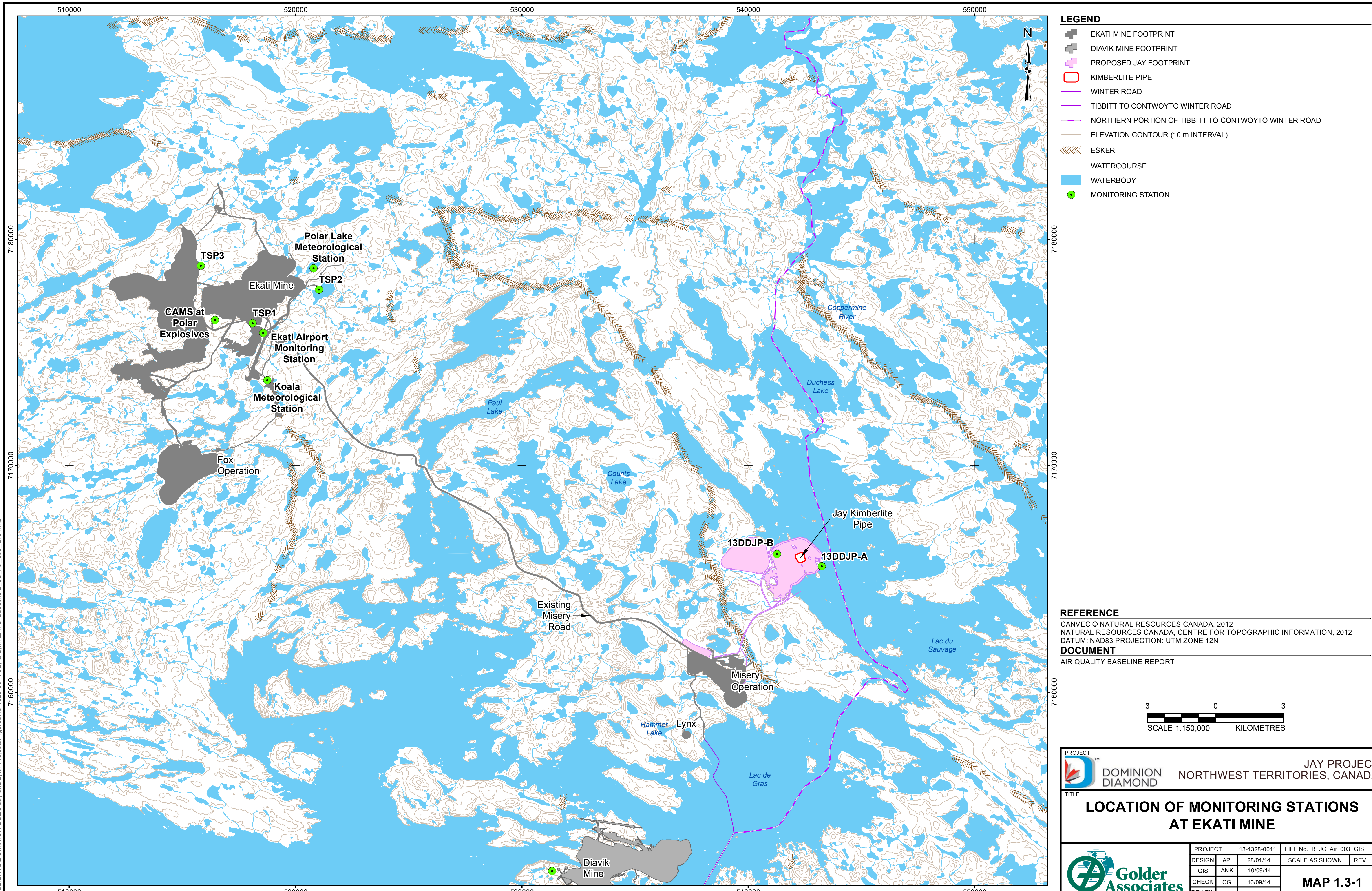
PROJECT		13-1328-0041	FILE No. B_JC_Air_004_GIS	
DESIGN	SM	12/08/14	SCALE AS SHOWN	REV 0
GIS	ANK	10/09/14	MAP 1.1-2	
CHECK	CG	10/09/14		
REVIEW	SM	10/09/14		

1.3 Baseline Study Area

The broader study area includes representative air quality and meteorological station locations in the NWT and Nunavut. The breadth of the study area allows for the inclusion of station data from locations that share similar northern climatic and environmental conditions as the Project location. Data from stations in the study area further from the Project including air quality monitoring and/or meteorological stations at Fort Liard, Inuvik, Norman Wells, Yellowknife, Lupin, Daring Lake, Snare Rapids, and Snap Lake Mine were also used to characterize baseline conditions.

The closest industrial development, the Ekati Mine's Misery Pit, is located approximately 6 km south-southwest of the Jay pipe. The Diavik Diamond Mine, which is located approximately 14 km from the Jay pipe, is the next nearest industrial development. Other industrial developments in the region are the Snap Lake Mine, located 120 km to the south, and the Gahcho Kué Mine, located 137 km to the southeast.

One continuous air monitoring station (CAMS), three high-volume air sampler (HVAS) stations, and three meteorological stations at the Ekati Mine were used to help characterize baseline air quality conditions in the baseline study area. The locations of these stations are shown in Map 1.3-1.
In addition, in 2013, two monitoring stations were installed in the immediate vicinity of the Project near Lac du Sauvage to help characterize the existing air quality environment at the Project site. The locations of the two monitoring stations are shown in Map 1.3-2.



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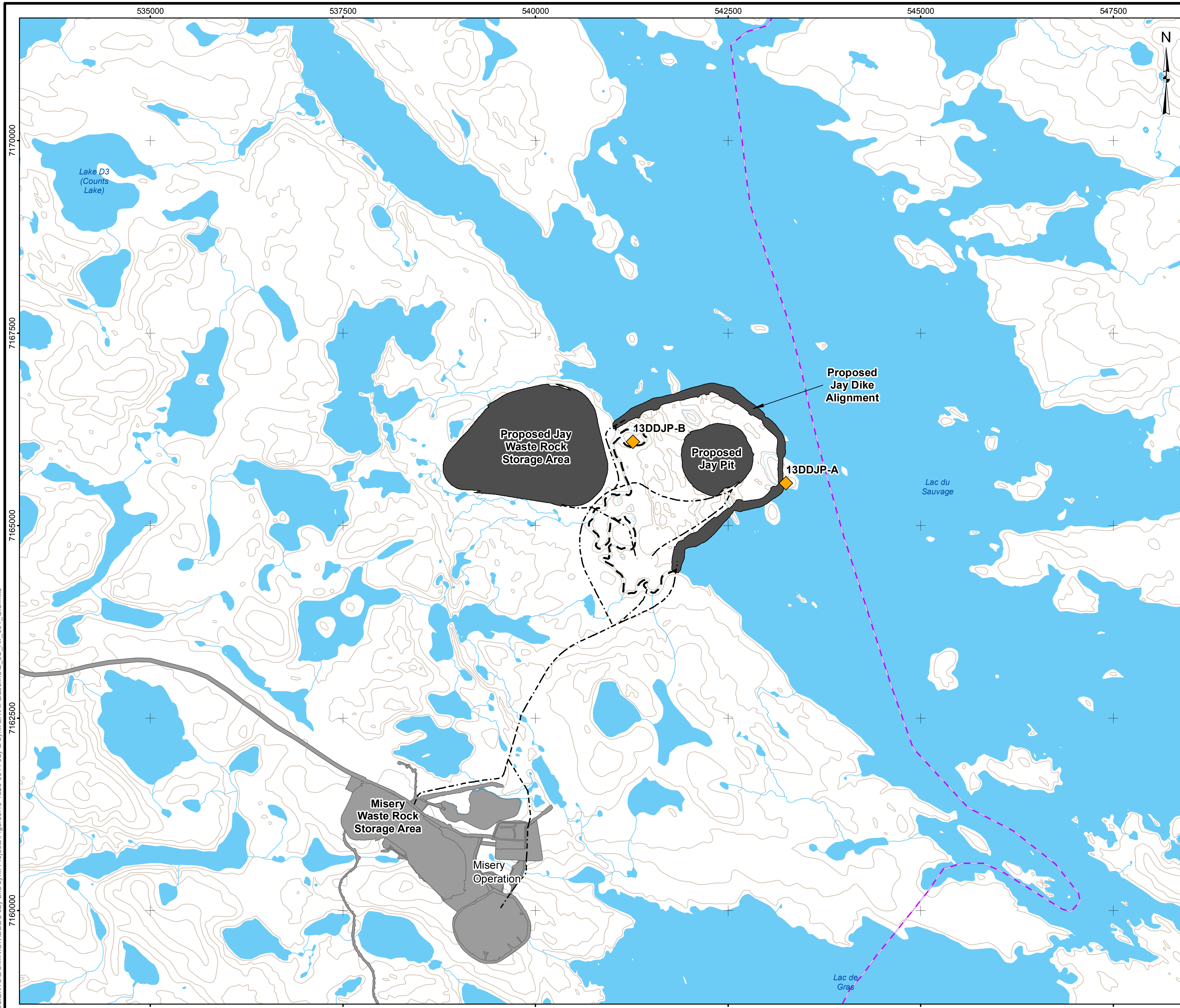

LEGEND

- EKATI MINE FOOTPRINT (MISERY OPERATION)
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- AIR QUALITY STATION

JAY PROJECT FOOTPRINT

- PROPOSED JAY ROAD / POWERLINE / PIPELINE
- EXISTING SHORELINE OF DEWATERED AREA
- PROPOSED JAY PROJECT INFRASTRUCTURE

REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

AIR QUALITY BASELINE REPORT

1 0 1

SCALE 1:50,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LOCATION OF MONITORING STATIONS AT JAY PIPE

Golder Associates

PROJECT	13-1328-0041		FILE No. B_JC_Air_001_GIS	
DESIGN	AP	28/11/13	SCALE AS SHOWN	REV 0
GIS	ANK	10/09/14	**MAP 1.3-2**	
CHECK	CG	10/09/14		
REVIEW	SM	10/09/14		

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2 METEOROLOGICAL AND AIR QUALITY METHODS

This section reports monitoring locations, and the equipment used to measure local meteorology and air quality. It includes a discussion of the data quality checks and the various sources of regional climate and air quality data. It also summarizes the regulatory criteria governing air quality in the NWT.

2.1 Meteorological Monitoring

Two monitoring stations have provided meteorological data at the Ekati Mine. The Polar Lake Meteorological Station (Polar Station) has been in operation since May 2006, and the Koala Meteorological Station (Koala Station) has been in operation since January 1995.

Polar Station is located at Universal Transverse Mercator (UTM) coordinates 520,796 metres (m) east and 7,178,714 m north (Zone 12, North American Datum [NAD] 83) (Map 1.3-1). Polar Station data were collected hourly during the summer months. Maximum and average values were collected for relative humidity, temperature, and wind; total values were collected for rainfall.

Koala Station is located at UTM 518,743 m east and 7,173,772 m north (Zone 12, NAD 83) (Map 1.3-1). Koala Station data were collected hourly year-round. Average values were collected for relative humidity, temperature, and wind. Rainfall data were reported as totals.

Koala Station reported a more robust year-round data set and was, therefore, used as the primary station for determining meteorological conditions at the Project. The meteorological monitoring equipment installed at Koala Station is listed in Table 2.1-1.

The data collected at Ekati monitoring stations between 2009 and 2012 were subject to data quality assurance checks (BHP Billiton 2012).

Table 2.1-1 Meteorological Measurement Instruments at Koala Meteorological Station

Parameter	Instrumentation
Temperature	
Average air temperature -55 degrees Celsius (°C) to +50°C	Viasala HMP45C
Wind	
Wind speed in kilometres per hour (km/hr)	05103 RM Young Anemometer at 10 metre (m) height
Wind direction degrees (°)	
Standard deviation of wind direction degrees (°)	
Precipitation	
Rainfall in millimetres (mm)	Sierra Misco 2500-P tipping bucket rain gauge
Snowfall in millimetres (mm)	Nipher snow gauge
Relative Humidity	
Relative humidity in percent (%)	Viasala HMP45C
Battery Power	Solar cell with battery backup
Data Logger	Campbell Scientific CR10

Source: BHP Billiton (2012).

2.2 Air Quality Monitoring

An air quality monitoring program was initiated in 1994 at the Ekati site before the Ekati Mine was developed. It recorded data intermittently, and continues to do so to the present day. An ambient air quality monitoring program was undertaken at the Project from July to August, 2013 to monitor nitrogen dioxide (NO_2), ammonia (NH_3), particulate matter of mean aerodynamic diameter less than 2.5 microns ($PM_{2.5}$), and total suspended particulate (TSP) at two stations identified as 13DDJP-A and 13DDJP-B (Map 1.3-2). The main purpose of collecting data at the Jay Pit stations was to understand background concentrations of the selected parameters beyond the immediate vicinity of the Ekati development.

The NO_2 and NH_3 data were collected simultaneously using passive air quality samplers from July to October 2013 near the proposed Jay Pit. Passive sensors are designed to provide average concentrations over a 30-day period; however, because site access was limited, measurements were taken nominally on a monthly cycle and variations occurred in total length of sample. The $PM_{2.5}$ and TSP data were collected intermittently using active BGI PQ100 particulate samplers over 24-hour periods approximately once per month. Collected data were then sent to an accredited laboratory for analysis and reporting.

High volume air sampler stations, TSP-1, TSP-2, and TSP-3, at the Ekati Mine (Map 1.3-1) also monitored TSP concentrations in 2013. An HVAS has been used to collect TSP data at the Ekati site in the summer of 1994 and since 1997, HVAS systems have been used to collect TSP data at Ekati Mine during the summer. The HVAS systems are run approximately every six days and draw ambient air through a filter for a 24-hour period. The HVAS monitoring was extended to the winter months in 2010 and 2011. The current operational HVAS units are located in the dominant easterly and north-westerly wind directions, downwind of the Ekati main camp (Map 1.3-1).

A CAMS was installed at Grizzly Lake in 2007 but was relocated in 2008 to the current Ekati Polar Explosives site (Map 1.3-1). Continuous nitrogen oxides (NO_X), sulphur dioxide (SO_2), $PM_{2.5}$, and TSP concentrations are measured at the CAMS. Teledyne 200E and 100E analyzers measure NO_X and SO_2, respectively, and two Met One BAM-1020 particulate analyzers measure $PM_{2.5}$ and TSP. Data were recorded using a data acquisition system housed at the Polar Explosives site. Data were manually retrieved each month. Collected data were then sent to an accredited laboratory for analysis and reporting.

Data from the Polar Explosives station and the Ekati HVAS stations are not representative of background concentrations at the Project because of their proximity to emissions from Ekati Mine. These stations are located immediately near roads or infrastructure or are within 300 m of sources. In comparison, the Polar Explosives station and the HVAS stations are on average approximately 25 km from the Project location. They are included in the results for reference.

The parameters that were monitored and the equipment installed to measure the air quality at the Project and Ekati Mine sites are listed in Table 2.2-1.

Table 2.2-1 Air Quality Parameters and Equipment

Parameter	Instrument	Reason for Collection
SO_2 – long-term measurements taken over periods of approximately 30 days	Passive Monitor	SO_2 is generated from the combustion of sulphur-containing fuels, such as diesel
SO_2 – continuous measurements	Teledyne 100E	SO_2 is generated from the combustion of sulphur-containing fuels, such as diesel
NO_2 – long-term measurements taken over periods of approximately 30 days	Passive Monitor	NO_2 is generated from the combustion of fuel
NO_2 – continuous measurements	Teledyne 200E	NO_2 is generated from the combustion of fuel
NH_3 – long-term measurements taken over periods of approximately 30 days	Passive Monitor	NH_3 is generated from natural decay processes and explosives production, and is used in the CALPUFF model because it is involved in reactive chemistry with other compounds
$PM_{2.5}$ – continuous measurements	Met One BAM-1020	$PM_{2.5}$ is generated from mechanical mining and construction activity, vehicle movement, and diesel fuel combustion
$PM_{2.5}$ – 24-hour measurements	BGI PQ100 Particulate Sampler	$PM_{2.5}$ is generated from mechanical mining and construction activity, vehicle movement, and diesel fuel combustion
TSP – continuous measurements	Met One BAM-1020	TSP is generated from mechanical mining and construction activity, vehicle movement, and diesel fuel combustion
TSP – 24-hour measurements	BGI PQ100 Particulate Sampler and Tisch TE-5170 HiVol Sampler	TSP is generated from mechanical mining and construction activity, vehicle movement, and diesel fuel combustion

SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide; NH_3 = ammonia; $PM_{2.5}$ = particulate matter of mean aerodynamic diameter less than 2.5 microns; TSP = total suspended particulate.

The locations of the Ekati Mine monitoring stations are shown in Map 1.3-1.

The UTM coordinates of the two Project-specific stations installed in 2013 are presented in Table 2.2-2. The two Project stations are shown in Photos 2.2-1 and 2.2-2.

The data collected in 2013 from the two Project stations were not intended to provide an exhaustive record; rather, they were used to confirm the assumption that background conditions of the selected compounds were low in the absence of development in the immediate area of the stations. The two monitoring locations were selected to characterize the air quality environment in areas nominally aligned with the prevailing regional downwind direction from the proposed Jay Pit location. It is expected that the monitoring stations near the proposed Jay Pit will be indicative of regional background air quality for the components monitored.

Emissions from the Ekati and Diavik Diamond Mine operations are expected to contribute to the concentrations measured at the proposed Project location stations, but the contributions are expected to be low given the distance between the stations and the existing operations. A review of the predictive modelling from previous assessment work at the Ekati Mine supports this expectation (BHP Billiton 2006).

Table 2.2-2 Project-Specific Station Locations

Receptor	Location	UTM (Zone 12 W, NAD 83)	
		Easting (m)	Northing (m)
13DDJP-A	Located on a medium-sized island on Lac du Sauvage, immediately southeast of the proposed Jay Pit	543,253	7,165,551
13DDJP-B	Located on a peninsula on Lac du Sauvage immediately northwest of the proposed Jay Pit	541,267	7,166,089

m = metre; W = west; NAD = North American Datum; UTM = Universal Transverse Mercator.

Photo 2.2-1 Station 13DDJP-A

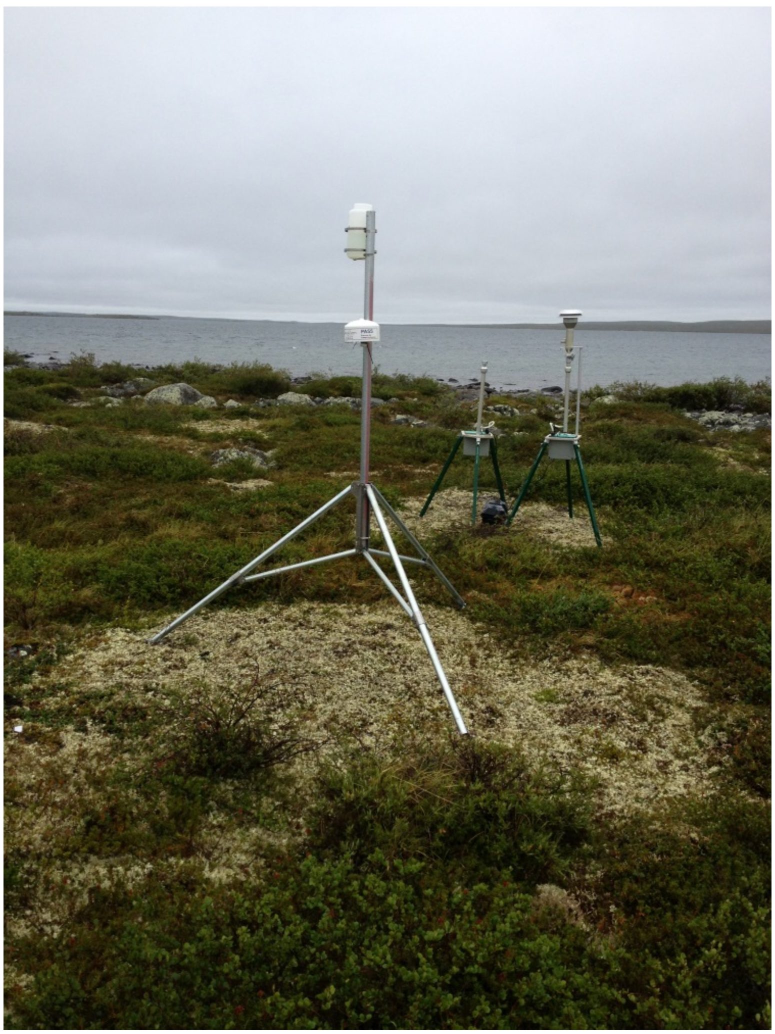
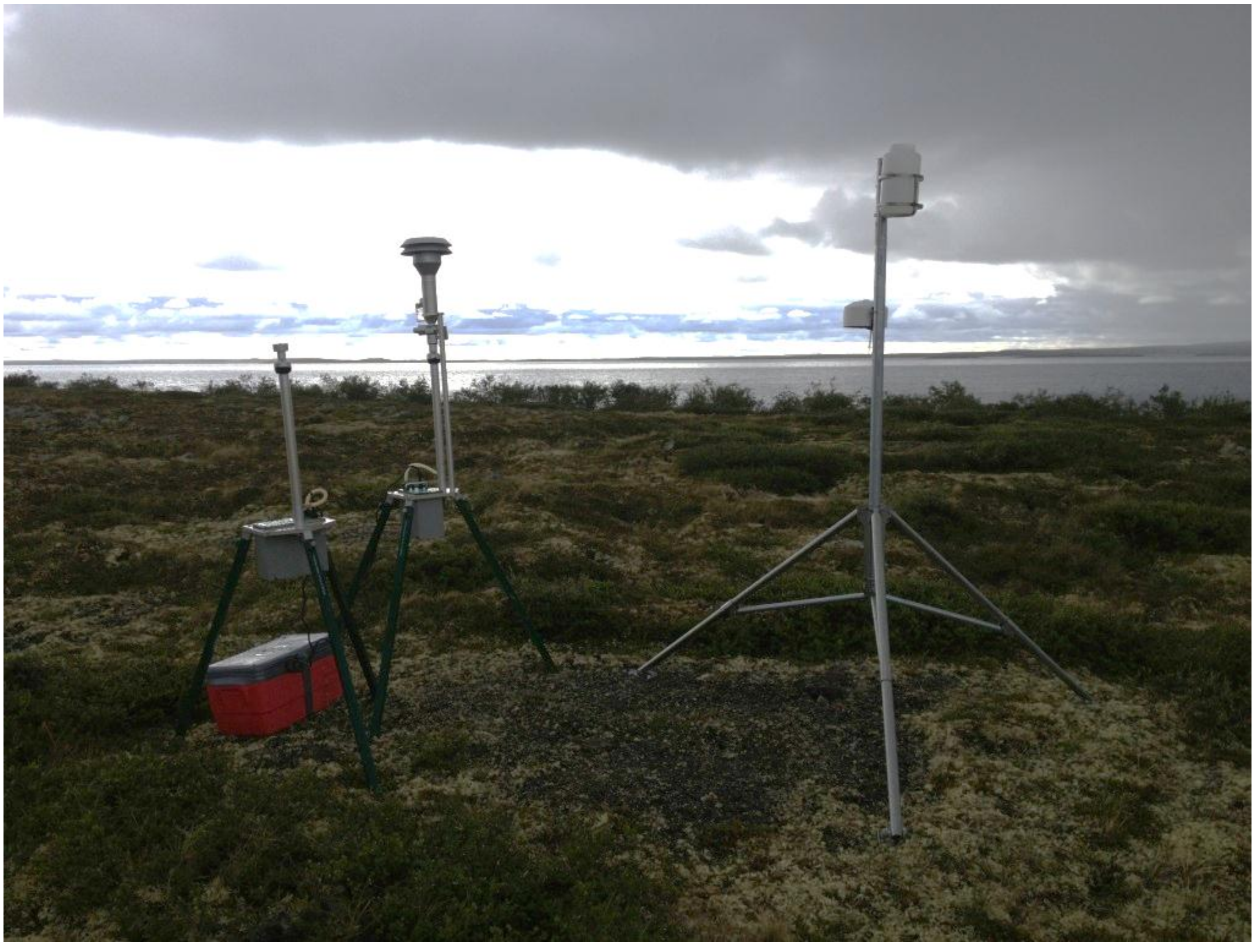


Photo 2.2-2 Station 13DDJP-B



The data collected at the proposed Jay Pit baseline monitoring stations in 2013 were subject to data quality assurance checks on site. Passive samplers and particulate filters were sent for analysis to Maxxam Analytics in Edmonton, Alberta.

2.3 Other Data Sources

2.3.1 Meteorology and Climate Data

Climate normals, which are statistics based on 30 years of data, were available from the Environment Canada Lupin Airport monitoring station (Lupin A) through the National Climate Archive website (Environment Canada 2013). The Lupin A station is in Nunavut, which is approximately 130 km north of the Project site.

Meteorological data available from the Ekati Airport monitoring station (Ekati A) (Map 1.3-1) were also used to document existing conditions.

2.3.2 Air Quality Data

The GNWT Department of Environment and Natural Resources and Environment Canada also monitor air quality in the NWT. Air quality monitoring data from the De Beers Canada Inc. (De Beers) Snap Lake Mine are also referenced in this report. The approximate distance of each station from the Project site is listed in Table 2.3-1.

Table 2.3-1 Distance of Jay Project to Other Northwest Territories Monitoring Sites

Monitoring Station	Approximate Distance From the Project (km)	Direction
Yellowknife	317	SW
Inuvik	1,090	WNW
Norman Wells	765	W
Fort Liard	835	SW
Daring Lake	50	WNW
Snare Rapids	296	SW
Snap Lake Mine	120	S

km = kilometre; S = south; SW = southwest; W = west; WNW = west-northwest.

2.4 Ambient Air Quality Criteria

The GNWT has established air quality criteria in the NWT (GNWT 2014) for the following compounds:

- NO_2;
- SO_2;
- ozone (O_3);
- carbon monoxide (CO);
- TSP; and,
- $PM_{2.5}$.

A summary of the Northwest Territories Ambient Air Quality Standards (ENR 2014) and objectives for regulated compounds, which include $PM_{2.5}$ and CO, is provided in Table 2.4-1. The guidelines and objectives refer to averaging periods ranging from one hour to one year. Because quantities of ozone emitted by the Project are not expected to affect local air quality, ozone is not tabulated here.

Environment Canada has established Canada-Wide Standards (CWS) for particulate matter and ozone (CCME 2006). The CWS provide an alternative regulatory tool for the management of environmental issues of national interest. The CWS are intended to be achievable targets that will reduce health and environmental risks within a specific timeframe. The CWS for $PM_{2.5}$ is included for comparison (CCME 2006). The Canadian Council of Ministers of the Environment will establish new Canadian Ambient Air Quality Standards (CAAQS) under the *Canadian Environmental Protection Act* 1999 and will replace the current CWS (CCME 2012).

The Government of Alberta has established the Alberta Ambient Air Quality Objectives (ESRD 2013a,b), and the Government of British Columbia has established the British Columbia Ambient Air Quality Objectives (BC MOE 2013). These objectives are presented for comparison (Table 2.4-1).

Table 2.4-1 Ambient Air Quality Standards and Other Benchmarks

Parameter	NWT Standards[(a)]	Canada-Wide Standards[(b)]	CAAQS[(c)]	Other Benchmarks
SO_2 (µg/m^3)				
1-hour	450	—	—	450[(d)]
24-hour	150	—	—	125[(d)]
Monthly	—	—	—	30[(d)]
Annual	30	—	—	20[(d)]
NO_2 (µg/m^3)				
1-hour	400	—	—	300[(d)]
24-hour	200	—	—	—
Annual	60	—	—	45[(d)]
TSP (µg/m^3)				
24-hour	120	—	—	100[(d)]
Annual	60	—	—	60[(d)]
PM_{10} (µg/m^3)				
24-hour	—	—	—	50[(e)]
Annual	—	—	—	—
$PM_{2.5}$ (µg/m^3)				
24-hour	28	30	28	30[(d)]
Annual	10	—	10.0	8[(e)]
CO (µg/m^3)				
1-hour	15,000	—	—	15,000[(d)]
8-hour	6,000	—	—	6,000[(d)]

a) ENR (2014).

b) CCME (2000). Based on 98th percentile, averaged over three consecutive years.

c) CCME (2012). CAAQS (Canadian Ambient Air Quality Standard) Based on 98th percentile, averaged over three consecutive years, will replace the Canada-Wide Standards in 2015.

d) ESRD (2013a) Alberta Ambient Air Quality Objectives.

e) BC MOE (2013) British Columbia Ambient Air Quality Objectives.

NWT = Northwest Territories; CAAQS = Canadian Ambient Air Quality Standards; SO_2 = sulphur dioxide; NO_2 = nitrogen dioxide; TSP = total suspended particulate; PM_{10} = particulate matter of mean aerodynamic diameter less than 10 microns; $PM_{2.5}$ = particulate matter of mean aerodynamic diameter less than 2.5 microns; CO = carbon monoxide; µg/m^3 = micrograms per cubic metre; — = not available.

3 CLIMATE

The climate of a region is described by long-term averages of observed meteorological variables. It is often characterized by 30 continuous years of meteorological observations at a given location. Climate normals, which present the average meteorological measurements at a given station for periods between 1961 and 1990, 1971 and 2000, and 1981 and 2010, are provided by Environment Canada. The station closest to the Project with a long enough record to provide climate normals is Lupin A in Nunavut. It is located 130 km northwest of the Project. The climate measurements that are available at Lupin A for the period 1981 to 2010 are summarized in Table 3-1.

3.1 Winds

The average winds at Lupin A are typically from the north or northwest, ranging between 14 kilometres per hour (km/hr) and 20 km/hr, with higher velocity winds in the winter months. Because Lupin A is located north of the treeline, recorded wind speeds are expected to be higher there than at locations below the treeline.

3.2 Precipitation

Cold, Arctic air holds little moisture, resulting in low overall precipitation rates, with much of the precipitation occurring in the form of snow. At Lupin A, the mean annual total rainfall is 161 millimetres (mm), with most of this occurring from June to September (Environment Canada 2013). These months align with the time that the surrounding lakes are expected to be ice-free and moisture will be exchanged to the atmosphere from the lakes. Snowfall occurs year-round, with most of it falling between September and May. October experiences the greatest amount of snowfall, consistent with the period of time when the lakes are not yet completely frozen, the air is colder than the open water, and there is enhanced moisture exchange resulting in snow. The average total annual precipitation at Lupin A is 299 mm.

3.3 Temperature

Observations at the Lupin A station show the mean air temperature has a large seasonal dependence. In the winter (January), a daily mean of -30 degrees Celsius (°C) was recorded, while in the summer (July) the recorded daily mean was 12°C (Environment Canada 2013). By October, mean temperatures are generally well below freezing at -8°C and remain at sub-freezing levels until June. The annual daily mean obtained from data recorded at the Lupin A station from 1981 to 2010 was -10.9°C. The climatological extreme and average temperatures for 1981 to 2010 at Lupin A are summarized in Table 3-1.

Table 3-1 Lupin Airport Monitoring Station Climate Normals, 1981 to 2010

Parameter	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature													
Daily average (°C)	-29.9	-28.5	-24.8	-15.8	-5.9	6.4	11.5	8.8	2.1	-8.4	-20.4	-26.2	-10.9
Average daily maximum (°C)	-26.3	-24.9	-20.9	-11.5	-2.1	10.8	16.3	12.6	4.8	-5.8	-16.9	-22.6	-7.2
Average daily minimum (°C)	-33.4	-32.1	-28.7	-20.1	-9.6	1.9	6.7	5.0	-0.6	-10.9	-23.9	-29.7	-14.6
Extreme maximum (°C)	-5.0	-5.0	0.5	6.0	17.5	27.5	31.0	27.5	21.0	13.0	0.0	-4.5	31.0
Extreme minimum (°C)	-49.0	-46.0	-44.0	-38.0	-29.5	-9.0	-1.5	-6.5	-13.5	-30.5	-40.5	-42.0	-49.0
Precipitation													
Rainfall (mm)	0.0	0.0	0.0	0.4	5.3	26.8	41.1	59.8	25.5	1.6	0.0	0	160.5
Snowfall (cm)	9.4	7.8	12.2	14.3	12.5	3.6	0.4	2.6	17.1	27.1	17.4	13.7	138.0
Total precipitation (mm)	9.4	7.8	12.2	14.6	17.8	30.4	41.5	62.5	42.6	28.7	17.4	13.7	298.5
Extreme daily total precipitation (mm)	11.6	14.2	10.0	13.8	14.3	36.8	41.8	38.6	34.2	31.8	14	10	41.8
Days with precipitation >0.2 mm	9	8.6	9.7	10.1	9.1	9.2	12.2	16.4	15.4	17.5	13.8	10.9	141.9
Wind													
Average speed (km/hr)	17.8	19.0	19.2	14.2	17.9	17.1	16.6	17.0	19.8	20.1	15.4	19.3	17.8
Most frequent direction	NW	NW	N	SW	N	NW	N	N	NW	SW	N	NW	NW

Source: Environment Canada (2013).

°C = degrees Celsius; cm = centimetre; mm = millimetre; km/hr = kilometres per hour; > = greater than; NW = northwest; N = north; SW = southwest.

4 METEOROLOGY

Weather describes atmospheric conditions at a specific time, in contrast to the long-term averages used to describe climate. The following subsections describe the observed weather at the Project.

4.1 Wind Speed and Direction

A windrose is often used to illustrate the frequency of wind direction and the magnitude of wind velocity. The lengths of the bars on the windrose indicate the frequency and speed of wind; the direction from which the wind blows is illustrated by the orientation of the bar in 1 of 16 directions. In this section, windroses characterize the typical winds that have occurred at the Project location in the last five years.

Two monitoring stations at the Project, the Koala and Polar stations, have measured wind speed and direction. The nearby Ekati A Environment Canada station also measures wind speed and direction. The following sections detail those measurements for the years 2009 to 2013.

4.1.1 Koala Meteorological Station

The location of Koala Station is shown in Map 1.3-1. At Koala Station, hourly wind speed and wind direction were measured year-round. The windrose for winds measured between 2009 and 2013 at Koala Station is shown in Figure 4.1-1.

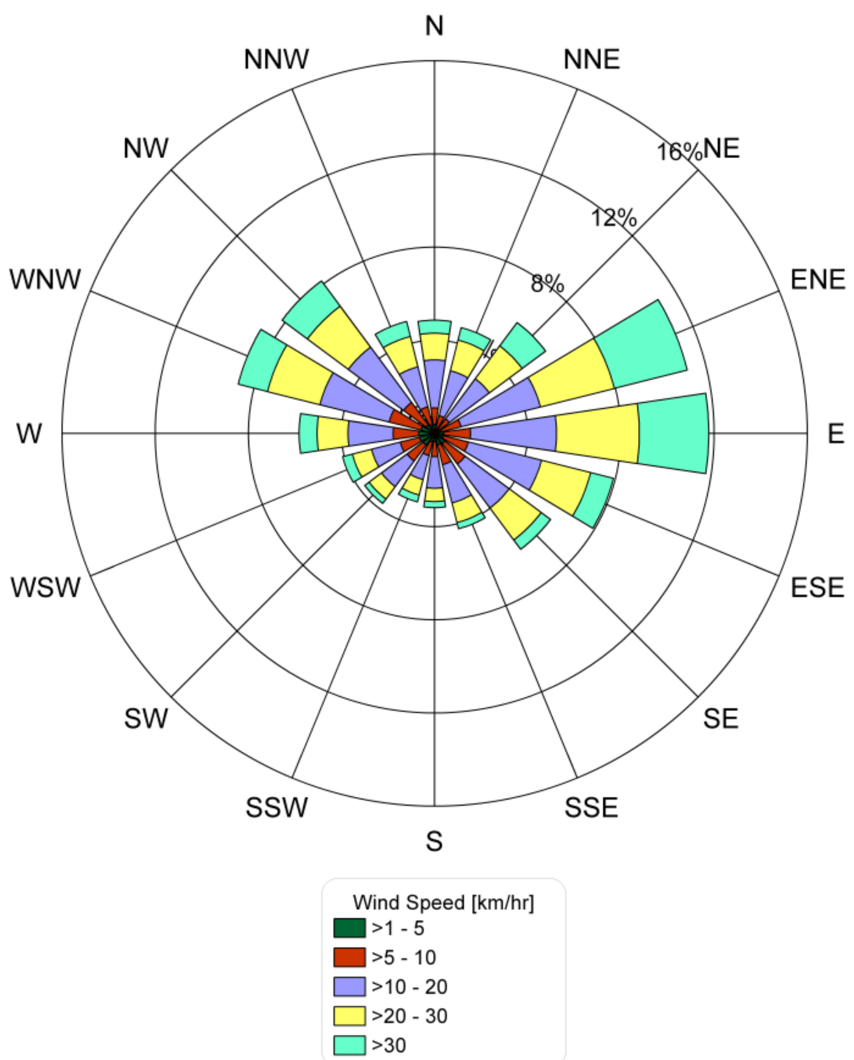
The predominant wind at Koala Station is from the east. An almost equal percentage of winds were measured from the east-northeast, and winds were observed from the west-northwest and northwest more than 8 percent (%) of the time.

The dominant wind patterns change during the summer ice-free period, which occurs nominally between June and October, and the winter ice-bound period, which typically occurs between November and May.

During the summer, the predominant wind is from the east-northeast; smaller percentage of winds is observed from the northwest than seen in the full-year windrose. The June to October windrose for winds observed at Koala Station is shown in Figure 4.1-2.

During the winter, winds from the east, east-northeast, west-northwest and northwest dominate the wind pattern. The winter winds measured at Koala Station are shown in Figure 4.1-3.

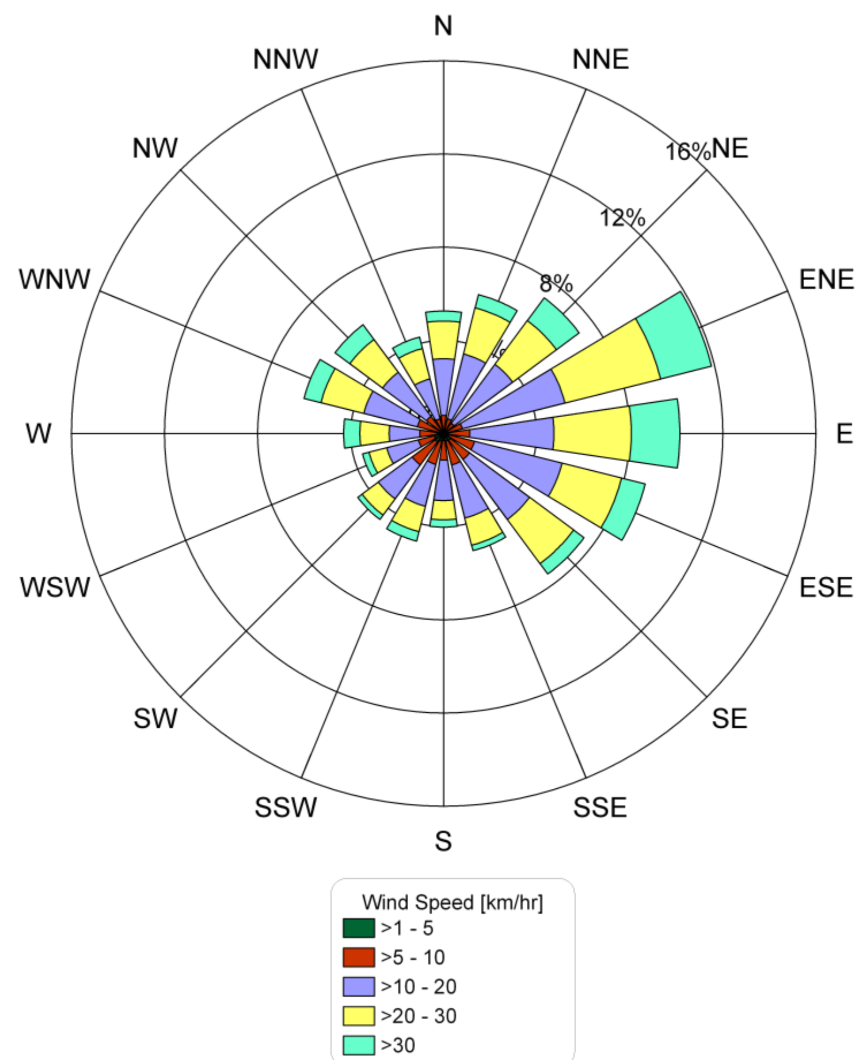
Figure 4.1-1 Koala Meteorological Station Windrose, 2009 to 2013



Note: Windrose is based on year-round measurements of wind speed and direction from 2009 to 2013.

km/ hr = kilometres per hour; > = greater than; % = percent.

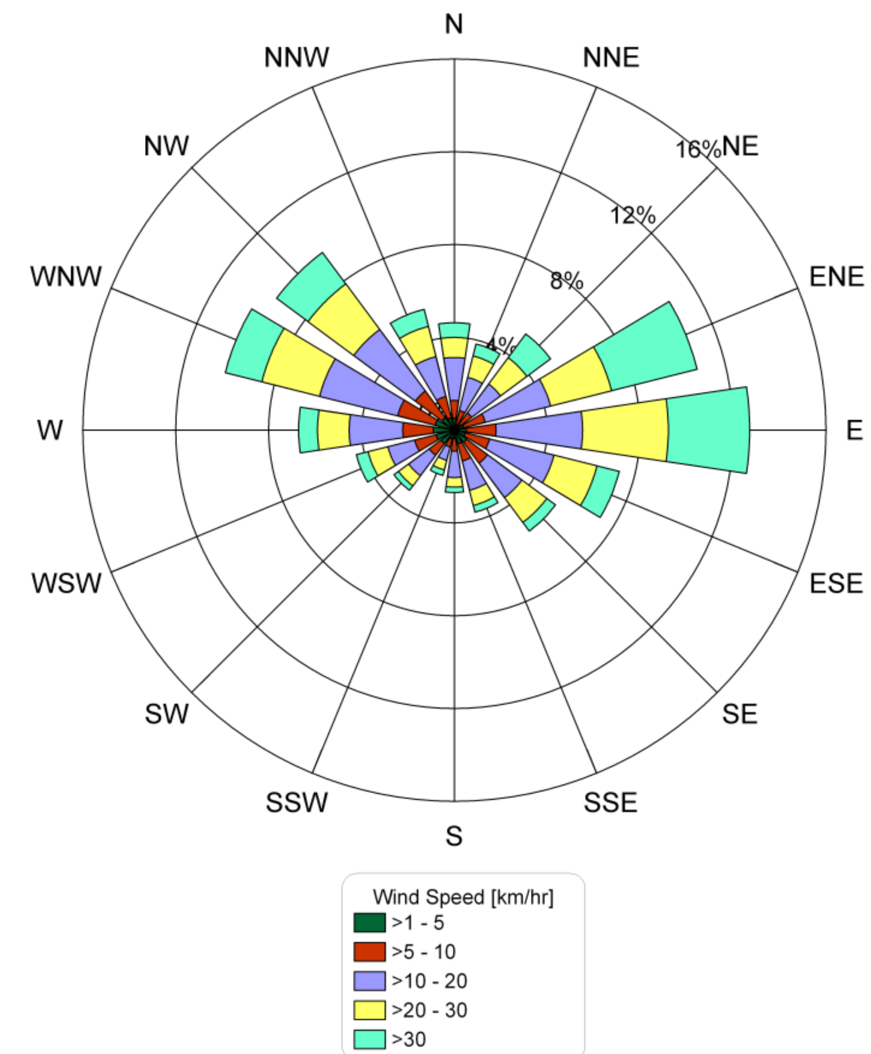
Figure 4.1-2 Koala Meteorological Station Summer Windrose, 2009 to 2013



Note: Windrose is based on measurements of wind speed and direction from June to October, each summer from 2009 to 2013.

km/ hr = kilometres per hour; > = greater than; % = percent.

Figure 4.1-3 Koala Meteorological Station Winter Windrose, 2009 to 2013



Note: Windrose is based on measurements of wind speed and direction from November to May, each winter from 2009 to 2013.

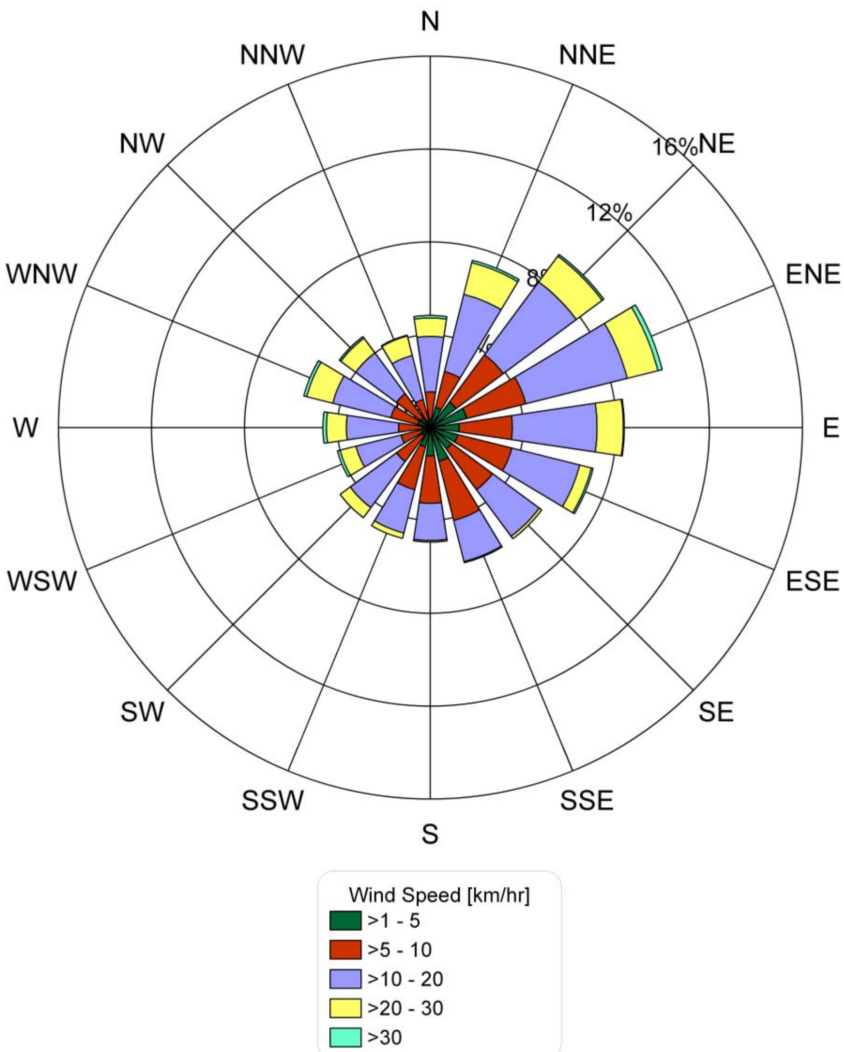
km/ hr = kilometres per hour; > = greater than; % = percent.

4.1.2 Polar Lake Meteorological Station

The location of Polar Station is shown in Map 1.3-1. Wind speed and direction were measured at Polar Station over the summer months. The windrose for winds measured for the most recent five years from 2009 to 2013 during this period is shown in Figure 4.1-4.

The dominant wind is from the east-northeast. Winds were also observed from the east and northeast more than 8% of the time. The winds observed at Polar Station are consistent with the winds observed at Koala Station during the summer months (Figure 4.1-2).

Figure 4.1-4 Polar Lake Meteorological Station Summer Windrose, 2009 to 2013

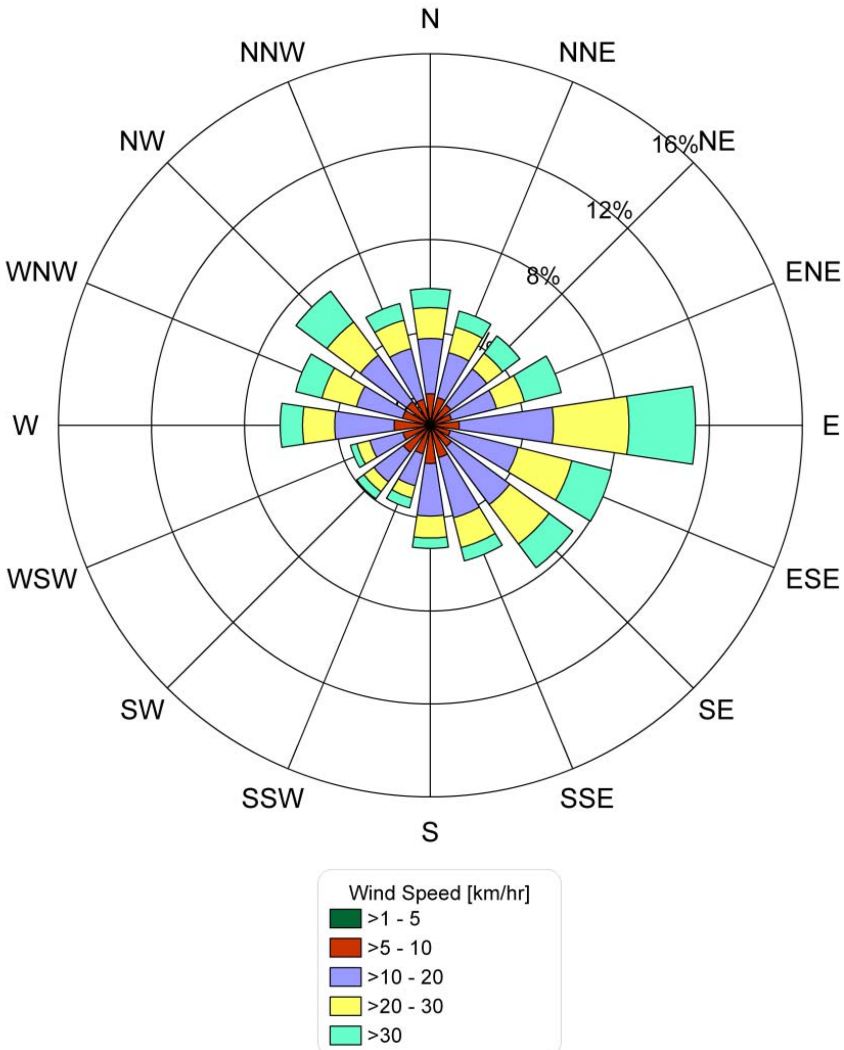


Note: Windrose is based on measurements of wind speed and direction from June to October, each summer from 2009 to 2013.
km/ hr = kilometres per hour; > = greater than; % = percent.

4.1.3 Ekati Airport Monitoring Station

The location of Ekati A is shown in Map 1.3-1. The station is in operation only during the hours that the Ekati Airport is in operation. The station measures meteorological variables for 12 hours of the day. The windrose for Ekati A is shown in Figure 4.1-5. The predominant wind measured at Ekati A is from the east.

Figure 4.1-5 Ekati Airport Monitoring Station Windrose, 2009 to 2013



Note: Windrose is based on 12-hour measurements of wind speed and direction when the airport is operation, from 2009 to 2013.
km/ hr = kilometres per hour; > = greater than; % = percent.

4.2 Precipitation

Precipitation (i.e., snowfall, rainfall, and total precipitation) is measured at Koala Station. Precipitation is not measured at the Polar or Ekati A stations.

Snowfall was measured as snow-water equivalent during the winter at Koala Station from 2008 to 2013. Data were retrieved approximately every two weeks. Rainfall was also measured at Koala Station; data were recorded automatically.

The majority of rainfall at Koala Station occurs between June and October, while the majority of the snowfall occurs between November and April. The months of July through September experience the greatest amount of precipitation, and this result is consistent with the climate normal measured at Lupin A (Table 3-1). A summary of the monthly precipitation readings in millimetres at Koala Station from 2009 to 2013 is provided in Tables 4.2-1 to 4.2-3.

Table 4.2-1 Total Snowfall Measured at Koala Meteorological Station, 2008 to 2012

Year	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	June (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)
2008	29.6	1.2	6.6	25.0	0.0	0.0	0.0	0.0	0.0	0.0	18.9	6.0
2009	6.8	16.6	18.9	41.0	16.0	0.0	0.0	0.0	0.0	16.1	58.1	13.9
2010	26.8	4.8	7.3	23.5	5.1	0.0	0.0	0.0	0.0	16.8	39.4	18.6
2011	11.0	23.6	3.4	13.6	0.0	0.0	0.0	0.0	0.0	56.1	49.8	52.8
2012	44.5	83.8	55.9	15.1	1.8	—	—	—	—	—	—	—

Source: Dominion Diamond (2014).
Notes: Snowfall was measured as snow-water equivalent. Data are unavailable from June to December 2012.
mm = millimetre; — = not available.

Table 4.2-2 Total Rainfall Measured at Koala Meteorological Station, 2008 to 2012

Year	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	June (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)
2008	0.0	0.0	0.0	0.0	5.6	45.0	37.6	156.5	62.0	8.6	0.0	17.0
2009	0.0	0.0	0.0	0.0	0.0	17.3	41.9	20.1	38.9	3.3	1.0	0.0
2010	0.0	0.0	0.0	0.0	8.0	32.4	58.0	7.2	26.2	1.2	0.0	0.0
2011	0.0	0.0	0.3	0.0	0.0	5.3	47.8	91.7	98.6	17.8	0.0	0.0
2012	0.0	0.0	0.0	2.0	8.9	0.8	22.1	50.0	45.5	13.0	0.0	0.0

Source: Dominion Diamond (2014).
mm = millimetre.

Table 4.2-3 Total Precipitation Measured at Koala Meteorological Station, 2008 to 2012

Year	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	June (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Year
2008	29.6	1.2	6.6	25.0	5.6	45.0	37.6	156.5	62.0	8.6	18.9	23.0	419.6
2009	6.8	16.6	18.9	41.0	16.0	17.3	41.9	20.1	38.9	19.4	59.1	13.9	309.9
2010	26.8	4.8	7.3	23.5	13.1	32.4	58.0	7.2	26.2	18.0	39.4	18.6	275.3
2011	11.0	23.6	3.6	13.6	0.0	5.3	47.8	91.7	98.6	73.9	49.8	52.8	471.7
2012	44.5	83.8	55.9	17.1	10.7	0.8	22.1	50.0	45.5	13.0	0.0	0.0	343.4
Average	23.7	26.0	18.5	24.0	9.1	20.1	41.5	65.1	54.2	26.6	33.4	21.7	363.9

Source: Dominion Diamond (2014).
mm = millimetre.

4.3 Temperature

This section presents the measured temperature at Koala Station between 2009 and 2013. The ranges of monthly mean temperatures at Koala Station between 2009 and 2013 are presented in Table 4.3-1.

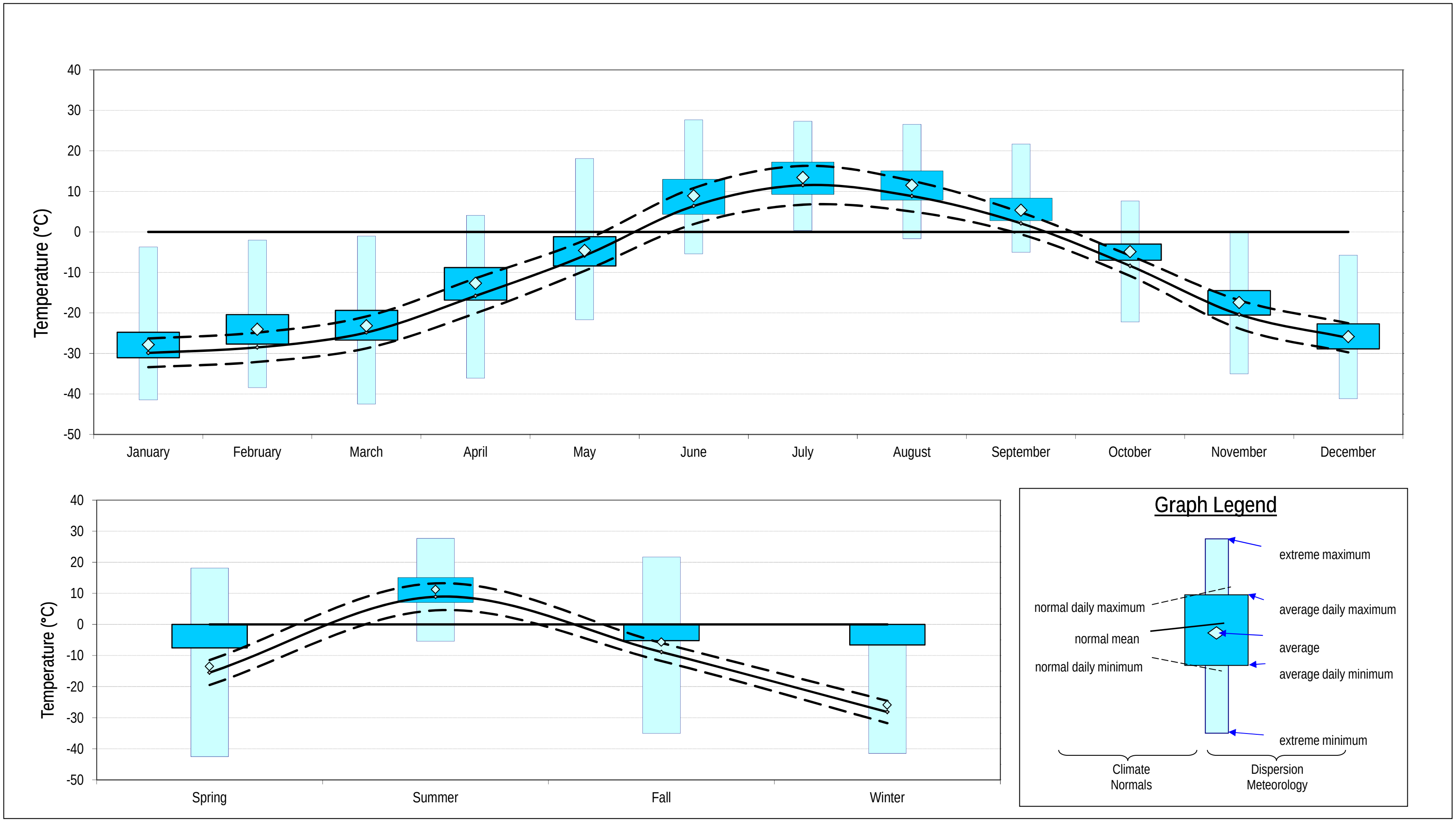
Table 4.3-1 Observed Temperatures at Koala Meteorological Station, 2009 to 2013

	Jan (°C)	Feb (°C)	Mar (°C)	Apr (°C)	May (°C)	Jun (°C)	Jul (°C)	Aug (°C)	Sep (°C)	Oct (°C)	Nov (°C)	Dec (°C)
Daily average	-27.8	-24.1	-23.2	-12.7	-4.6	8.9	13.4	11.5	5.3	-4.9	-17.4	-25.9
Standard deviation	7.0	7.3	9.3	7.1	6.9	6.5	4.7	4.7	4.5	5.6	6.6	6.6
Daily maximum	-24.8	-20.4	-19.4	-8.8	-1.2	13.0	17.3	15.1	8.4	-3.0	-14.5	-22.7
Daily minimum	-31.1	-27.7	-26.7	-16.8	-8.4	4.3	9.3	7.8	2.8	-7.0	-20.5	-28.9
Extreme maximum	-3.7	-2.0	-1.0	4.1	18.1	27.7	27.4	26.6	21.7	7.6	0.0	-5.7
Extreme minimum	-41.5	-38.4	-42.5	-36.1	-21.7	-5.4	0.3	-1.7	-5.1	-22.2	-35.1	-41.2

Source: Dominion Diamond (2014).
°C = degrees Celsius.

The average temperatures observed from 2009 to 2013 are shown in Figure 4.3-1. The Lupin A station climate normals are also plotted as dotted and solid lines. The average temperatures observed at Koala Station are slightly above the Lupin A station climate normals.

Figure 4.3-1 Average Measured Temperatures at Koala Meteorological Station, 2009 to 2013



°C = degrees Celsius.

4.4 Relative Humidity

Relative humidity is the ratio of the amount of water vapour present in the air to the amount of vapour necessary for saturation at the same temperature and pressure. Relative humidity was measured at Koala Station from 2009 to 2013; monthly average relative humidity at Koala Station, expressed as a percentage of saturation, is summarized in Table 4.4-1.

Table 4.4-1 Monthly Average Relative Humidity at Koala Meteorological Station, 2009 to 2013

Year	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
2009	76.3	76.9	75.6	86.5	82.8	74.7	70.7	75.8	84.1	87.8	86.6	77.2
2010	76.5	81.7	84.5	87.7	84.9	69.8	73.3	72.0	86.8	90.7	86.5	81.7
2011	79.7	78.1	78.0	—[a]	63.5	65.7	62.0	77.9	86.3	95.9	88.8	83.2
2012	79.5	82.5	81.7	85.3	89.0	62.5	62.6	75.2	80.9	92.6	85.2	78.0
2013	74.2	79.7	80.7	82.3	85.7	62.7	72.6	69.0	87.4	91.4	89.0	61.5
Average	77.2	79.8	80.1	85.5	81.2	67.1	68.2	74.0	85.1	91.7	87.2	76.3

Source: Dominion Diamond (2014).
a) Measurement unavailable due to instrument failure.
% = percent; — = not available.

4.5 Solar Radiation

Solar radiation levels measured at the surface are a function of hours of sunlight and sun azimuth angle, as well as a function of local weather conditions. Changes in weather variables may cause the annual peak in solar radiation to fluctuate from year to year.

Solar radiation was measured at Polar Station during the summer months while the station was active. The average solar radiation measured each year is presented in Table 4.5-1.

Table 4.5-1 Average Solar Radiation During the Summer at Polar Lake Meteorological Station, 2009 to 2013

	2009	2010	2011	2012	2013
Start date (dd/mm/yyyy)	06/12/2009	06/17/2010	06/24/2011	07/11/2012	07/8/2013
End date (dd/mm/yyyy)	10/6/2009	10/9/2010	10/11/2011	10/12/2012	09/30/2013
Average (kW/m^2)	0.167	0.148	0.177	0.144	0.148
Maximum (kW/m^2)	0.800	0.774	0.828	0.811	0.764

Source: Dominion Diamond (2014).
kW/m^2 = kilowatts per square metre; dd/mm/yyyy = day/month/year.

5 AIR QUALITY MONITORING AT THE PROJECT

5.1 Nitrogen Dioxide Monitoring

The maximum 30-day NO_2 concentration observed at the two Project stations during the 2013 monitoring period was 1.5 micrograms per cubic metre (µg/m³); the minimum 30-day concentration was below the detection threshold of 0.2 µg/m³. The average NO_2 concentration recorded at the Project stations was 0.5 µg/m³ (Table 5.1-1). Two-thirds of the sample measurements were below the detection limit.

Table 5.1-1 Jay Pit Air Quality Stations Nitrogen Dioxide Results, 2013

Station	Month[(a)]	Sample Concentration (µg/m³)	Sample Concentration (ppb)
13DDJP-A	August	1.5	0.8
	September	<0.6	<0.3
	October	<0.2	<0.1
13DDJP-B	August	0.9	0.5
	September	<0.6	<0.3
	October	<0.2	<0.1
	Average[(b)]	**0.5**	**0.3**

a) Nominal monthly values; start and end dates varied to accommodate site logistics.
b) Sample concentrations below the detectable limit are treated as half the detectable limit for calculating the average.
ppb = parts per billion; µg/m³ = micrograms per cubic metre; < = less than.

The maximum 1-hour NO_2 concentration observed at the Polar Explosives CAMS during the monitoring period was 295.3 µg/m³. The maximum 24-hour NO_2 concentration observed at the CAMS during the monitoring period was 160.4 µg/m³. The data from 2009 to 2011 at the Polar Explosives CAMS are summarized for reference in Table 5.1-2.

Table 5.1-2 Polar Explosives Continuous Air Monitoring Station Nitrogen Dioxide Results, 2009 to 2013

Year	2009	2010	2011
1-hour maximum (µg/m³)	295.3	255.8	120.4
24-hour maximum (µg/m³)	133.9	160.4	61.9

Source: BHP Billiton (2012).
µg/m³ = micrograms per cubic metre.

5.2 Sulphur Dioxide Monitoring

The maximum 1-hour SO_2 concentration observed at the Polar Explosives CAMS during the monitoring period was 31.4 µg/m³. The maximum 24-hour SO_2 concentration observed at the CAMS during the monitoring period was 11.3 µg/m³. The Polar Explosives CAMS SO_2 concentrations are higher than the background concentrations at the Project; however, data from 2009 to 2011 at the Polar Explosives CAMS are summarized for reference in Table 5.2-1.

Table 5.2-1 Polar Explosives Continuous Air Monitoring Station Sulphur Dioxide Results, 2009 to 2011

Year	2009	2010	2011
1-hour maximum (µg/m³)	23.6	31.4	28.8
24-hour maximum (µg/m³)	11.3	10.0	10.2

Source: BHP Billiton (2012).
µg/m³ = micrograms per cubic metre.

5.3 Ammonia Monitoring

The maximum 30-day NH_3 concentration observed at the two Project stations during the 2013 monitoring period was 6.8 µg/m³; the minimum 30-day concentration was below the detection threshold of 0.07 µg/m³. The average 30-day NH_3 concentration recorded at the Project stations was 1.7 µg/m³ (Table 5.3-1). One sample was below the detection limit.

Table 5.3-1 Jay Pit Air Quality Stations Ammonia Results, 2013

Station	Month[(a)]	Sample Concentration (µg/m³)	Sample Concentration (ppb)
13DDJP-A	August	<0.07	<0.1
	September	6.8	9.7
	October	0.6	0.8
13DDJP-B	August	0.3	0.4
	September	2.3	3.2
	October	0.1	0.2
Average[(b)]		**1.7**	**2.4**

a) Exposure period for nominal monthly values was approximately 30 days; however, start and end dates varied to accommodate site logistics.
b) Sample concentrations below the detectable limit were treated as half the detectable limit for calculating the average.
ppb = parts per billion; µg/m³ = micrograms per cubic metre; < = less than.

5.4 $PM_{2.5}$ Monitoring

The maximum 24-hour $PM_{2.5}$ concentration observed at the two Project stations during the 2013 monitoring period was 5.9 µg/m³; the minimum 24-hour concentration was 0.3 µg/m³. The average $PM_{2.5}$ concentration recorded at the Project stations was 1.3 µg/m³ (Table 5.4-1). These data indicate that background concentrations of $PM_{2.5}$ are low near the Project.

Table 5.4-1 Jay Pit Air Quality Stations $PM_{2.5}$ Results, 2013

Station	Month [a]	Sample Concentration (µg/m³)
13DDJP-A	July	1.0
	August	0.5
	September	0.6
	October	—
13DDJP-B	July	5.9
	August	0.4
	September	0.5
	October	0.3
	Average	**1.3**

a) One 24-hour sample was taken at each station per month.

— = not available; $PM_{2.5}$ = particulate matter of mean aerodynamic diameter less than 2.5 microns; µg/m³ = micrograms per cubic metre.

The maximum 24-hour $PM_{2.5}$ concentration observed at the Polar Explosives CAMS during the monitoring period was 31.0 µg/m³. The Polar Explosives CAMS $PM_{2.5}$ concentrations are not representative of background concentrations at the Project because of their close proximity to emissions from the Ekati operation; however, the 2009 to 2011 data from this air monitoring station are summarized for reference in Table 5.4-2.

Table 5.4-2 Polar Explosives Continuous Air Monitoring Station $PM_{2.5}$ Results, 2009 and 2011

Year	2009[a]	2010	2011[b]
24-hour maximum (µg/m³)	31.0	—	9.4

Source: BHP Billiton (2012).

a) Data were only available for seven months (January to July).

b) Data were only available for July and August.

— = not available; µg/m³ = micrograms per cubic metre; $PM_{2.5}$ = particulate matter of mean aerodynamic diameter less than 2.5 microns.

5.5 Total Suspended Particulates Monitoring

The maximum 24-hour TSP concentration observed at the two Project stations during the 2013 monitoring campaign was 7.4 µg/m³; the minimum 24-hour concentration was 0.2 µg/m³. The average TSP concentration recorded at the Project stations was 1.8 µg/m³ (Table 5.5-1). These data indicate that background concentrations of TSP are low in the Lac du Sauvage region of the Project.

Table 5.5-1 Jay Pit Air Quality Stations Total Suspended Particulates Results, 2013

Station	Month[(a)]	Sample Concentration (µg/m³)
13DDJP-A	July	7.4
	August	1.0
	September	0.2
	October	0.8
13DDJP-B	July	—
	August	0.9
	September	0.5
	October	—
	Average	**1.8**

a) One 24-hour sample was taken at each station per month.
— = no data collected or invalid measurement; µg/m³ = micrograms per cubic metre.

The maximum 24-hour TSP concentration observed at the CAMS during the monitoring period was 248.4 µg/m³. The Polar Explosives CAMS TSP concentrations are not representative of background concentrations at the Project; however, the 2009 to 2011 data from this air monitoring station are summarized for reference in Table 5.5-2.

Table 5.5-2 Polar Explosives Continuous Air Monitoring Station Total Suspended Particulates Results, 2009 to 2011

Year	2009	2010	2011
24-hour maximum (µg/m³)	74.7	153.8	248.4

Source: BHP Billiton (2012).
µg/m³ = micrograms per cubic metre.

The maximum 24-hour TSP concentration observed at the Ekati HVAS stations during the monitoring period was 561.4 μg/m³. The Ekati HVAS TSP concentrations are not representative of background concentrations at the Project because of the close proximity to the Ekati operations; however, the 1994 to 2011 data from this station are summarized for reference in Table 5.5-3.

Table 5.5-3 Summary of High-Volume Air Sampling Data, 1994 to 2011

Year	Sample Station	Maximum TSP 24-Hour (μg/m³)	Average TSP 24-Hour (μg/m³)
1994	TSP-1	320	57.2
1997	TSP-1	37.6	15.7
1998	TSP-1	137.9	50
1999	TSP-1	117	40.4
	TSP-2	19.9	4.5
2000	TSP-1	205.9	69
	TSP-2	59.4	13.4
2001	TSP-1	561.4	93.5
	TSP-2	94.8	14.96
2002	TSP-1	294.3	87.1
	TSP-2	55.5	15.6
2003	TSP-2	50.9	17.2
2004	TSP-2	101.4	29.73
2005	TSP-2	12.9	4.3
2006	TSP-2	Out of service	Out of service
2007	TSP-2	15.5	4.9
	TSP-3	35.5	5.94
2008	TSP-2	90.32	15.5
	TSP-3	267.51	36.6
2009	TSP-2	35.61	7.87
	TSP-3	96.71	27.96
2010	TSP-2	171.75	24.44
	TSP-3	87.3	16.23
2011	TSP-2	40.47	9.66
	TSP-3	54.13	9.68

Source: BHP Billiton (2012).

TSP = total suspended solids; μg/m³ = micrograms per cubic metre.

6 AIR QUALITY MONITORING AT OTHER LOCATIONS

6.1 Nitrogen Oxides Monitoring

Concentrations of NO_2 and NO_X are continuously monitored at four locations in the NWT: the GNWT Air Quality Monitoring Network stations at Fort Liard, Inuvik, Norman Wells, and Yellowknife. Because these stations are in or near communities, reported NO_2 and NO_X concentrations are affected by local emissions.

6.1.1 Nitrogen Oxides

Years with less than 75% of data availability at a station were not considered for calculating background averages. Of years with 75% or greater data availability, the average annual background NO_X concentration at the GNWT stations was 6.8 μg/m³. Concentrations are presented in Table 6.1-1.

6.1.2 Nitrogen Dioxide

Years with less than 75% of data availability at a station were not considered for calculating background averages. Of years with 75% or greater data availability, the average annual background NO_2 concentration at the GNWT stations was 4.0 μg/m³. Concentrations are presented in Table 6.1-2.

Table 6.1-1 Government of the Northwest Territories Stations Nitrogen Oxides Concentrations, 2003 to 2013

Station	Averaging Time	Parameter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fort Liard	all	data availability (%)	0.0	0.0	73.4	95.8	52.3	0.8	0.0	75.9	60.1	95.8	64.3
	annual	average (µg/m³)	—	—	5.0	0.9	1.3	35.9	—	3.6	3.3	5.5	1.3
Inuvik	all	data availability (%)	0.0	23.8	95.5	67.1	76.5	72.2	9.7	97.1	95.7	87.4	89.7
	annual	average (µg/m³)	—	14.4	7.4	4.6	4.0	2.4	16.3	8.5	7.9	8.6	8.0
Norman Wells	all	data availability (%)	0.0	0.0	54.8	95.6	95.8	96.0	95.9	73.4	95.0	93.0	93.9
	annual	average (µg/m³)	—	—	2.9	3.9	3.7	2.2	1.8	3.1	2.3	3.8	5.0
Yellowknife	all	data availability (%)	15.0	96.3	97.6	98.1	98.1	98.7	98.8	95.8	93.6	98.1	97.5
	annual	average (µg/m³)	30.8	15.0	13.1	10.7	8.3	7.2	6.4	13.9	10.0	5.7	10.3

Source: GNWT (2014).
% = percent; µg/m^3 = micrograms per cubic metre; — = not available.

Table 6.1-2 Government of the Northwest Territories Stations Nitrogen Dioxide Concentrations, 2003 to 2013

Station	Averaging Time	Parameter	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fort Liard	all	data availability (%)	0.0	0.0	73.4	95.8	52.3	0.8	0.0	75.9	60.1	95.8	64.3
	annual	average (µg/m³)	—	—	0.4	0.5	0.8	20.1	—	2.2	2.2	5.1	0.7
Inuvik	all	data availability (%)	0.0	23.8	95.5	67.1	76.5	72.2	9.7	97.1	95.7	87.4	89.7
	annual	average (µg/m³)	—	8.6	4.3	2.6	1.5	1.1	10.1	5.3	4.4	4.8	5.0
Norman Wells	all	data availability (%)	0.0	0.0	54.8	95.6	95.8	96.0	95.9	73.4	95.0	93.0	93.9
	annual	average (µg/m³)	—	—	1.2	2.5	2.4	1.4	2.1	2.5	2.8	2.8	3.8
Yellowknife	all	data availability (%)	15.0	96.3	97.6	98.1	98.1	98.7	98.8	95.8	93.6	98.1	97.5
	annual	average (µg/m³)	11.6	8.2	7.4	7.2	5.3	3.6	3.9	8.9	6.5	4.2	6.0

Source: GNWT (2014).
% = percent; µg/m^3 = micrograms per cubic metre; — = not available.

6.2 Sulphur Dioxide Monitoring

Sulphur dioxide concentrations are continuously monitored at four locations in the NWT: Fort Liard, Inuvik, Norman Wells, and Yellowknife. Because these stations are in or near communities, reported SO_2 concentrations are affected by local emissions.

Years with less than 75% of data availability at a station were not considered for calculating background averages. Of years with 75% or greater data availability, the average annual background SO_2 concentration at the GNWT stations was 1.3 µg/m³. Concentrations are presented in Table 6.2-1.

Table 6.2-1 Government of the Northwest Territories Stations Sulphur Dioxide Concentrations, 2003 to 2013

Station	Averaging Time	Parameter	2003	2004	2005	2006	2007	2008
Fort Liard	all	data availability (%)	0.0	0.0	27.8	95.0	95.7	95.6
	annual	average (µg/m³)	—	—	3.0	0.3	0.1	0.0
Inuvik	all	data availability (%)	0.0	0.0	23.8	94.7	93.2	95.1
	annual	average (µg/m³)	—	—	2.6	1.7	1.5	0.7
Norman Wells	all	data availability (%)	0.0	0.0	22.6	95.7	95.6	95.8
	annual	average (µg/m³)	—	—	0.1	1.0	1.8	1.0
Yellowknife	all	data availability (%)	6.1	92.8	92.5	91.8	90.7	98.1
	annual	average (µg/m³)	3.8	1.8	1.9	2.6	0.4	0.9

Station	Averaging Time	Parameter	2009	2010	2011	2012	2013
Fort Liard	all	data availability (%)	95.9	95.9	95.5	95.5	95.7
	annual	average (µg/m³)	0.8	1.9	1.0	0.7	0.3
Inuvik	all	data availability (%)	85.7	89.4	58.4	94.3	54.6
	annual	average (µg/m³)	1.6	0.5	1.2	2.2	0.2
Norman Wells	all	data availability (%)	96.0	96.0	91.8	82.9	81.1
	annual	average (µg/m³)	1.6	1.9	1.3	0.9	1.9
Yellowknife	all	data availability (%)	99.2	98.2	97.4	96.8	84.3
	annual	average (µg/m³)	1.9	2.0	1.6	0.4	0.5

Source: GNWT (2014).
% = percent; µg/m^3 = micrograms per cubic metre; — = not available.

6.3 Particulate Matter Monitoring

The GNWT Air Quality Monitoring Network consists of four permanent monitoring stations located in Yellowknife, Inuvik, Fort Liard, and Norman Wells. All four stations monitor $PM_{2.5}$; particulate matter of mean aerodynamic diameter less than 10 microns (PM_{10}) is measured in Yellowknife, Inuvik, and Fort Liard. However, the particulate data are not representative of the Project since these stations are located within or near communities and measured concentrations are influenced by local emissions.

Short-term seasonal particulate monitoring occurs at the NWT Tundra Ecological Research Station located at Daring Lake. Particulate monitoring has also taken place over several years at the De Beers Snap Lake Mine. Both Daring Lake and Snap Lake Mine data are discussed further in the subsections below.

6.3.1 Daring Lake

The Daring Lake Station monitored PM_{10} in the summer of 2002 and monitored $PM_{2.5}$ during the summer months beginning in 2003. The $PM_{2.5}$ and PM_{10} data from Daring Lake are considered representative of baseline conditions at the Project since the Daring Lake station is remote from industrial particulate emission sources. Particulate matter samples were collected using a Partisol sampler during the summers of 2002 to 2008, with PM_{10} measured in 2002 and $PM_{2.5}$ measured from 2003 to 2008.

From 2003 to 2008, $PM_{2.5}$ samples were collected at Daring Lake. The annual average concentrations during 2003 to 2008 ranged from 0.9 to 7.1 μg/m^3. The $PM_{2.5}$ concentration over the period averaged 3.1 μg/m^3; the maximum $PM_{2.5}$ concentration was 41.5 μg/m^3, on July 29, 2004. This reading was attributed to smoke from forest fires burning south of Great Slave Lake (De Beers 2010); average $PM_{2.5}$ concentrations in 2004 were elevated compared to the other monitoring years. Median values more accurately represent background $PM_{2.5}$ concentrations for the Daring Lake data set because the influence of outliers is reduced, such as $PM_{2.5}$ concentrations from forest fire activity. Median $PM_{2.5}$ concentrations over the period are 1.8 μg/m^3.

The maximum PM_{10} concentration in 2002 was 3.3 μg/m^3, with an average of 1.6 μg/m^3. While the background PM_{10} background value is slightly lower than the background value for $PM_{2.5}$, it is expected that there will be variation in ambient background concentrations from year to year, and the PM_{10} data set is more limited than the $PM_{2.5}$ data set. Normally, PM_{10} concentrations would be higher than $PM_{2.5}$ concentrations because $PM_{2.5}$ is included in the PM_{10} size fraction. To better characterize a background concentration for PM_{10}, a rural $PM_{10}/PM_{2.5}$ ratio of 1.5 was applied to the $PM_{2.5}$ median concentration (Brook et al. 1997). The background PM_{10} concentration calculated using this method is 2.7 μg/m^3.

Particulate concentrations recorded at the Daring Lake station are listed in Table 6.3-1.

Table 6.3-1 Daring Lake 24-Hour Particulate Concentrations, 2002 to 2008

Sample Date (day-month)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)					
	2002	2003	2004	2005	2006	2007	2008
08-Jun	—	—	3.9	—	—	—	—
11-Jun	—	0.8	4.7	—	—	—	—
14-Jun	—	3.1	2.5	—	—	—	—
17-Jun	—	2.2	4.6	—	—	—	—
18-Jun	1.9	—	—	—	—	—	—
20-Jun	—	0.1	7.9	—	—	—	—
21-Jun	0.3	—	—	—	0.3	—	—
23-Jun	—	1.9	1.8	—	—	—	—

Table 6.3-1 Daring Lake 24-Hour Particulate Concentrations, 2002 to 2008

Sample Date (day-month)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)					
	2002	2003	2004	2005	2006	2007	2008
24-Jun	1.5	—	—	—	5.4	—	—
26-Jun	—	1.7	9.3	—	—	—	—
27-Jun	1.9	—	—	0.0	2.8	—	—
29-Jun	—	1.0	14.2	—	—	—	—
30-Jun	—	—	—	2.5	—	—	—
02-Jul	—	—	1.9	—	—	—	—
03-Jul	1.3	1.3	—	—	—	—	—
05-Jul	—	—	5.6	0.6	—	—	—
06-Jul	—	0.6	—	—	—	—	—
08-Jul	—	—	1.1	2.4	—	—	—
09-Jul	3.3	6.8	—	—	1.5	1.0	—
11-Jul	—	—	5.4	3.8	—	—	0.6
13-Jul	—	—	—	—	—	1.7	—
14-Jul	—	—	2.8	3.6	—	—	0.8
15-Jul	1.3	2.5	—	—	0.9	—	—
16-Jul	—	—	—	—	—	1.1	1.5
17-Jul	—	—	2.9	0.3	—	—	—
18-Jul	0.3	3.3	—	—	—	—	—
19-Jul	—	—	—	—	0.9	—	5.7
21-Jul	2.1	—	—	—	—	—	5.3
23-Jul	—	5.7	17.2	1.5	4.1	0.0	—
24-Jul	2.9	—	—	—	—	—	3.4
26-Jul	—	15.4	5.4	0.1	1.3	0.4	—
27-Jul	—	—	—	—	—	—	5.5
29-Jul	—	—	41.5	1.0	1.3	1.7	—
01-Aug	—	—	1.8	2.8	—	0.7	—
02-Aug	—	—	—	—	1.9	—	—
04-Aug	—	—	6.4	1.8	—	3.7	1.9
07-Aug	—	—	—	0.6	—	—	—
08-Aug	—	—	1.0	—	—	—	—
09-Aug	—	—	—	—	—	0.1	—
10-Aug	—	—	—	0.1	—	—	7.0
11-Aug	—	—	—	—	0.4	—	—
12-Aug	—	—	—	—	—	0.0	—
14-Aug	1.8	—	—	—	1.2	—	—

Table 6.3-1 Daring Lake 24-Hour Particulate Concentrations, 2002 to 2008

Sample Date (day-month)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)					
	2002	2003	2004	2005	2006	2007	2008
16-Aug	—	—	—	0.8	—	—	—
17-Aug	—	—	—	—	1.3	—	—
18-Aug	0.0	—	—	1.4	—	—	—
19-Aug	—	—	—	—	—	0	—
Minimum	**0.0**	**0.1**	**1.0**	**0.0**	**0.3**	**0.0**	**0.6**
Maximum	**3.3**	**15.4**	**41.5**	**3.8**	**5.4**	**3.7**	**7.0**
Median	**1.7**	**2.1**	**4.7**	**1.2**	**1.3**	**0.7**	**3.4**
Average	**1.6**	**3.3**	**7.1**	**1.5**	**1.8**	**0.9**	**3.5**

Source: Fox (2014).

PM_{10} = particulate matter of mean aerodynamic diameter less than 10 microns; $PM_{2.5}$ = particulate matter of mean aerodynamic diameter less than 2.5 microns; — = not available; μg/m^3 = micrograms per cubic metre.

6.3.2 Snap Lake Mine

The TSP sampling data at the Polar Explosives CAMS and Ekati HVAS stations are not representative as baseline ambient data, and the Project sampling at Jay Pit stations was limited in scope; therefore, Snap Lake Mine TSP monitoring data were reviewed to assist in determining background TSP concentrations for the Project. The TSP samples were recorded with high-volume samplers pre-mining from 2001 to 2004 and 2006 at five stations at Snap Lake.

In 2001, 2004, and 2006, high-volume TSP air samples were collected at Snap Lake Mine during a care and maintenance phase and during development activity. Concentrations are presented in Table 6.3-2. Because site activity was minimal during the care and maintenance phase, and anthropogenic or human-related sources were not primary contributors to TSP (De Beers 2010), the TSP data recorded during 2002 best represent background air quality in the region. The median concentration recorded in 2002 was 3.1 μg/m^3.

Table 6.3-2 Snap Lake Mine Total Suspended Particulate Concentrations, 2002 to 2006

Year	Concentration (μg/m^3)														
	Minimum					Median					Maximum				
	HV001	HV002	HV003	HV004	HV005	HV001	HV002	HV003	HV004	HV005	HV001	HV002	HV003	HV004	HV005
2001	2.1	1.1	5.4	-	-	26	7.1	15	-	-	146	69	34	-	-
2002	0.3	0	0	-	-	5.2	3.1	2.7	-	-	22	26	12	-	-
2003	0.4	0.2	0.2	-	-	6	4.1	4.9	-	-	37	32	32	-	-
2004	0.1	1.1	0.4	-	-	13.6	18	6.6	-	-	140	73	86	-	-
2006	-	0	-	7	3	-	16	-	14	11	-	221	-	65	155
2001 to 2004, 2006	0.1	0	0	7	3	10	7.1	5.4	14	11	146	221	86	65	155

Source: De Beers (2010).

μg/m^3 = micrograms per cubic metre; - = not available.

6.4 Carbon Monoxide Monitoring

Carbon monoxide concentrations are continuously monitored at two locations in the NWT: Inuvik and Yellowknife. Because these stations are in or near communities, CO concentrations are affected by local emissions.

Years with less than 75% of data availability at a station were not considered for calculating background averages. Of years with 75% or greater data availability, the average annual background CO concentration at the GNWT stations was 259.2 µg/m³. Concentrations are presented in Table 6.4-1.

Table 6.4-1 Government of the Northwest Territories Ambient Carbon Monoxide Concentrations, 2004 to 2008

Station	Averaging Time	Parameter	2004	2005	2006	2007	2008
Inuvik	all	data availability (%)	0.0	0.0	0.0	0.0	0.0
		average (µg/m³)	—	—	—	—	—
Yellowknife	all	data availability (%)	98.6	90.1	82.2	99.2	98.1
		average (µg/m³)	76.6	117.3	174.1	451.2	252.2

Station	Averaging Time	Parameter	2009	2010	2011	2012	2013
Inuvik	all	data availability (%)	0.0	0.0	0.0	22.1	89.7
		average (µg/m³)	—	—	—	181.9	100.7
Yellowknife	all	data availability (%)	96.6	94.0	97.9	98.8	97.1
		average (µg/m³)	367.1	175.0	207.9	479.9	449.1

Source: GNWT (2014).
% = percent; µg/m^3 = micrograms per cubic metre; — = not available.

6.5 Ozone Monitoring

Ozone is monitored continuously at four stations in the GNWT Air Quality Monitoring Network: Yellowknife, Inuvik, Fort Liard, and Norman Wells. Ozone is also measured at the Environment Canada's Canadian Air and Precipitation Monitoring Network (CAPMoN) Snare Rapids station.

6.5.1 Yellowknife Station

The monitoring station in Yellowknife is the closest of the GNWT stations to the Project, and hence ozone concentrations are presented for the Yellowknife station only (Table 6.5-1). Typical monthly ozone concentrations at remote sites in Canada range between 40 and 80 µg/m^3; monthly concentrations for the Yellowknife station fall within this range, indicating that most of the ozone detected is likely naturally occurring (GNWT 2012). The average concentration between 2003 and 2013 was 49 µg/m^3.

6.5.2 Snare Rapids Station

Environment Canada's CAPMoN Snare Rapids station is located approximately 140 km northwest of Yellowknife. The monthly average ozone concentrations at Snare Rapids ranged from 35.3 to 77.0 µg/m³, with an overall annual average, using the most complete years of data for 2006, 2010, 2011, and 2012, of 57.3 µg/m³ (Table 6.5-2). Snare Rapids and Yellowknife are at comparable distances from the Project, and have comparable ozone concentrations. Because Snare Rapids station is not in a municipal setting, ozone data recorded at Snare Rapids station best represent background air quality at the Project.

Table 6.5-1 Government of the Northwest Territories Air Quality Monitoring Network Yellowknife Station Ozone Concentrations, 2003 to 2008

Station	Averaging Time	Parameter	2003	2004	2005	2006	2007	2008
Yellowknife	all	data availability (%)	88.9	98.3	97.9	94.9	98.2	95.4
	monthly	maximum (µg/m³)	67.9	61.1	75.3	70.4	67.2	75.1
		average (µg/m³)	44.9	47.0	52.4	51.6	48.8	47.0

Station	Averaging Time	Parameter	2009	2010	2011	2012	2013
Yellowknife	all	data availability (%)	93.2	97.5	93.2	98.3	98.8
	monthly	maximum (µg/m³)	57.2	69.5	66.8	67.3	61.9
		average (µg/m³)	45.2	51.4	50.0	52.5	47.9

Source: GNWT (2014).
% = percent; µg/m³ = micrograms per cubic metre.

Table 6.5-2 Canadian Air and Precipitation Monitoring Network Snare Rapids Ozone Concentrations, 2005, 2006, and 2010 to 2012

	Monthly Average (µg/m³)							
	2005	2006	2007	2008	2009	2010	2011	2012
January	—	54.8	—	—	—	62.0	62.5	58.2
February	—	58.6	—	—	—	66.5	64.6	64.1
March	—	71.4	—	—	—	69.0	69.4	70.1
April	—	76.9	—	—	—	77.0	63.5	72.8
May	—	67.6	—	—	—	68.5	71.0	70.4
June	—	61.6	—	—	—	62.5	56.7	61.1
July	—	43.5	—	—	—	43.2	49.5	50.1
August	—	43.4	—	—	—	45.9	36.9	37.7
September	—	39.8	—	—	—	39.1	35.3	38.5
October	—	52.3	—	—	49.2	50.3	39.3	50.1
November	52.6	65.0	—	—	57.2	58.4	55.0	57.3
December	60.2	62.1	—	—	60.8	58.6	60.0	58.0

Source: Stevens (2014).
µg/m³ = micrograms per cubic metre; — = not available.

7 SUMMARY

7.1 Meteorology and Climate

Baseline meteorological information on wind speed and wind direction, precipitation, temperature, relative humidity, and solar radiation was available from observations made at the Project. Long-term measurements of wind speed and wind direction, precipitation, and temperature were also available from the Lupin A station in Nunavut.

- **Wind Speed and Wind Direction:** Seasonal variation was observed, with the summer or primarily ice-free months being from June to October, and the winter months being primarily from November to May. Prevailing winds at the Project were from the east, with east winds more common in winter and east-northeast winds more common in summer. Winds were frequently recorded during the measurement period at greater than 30 km/hr.
- **Precipitation:** Rainfall occurred primarily in the summer months, and snowfall occurred primarily in the winter months. The months of July through September experienced the greatest amount of precipitation.
- **Temperature:** Median ambient temperatures at the Project ranged from a low of near -28°C in January to a high of near 13°C in July. Temperatures at the Project were similar to temperatures recorded at Lupin A.
- **Relative Humidity:** There was substantial seasonal variation in relative humidity recorded at the Project, with average values ranging from near 67% in June to near 92% in October.
- **Solar Radiation:** Solar radiation was only recorded during the summer months. Average solar radiation measured was 157 watts per square metre (W/m^2), with average peak solar radiation of 795 W/m^2.

7.2 Background Air Quality

During the summer and fall of 2013, monitoring was undertaken at the Project for NO_2, NH_3, $PM_{2.5}$, and TSP. Monitoring results from stations elsewhere in the NWT were also evaluated for applicability to Project baseline air quality concentrations.

Measurements of NO_X from the GNWT Air Quality Monitoring Network stations were included in this baseline. Although the data collected from these stations were influenced by anthropogenic sources, their concentrations were low, and they can be considered as a conservative estimate of background concentration for the Project. The reported NO_X background concentration is 6.8 µg/m³. The NO_2 background concentration is 4.0 µg/m³. This result is higher than Project station averages of 0.5 µg/m³ and can also be considered a conservative estimate of background NO_2.

The measurements that most accurately represent background SO_2 concentrations at the Project were collected from the GNWT Air Quality Monitoring Network stations. While the data collected from these stations were influenced by anthropogenic sources, their concentrations remained low and can be considered as a conservative background for the Project. The reported SO_2 background concentration for the Project is 1.3 µg/m³.

Publicly available data for NH_3 in the NWT are limited. The average NH_3 concentration measured at the Project stations was 0.5 µg/m³.

The measurements that most accurately represent background $PM_{2.5}$ and PM_{10} concentrations at the Project were collected from the research station at Daring Lake between 2002 and 2008. The TSP concentrations that most accurately represent background TSP concentrations at the Project were collected in 2002 from the Snap Lake Mine baseline. Other PM data collected in the region were more strongly influenced by anthropogenic sources and, therefore, have not been considered in determining background concentrations. The reported Daring Lake $PM_{2.5}$ background concentration is 1.8 µg/m³; this result is consistent with the Project station average of 1.3 µg/m³. The reported Daring Lake PM_{10} background concentration is 2.7 µg/m³. The Snap Lake Mine TSP background concentration is 3.1 µg/m³; this result is consistent with the Project station average of 1.8 µg/m³.

The measurements that most accurately represent background CO concentrations at the Project were collected from the GNWT Air Quality Monitoring Network stations. While the data collected from these stations were influenced by anthropogenic sources, their concentrations can be considered as a conservative background value for the Project. The reported CO background concentration is 259.2 µg/m³.

The measurements that most accurately represent background ozone concentrations at the Project were collected from the Snare Rapids CAPMoN station. The ozone background concentration is reported as 57.3 µg/m³.

8 REFERENCES

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9 GLOSSARY

Term	Definition
All-season road	An all-season road is a road that is motorable all year by the prevailing means of rural transport.
Ambient air	Outdoor or open air beyond the developed industrial footprint.
Ammonia (NH_3)	A pungent, colourless, gaseous, alkaline compound of nitrogen and hydrogen that is soluble in water, lighter than air, and can easily be condensed to a liquid by cold and pressure.
Anthropogenic	Human-related, often referring to an activity, development or disturbance on the landscape.
Background concentration	The concentration of a chemical in a defined control area during a fixed period before, during or after data gathering.
Carbon monoxide (CO)	A colourless, odourless, toxic gas at standard conditions that is a product of incomplete combustion of fossil fuels.
Climate normal	The arithmetic mean of climatological elements over 30 years used to describe the average climate conditions at a location.
Daily average	The arithmetic mean based on a data set of 24 1-hour averages for each day. Daily averages are only calculated for days with eighteen or more valid hours of data in the day.
Detection Limit (DL)	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (which may be zero) with a specified confidence level for a given method and representative matrix.
Emission	The act of releasing or discharging air contaminants into the ambient air from any source.
Mean	Arithmetic average value in a distribution.
Median	A single statistical value used to characterize a series of data values. Half of the data values are larger than the median value, and half of the data values are less than the median value.
Nitrogen dioxide (NO_2)	One of the component gases of oxides of nitrogen which also includes nitric oxide. In burning natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form nitric oxide, an ingredient in the brown haze observed near large cities. Nitric oxide is converted to nitrogen dioxide in the atmosphere. Cars, trucks, trains and planes are the major source of oxides of nitrogen in Alberta. Other major sources include oil and gas industries and power plants.
Nitrogen oxides (NO_X)	Consist of nitric oxide (NO) and nitrogen dioxide (NO_2) and are reported as equivalent NO_2.
Ozone (O_3)	A gas that occurs both in the Earth's upper atmosphere and at ground level. Ozone in the upper atmosphere protects living organisms by preventing damaging ultraviolet light from reaching the Earth's surface. Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals.
Particulate matter	Any aerosol that is released to the atmosphere in either solid or liquid form.
$PM_{2.5}$	Particulate matter with particle diameter nominally smaller than 2.5 micrometres (μm).
PM_{10}	Particulate matter with particle diameter nominally smaller than 10 micrometres (μm).
Relative humidity	The ratio of the amount of water vapour in the atmosphere to the amount necessary for saturation at the same temperature. Relative humidity is expressed in terms of percent and measures the percentage of saturation.
Solar radiation	The principal portion of the solar spectrum that spans from approximately 300 nanometres (nm) to 4,000 nm in the electromagnetic spectrum. It is measured in watts per square metre (W/m^2), which is radiation energy per second per unit area.
Sulphur dioxide (SO_2)	A colourless gas with a pungent odour.

Term	Definition
Total suspended particulate (TSP)	A term used to collectively describe tiny airborne particles or aerosols that are less than 100 micrometres in size.
Treeline	An area of transition between the tundra and boreal forest to the south.
Windrose	Graphic pie-type representation of frequencies of wind directions and speeds over a period of time (e.g., one year) for a meteorological station.
Winter road	Roads which are built over frozen lakes and tundra. Compacted snow and/or ice is used for embankment construction.